Oil-Source Rock Correlation Of Oil Seepage And Rock Samples Collected From The Cibulakan Formation At Palimanan Area, West Java

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Abstract. This paper presents the results and discussion of a petroleum geochemistry study performed on two oil seepage and seven outcrop samples collected from the Cibulakan Formation at Palimanan area, West Java. The presence of two oil seepages in Palimanan area indicates that there is an effective source rock which has produces hydrocarbon. The objectives of the study were to determine the hydrocarbon source potential of outcrops, and to characterise selected rock extracts and oil seepage samples, and determine the progenitor source facies at time generation/expulsion. The method used in this research is field study and laboratory analysis. Field studies were conducted on oil and rock sampling, while the geochemical laboratory analysis includes Total Organic Carbon, Rock-Eval Pyrolysis, Vitrinite Reflectance, Kerogen Typing, Bitumen Extraction, Liquid Chromatography, Gas Chromatography fingerprint and GC-MS biomarker. The oil-source rock correlation to its oil based on GC fingerprint (n-alkane distributions) and GC-MS biomarker (triterpanes and sterane distributions) has been done. The oil seepage is correlated with possible source rocks from the Cibulakan Formation. Based on the n-alkane distribution the oil seepage showed biodegradation, but based on the biomarker distributions, it is interpreted that the oil seepage have been generated from a source rock facies containing mainly non-marine algal debris (Type II Kerogen) mixed with some input from terrestrial higher plant organic matter (Type III Kerogen). The oil seepage shows a moderately good correlation with the rock extracts based on GC-MS biomarker data. These biomarker parameters has been successfully used to determine the origin of oil with its precursor source rock by correlating the rock extracts to possible source rocks in the oil and gas exploration.

1. Introduction
Oil seepage mapping on the island of Java has been carried out since the days of the Dutch East Indies. Oil and gas seepage has been met, which is referred to as one of the indications that the element of the petroleum system in the area has been fulfilled, and this information is very strong data in exploration activities. Found seepage of oil in Palimanan area which is also used for things that contain effective coal which has the ability to present and remove petroleum.

The problem is how we can identify the source rock that is the origin of the oil seepage from which formation. Based on the provisional estimates, the source rocks are rocks that are included in the
Cibulakan Formation, because the oldest rocks revealed in this area are the Cibulakan Formation which consists of the limestone at the bottom and is covered by clay sediments with thin layers of limestone at the top [1–4].

This study is intended to determine the potential and maturity of hydrocarbon source rock from outcrops and to identify the characteristics of rock extracts and their relationship with oil seepage in the Palimanan region. Next is a correlation between oil seepage and rock extract from the Cibulakan Formation to determine the source of origin of organic matter, depositional environment and the possibility of effective source rocks that have formed and removed petroleum.

2. Data and Method

This research begins with taking oil seepage samples and rock outcrops in the field, then analyzes the geochemical laboratory which includes Total Organic Carbon (TOC), Pyrolysis Rock-Eval (RE), Reflection of Vitrinite (Ro), Kerogen Type (KT), Extraction Bitumen, Liquid Chromatography (LC), fingerprint Gas Chromatography (GC) and biomarkers of Gas Chromatography - Mass Spectrometry (GC-MS) [2,5–8].

![Image](Image1.jpg)

Gambar 1. Location map of Oil Seepage and outcrops in the Palimanan Region

3. Result and Discussion

3.1. Source Rock Evaluation

Source rocks in productive hydrocarbon basins in Indonesia can be classified as lacustrine, fluvio-deltaic and marine. Petroleum in Indonesia can also be classified as lacustrine, fluvio-deltaic and marine based on various geochemical parameters, including pyrolysis of gas chromatography in asphalten fraction and GC-MS biomarker data (Robinson K.M., 1987).

Analysis of total organic carbon (TOC) was carried out on seven claystone samples taken from the Cibulakan Formation. From the TOC data, two claystone samples have a price below 0.50 wt.%, While the other five claystone samples show TOC prices above 1.00 wt.%, Where the highest price in outcrop samples with the label ‘IC 05’ is 4.43 wt.%. These results indicate that the content of organic material is in the low category to very good.

| Sample ID | Area          | Lithology | TOC (wt.%) | mg/gm rock | S<sub>1</sub> | S<sub>2</sub> | S<sub>3</sub> | Tmax (°C) | Oil Production Index (OPI) | Potential Yield | Hydrogen Index | Oxygen Index |
|-----------|---------------|-----------|------------|-------------|--------------|--------------|-------------|------------|---------------------------|----------------|----------------|------------|
| B 03      | Penawaran River| dcl gy Clyst | 0.42       | 0.09 0.00 0.00 | -            | 1.00         | 0.09        | 0           | 0                         |                |                |            |
| PB 01     | Penawaran River| btsh/gy Clyst | 0.47       | 0.05 0.00 0.10 | 452          | 0.28         | 0.18        | 28          | 21                        |                |                |            |
| IC 01A    | Cement Factory| dcl gy Clyst | 3.32       | 0.14 0.11 0.05 | 539          | 0.56         | 0.25        | 3           | 2                         |                |                |            |
| IC 04     | Cement Factory| dcl gy Clyst | 2.51       | 6.18 2.85 0.49 | 331          | 0.68         | 9.03        | 114         | 20                        |                |                |            |
| IC 05     | Cement Factory| dcl gy Clyst | 4.43       | 10.08 14.98 0.50 | 363          | 0.40         | 25.06       | 338         | 11                        |                |                |            |
| IC 27     | Cement Factory| med gy Clyst | 1.26       | 0.06 0.09 0.21 | 362          | 0.40         | 0.15        | 7           | 17                        |                |                |            |
| IC 34     | Cement Factory| dcl gy Clyst | 3.63       | 2.28 3.27 0.23 | 445          | 0.41         | 5.55        | 90          | 6                         |                |                |            |

*Pyrolysis by Rock Eval II; TOC content by Leco Analyzer

S<sub>1</sub> = Free Hydrocarbons, S<sub>2</sub> = Pyrolysable Hydrocarbons, S<sub>3</sub> = Organic CO<sub>2</sub>, Oil Production Index = Transformation Ratio = S<sub>1</sub>/(S<sub>1</sub>+S<sub>2</sub>), Tmax = Temperature of Maximum S<sub>2</sub>, Potential Yield = (S<sub>1</sub>+S<sub>2</sub>) x 100, Hydrogen Index = (S<sub>2</sub>/TOC) x 100, Oxygen Index = (S<sub>3</sub>/TOC) x 100.
Rock-Eval pyrolysis data obtained the price of S1 + S2 of 0.09 to 25.06 mg/gram of rock, this states that the claystone analyzed has a potential value of not potential to very potential as source rock (Table 1). The six samples of sedimentary rocks analyzed showed a tendency to form a gas (prone gas, HI <200), while samples labeled ‘IC 05’ showed a tendency to form oil (oil and gas prone, HI 338).

3.2. Maturity of Organic material
Determination of the maturity level of organic material from claystone based on data from maximum temperature, vitrinite reflection (Ro) and Heat Alteration Index or color spore index (TAS)

From the Tmak data obtained two claystone samples labeled ‘IC 01A’ and ‘IC 34’ have a Tmak price greater than 435 ºC, three samples ‘IC 04’, ‘IC 05’ and ‘IC 27’ indicate Tmak prices below 435ºC, while the two samples ‘B 03’ and ‘PB 01’ were not detected, because the S2 score was very small. The lowest Tmak price is 331 ºC in the ‘IC 04’ sample, while the highest Tmak price is ‘IC 01A’, which is 539 ºC. The level of maturity of organic material based on the price of Tmak varies from immature to post-cooked. This statement is in accordance with the price of the Alteration Bahang, TAS 2 / 3-6 Index (Table 2).

Table 2. Kerogen data summary

| SAMPLE ID | F.A. | A. | C. | S. | S2 | L. | S1 | Ro  | TAS  | Fluorescence Colour | Preserv. | F.A. | Herb | Ang |
|-----------|-----|---|---|---|---|---|---|-----|------|---------------------|----------|------|-----|-----|
| PB 01     | 78  | - | 5 | - | - | - | 6 | 15  | M-G  | 0.95                | 5        | -    | -   | m  |
| IC 01A    | 91  | - | 2 | - | - | - | 2 | 7   | G    | 1.78                | 6        | -    | -   | m  |
| IC 05     | 76  | 10| 5 | 0.5| - | 0.5| 16| 8   | P    | 0.32                | 2/3      | 1    | 1   | m  |

Vitrinite reflectivity (Ro) data, one claystone sample showed a number below 0.50% and two samples showed a number above 0.50% Ro. The lowest price is 0.32% Ro in claystone samples labeled ‘IC 05’, while the highest price is 1.78% Ro in the sample with the label ‘IC 01A’. This states that the sedimentary rock analyzed is immature to post-mature to produce hydrocarbons (Table 2).

3.3. Bitumen and oil characteristics
Extraction was carried out on seven outcrops to separate bitumen from rock and kerogen. From the extraction data, the bitumen prices were 396-28,362 ppm and hydrocarbons were 230-22,897 ppm (Table 3), which stated that the organic material that could be extracted was of low quality so it was very good for producing liquid hydrocarbons. Based on the calculation results obtained the EOM / TOC ratio (3.14-18.24) and HC / TOC (1.82-10.78) which states that the claystone extraction samples ‘B 03’, ‘PB 01’, ‘IC 01A’ and ‘IC 27’ are generations indigenous local hydrocarbons, except for sedimentary rock samples ‘IC 04’, ‘IC 05’ and ‘IC 34’ which have EOM / TOC ratios (31.83-95.14) and HC / TOC (23.01-81.91), possibly migration liquid hydrocarbons, because generally the migration of liquid hydrocarbons has an EOM / TOC ratio> 25 and HC / TOC> 20.
Analysis of liquid chromatography or column chromatography was carried out to separate the bitumen and oil into fractions which differed in chemical composition, namely saturate fraction, aromatic and NSO or resin. The column chromatography results showed saturate hydrocarbon concentrations that varied from low on the IC A 01A sample (Sat 17.84%) to moderate at 03 B 03 o (Sat 51.77%). Five samples' B 03 ', PB 01 ', IC 01A ', IC27 ' and IC34 ' have high non-hydrocarbon concentrations (NSO + asphaltene 27.71-73.30%), except for two sedimentary rock samples with label ' IC 04 ' (NSO + asphaltene 13.91%) and ' IC 05 ' (NSO + asphaltene 19.27%).

3.4. Gas Chromatograph Analysis (GC) Analisis Kromatografi Gas (GC)

The method used in the analysis of fingerprints of hydrocarbons is using the gas chromatography technique (ASTM D-2887). The gas chromatography equipment used is the HP 5890 Series II which is equipped with a FID detector (Flame Ionisation Detector). The temperature program is from 28 °C to 280 °C with a temperature rise of 6 °C per minute through the capillary glass cup CP-Sil-5CB and the hydrogen gas carrier.

Gas chromatography analysis was carried out on two oil seepage samples and three rock extracts. Chromatograms for oil seepage labeled ' P 01A ' (Figure 2) are characterized by no appearance of normal, pristane and fitane alkane peaks, this indicates that oil seepage has been biodegradable. While the chromatogram on oil shene samples with the label ' P 01B ' is characterized by peaks such as chemical solvents with a very limited normal alkane distribution. Overall the sample chromatogram "P 01B" does not indicate the presence of petroleum, possibly this is an indigenous hydrocarbon originating from organic material that is attached to soil or sediments in the local area. The appearance of the chromatogram in rock extract samples with the label ' IC 01A ', ' IC 04 ' and ' IC 05 ' is indicated by the normal alkane distribution which ranges from nC13 to nC20 + and nC30 +. (Figure 2).

Unobserved light components, namely the concentration of normal alkane with carbon below nC12, possibly due to evaporation factors and / or biodegradation process.

Based on the results of GC calculations, the comparison between pristane and fitana as depositional environmental indicators and facies sources ranged from 2.36 to 3.42, this indicates that the sample of rock extract originates from sub-oxic deposition conditions.
Gambar 3. Prista ne/nC\textsubscript{17} versus Phytane/nC\textsubscript{18} Diagram

From the Pristana / nC\textsubscript{17} diagram compared to Fitana / nC\textsubscript{18} (Figure 3) shows rock extract samples in the category "Mixed Organic Sources" (Kerogen Type II-III mixture).

3.5. Biomarker Analysis GC-MS

Biomarkers (biological markers) are markers of biology or life. All living things carry biomarkers. In geochemistry, biomarkers can be analyzed and identified using gas chromatography - mass spectrometry (GC-MS). The GC-MS equipment used is the Perkin Elmer GC Clarus 600 which is equipped with a Clarus SQ 8C mass spectrometry detector and a DB-5MS column. GC-MS analysis was carried out on two oil seepage samples and three rock extracts at saturate fraction. The following is a brief description of the interpretation of biomarker data as follows:

The m / z 191 mass fragmentogram (Figure 4) shows that oil seepage samples and rock extracts have a distribution of tricyclic and tetracyclic exposure whose number of carbon atoms ranges from C19 to C27 (Compound A-J). The amounts of C19 and C20 (Peak A-C) of tricyclic compounds relative to the tricyclic compound C23 (Peak F) are indications of facies whose source comes from land plant material.

The presence of 18\textalpha\textsubscript{(H)} - Oleanana in oil seepage samples and rock extracts, where these compounds are thought to be land plants. Especially flowering plants or angisperms that began to evolve since the Cretaceous era. Oleanana is often found in Cretaceous or younger (Tertiary) samples of deltaic sedimentary rocks.

The m / z 217 mass fragmentogram (Figure 5) shows that oil seepage samples and rock extracts have a proportion of C27 sterane (43.70-63.73\%) relative to sterane C29 (24.52-47.97\%), this is the role of organic matter derived from algae. From the calculation of the percentage of carbon total area and plotted into a triangle diagram in Figure 6, it shows that oil seepage is located in the Deep Lacustrine environment, while rock extract is in the depositional environment Shallow Lake "(Shallow Lacustrine).

| Sample ID | Type of Parameter | Total % | Total % | C\textsubscript{19} Resins | C\textsubscript{25} Hopane | C\textsubscript{29+} Oleanane | C\textsubscript{23} Morelaine | C\textsubscript{29+} Morelaine | C\textsubscript{29} Tricyclic Hopanes | C\textsubscript{27} Sterane |
|-----------|-------------------|---------|---------|---------------------|-----------------|-----------------|----------------|----------------|----------------|----------------|
| P 01A (oil seepage) | a, b, c | 3.17 | 29.39 | 43.00 | 27.61 | 0.54 | 0.11 | 0.14 | 5.00 | 1.89 | 2.57 | 2.15 | 0.00 |
| P 01B (oil shene) | a, c | 3.72 | 20.18 | 43.30 | 36.54 | 0.54 | 0.15 | 0.13 | 4.81 | 2.00 | 1.86 | 2.07 | 0.00 |
| IC 01A (rock extract) | a, c | 3.26 | 30.83 | 33.81 | 35.35 | 0.53 | 0.12 | 0.14 | 4.82 | 2.00 | 1.74 | 0.63 | 0.00 |
| IC 04 (rock extract) | a, c | 2.13 | 20.18 | 42.11 | 37.71 | 0.62 | 0.07 | 0.17 | 4.66 | 2.00 | 1.86 | 2.07 | 0.00 |
| IC 05 (rock extract) | a, c | 2.13 | 17.18 | 48.57 | 34.25 | 0.62 | 0.04 | 0.18 | 4.88 | 1.78 | 2.00 | 2.14 | 0.00 |

a = Source; b = Maturity; c = Migration
Table 5. Sterane data (m/z 217)

| Sample ID                | Type of Parameter | Total C | Total C27 | % C27 20R Steranes | Total C28 | C27 20R | C28 20R | Total C48 | C48 20R | Total C4M | C4M 20R | Total Des C | C Des 20R | Total C20R | C20R 20R | Total Des C20R | C Des 20R | Total Des C4M | C4M 20R | Total Des C48 | C48 20R | Total Des C4M | C4M 20R |
|--------------------------|------------------|---------|-----------|---------------------|-----------|---------|---------|-----------|---------|-----------|---------|-----------|---------|-----------|---------|---------------|---------|---------------|---------|---------------|---------|---------------|---------|
| P 01A (oil seepage)     | a,b,c            | 8.75    | 24.77     | 63.73               | 11.76     | 24.52   | 2.75    | 0.00      | 0.75    | 0.27      | 0.86    | 0.00      | 0.10    | 0.00        | 0.00    | 0.00         | 0.00    | 0.00         | 0.00    |
| P 01B (oil shene)       | a,b,c            | 9.05    | 18.64     | 52.96               | 17.61     | 29.44   | 1.80    | 0.00      | 0.76    | 0.23      | 0.51    | 0.00      | 0.05    | 0.00        | 0.00    | 0.00         | 0.00    | 0.00         | 0.00    |
| IC 01A (rock extract)   | a,b,c            | 5.99    | 7.54      | 46.51               | 4.72      | 47.97   | 0.97    | 0.00      | 0.45    | 0.73      | 1.24    | 0.00      | 0.10    | 0.00        | 0.00    | 0.00         | 0.00    | 0.00         | 0.00    |
| IC 04 (rock extract)    | a,b,c            | 5.93    | 8.50      | 45.07               | 8.88      | 46.05   | 0.98    | 0.00      | 0.39    | 0.45      | 2.05    | 0.00      | 0.08    | 0.00        | 0.00    | 0.00         | 0.00    | 0.00         | 0.00    |
| IC 05 (rock extract)    | a,b,c            | 6.77    | 9.27      | 43.70               | 11.43     | 44.86   | 0.97    | 0.00      | 0.51    | 0.45      | 1.52    | 0.00      | 0.07    | 0.00        | 0.00    | 0.00         | 0.00    | 0.00         | 0.00    |

* a = Source; b = Maturity; c = Migration

Figure 4. GC-MS Fragmentograms Saturate Fraction (m/z 191)

Figure 5. GC-MS Fragmentograms Saturate Fraction (m/z 217)

Figure 6. Sterane composition and source rock depositional environment
4. Conclusion

Based on data from the results of the geochemical laboratory analysis, the following conclusions can be drawn:

The outcrops of claystone analyzed have organic material in the bad category to very good. The potential for generating hydrocarbons from six sedimentary rocks shows a tendency to form gas (prone gas, HI <200), while one sample labeled ‘IC 05’ shows a tendency to form oil (oil and gas prone, HI 338). The maturity level of the organic material is immature to post-mature.

Extractable organic material of low quality is very good for producing liquid hydrocarbons. Oil seepage ‘P 01A’ has been biodegradable, while ‘P 01B’ is probably an indigenous hydrocarbon originating from organic material attached to sediments in the area.

Based on the biomarker distribution, it was interpreted that oil seepage and rock extract originated from source rock facies containing non-marine algae (Kerogen Type II) with the contribution of several terrestrial organic materials (Kerogen Type III).

Oil seepage shows a fairly good correlation with rock extract based on GC-MS biomarker data.

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