

Biomarker characteristics of source rock and oil seepage correlation in Central Java

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Abstract. The presence of oil seepage in Central Java indicates that there is an effective petroleum system. The problem is where the oil was derived from. Biomarker characteristic is used to provide information on source rock organic matter input, depositional environment and correlation between source rock and oil seepage. The method used for this study is GC and GCMS analyses of the rock extract and oil seepage. The biomarker characteristic suggests that oil seepage in Banjarnegara is derived from the Totogan Formation, while that in Bayat is derived from the Wungkal Formation. Oil seepage in Cipluk area is deposited in the estuarine environment. Therefore, it cannot be correlated with the Kerek Formation. Oil seepage in Kedungjati and Bantal area is not derived from the Kerek and Pelang Formation.

1. Introduction

The North Serayu Trough/Basin is located in the northern part of Central Java and was later uplifted to become the North Serayu Range [1]. This basin extends eastward into the Randublatung Zone and the Kendeng Ridge, and its westward extension unites with the Bogor anticlinorium belt [1, 2]. The oil seepages and one oil field located in the North Serayu Zone are found in the areas of Karang Kobar, Bawang and Subah, Klantung and Sodomerto, Kaliwaru, West of Mt. Ungaran (many seepages), and East of Mt. Ungaran [1, 2]. The occurrence of oil seepage in the area proves that the area is found to be an effective source rock. The problem that arises on the occurrence of oil seepages in Central Java is that the sources of these seepage remain unknown. Research on oil seepages in Central Java has been conducted in several locations such as in Lawen, Banjarnegara [3], Cipluk Kendal [4], Kedungjati [5] and Bantal [6], Semarang. This paper discusses the characteristic of source rock biomarker and oil seepage and the relationship between source rock biomarker and oil seepage using data from the previous researchers. The method used for this study is Chromatography (GC) and Gas Chromatography Mass Spectrometry (GCMS) analyses of the rock extract and oil seepage. The GC analysis was performed to determine the environment, thermal maturity level, biodegradation [7]. While the GCMS analysis was performed after the GC analysis to find out more details of undetectable organic compounds on GC chromatograms.

2. Biomarker Characteristic

In Central Java area, there are many oil seepages such as in Lawen Banjarnegara [3], Cipluk Kendal [4], Kedungjati [5] and Bantal Semarang [6]. The result of GCMS analysis for LW 05 sample from Lawen Banjarnegara [3] is shown in Figure 1. Prs/Phy ratio has a value of 1.66 showing that the oxyisity of the environment that this sample deposited was low (suboxic). CPI ratio value is 1.06 showing that the oil had been spilled out from the immature source rock that has maturity level of 0.8% Ro. Plot of ratio



sterane C27, C28 and C29 in the Huang and Meinschein triangle [8] showing the depositional environment of the source rock was estuarine or shallow lacustrine (Figure 2). This shallow environment is evidenced by the relatively high organic material content that is derived from terrestrial materials, such as oleanane and resin (OL and R in Figure 3) [7].

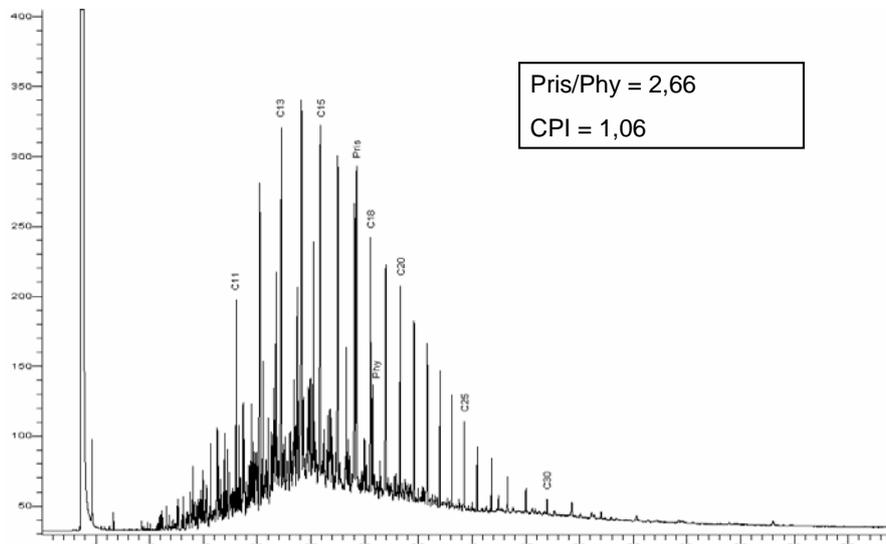


Figure 1. Gas Chromatography of oil seepage LW-05A in the Lawen, Banjarnegara [3].

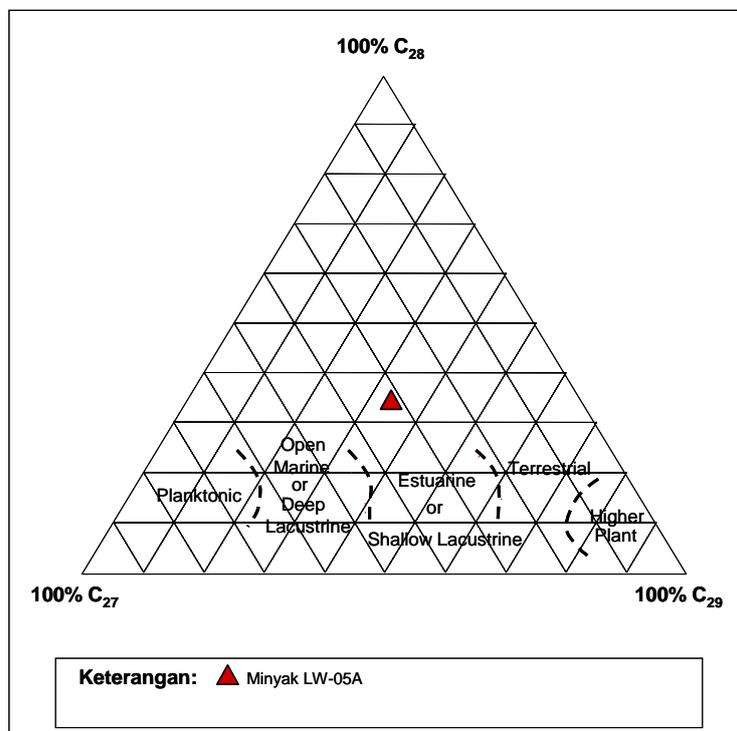


Figure 2. Plot ratio sterana C₂₇, C₂₈ dan C₂₉ [8].

The geochemical characteristic of Cipluk oil [4] corresponding to liquid chromatography data for all oils suggests predominant levels of saturated hydrocarbons (66.02 %) and secondary levels of aromatic hydrocarbons (30.96 %). The concentrations of polar compounds (NSO's) and asphaltene for Cipluk

oils are relatively low (NSO 2.37 % and Asphaltene 0.65 %). The total asphaltene level for Cipluk oil suggests these oil are mildly biodegraded. These results, together with relatively high saturated/aromatic ratios (2.13) generally suggest that all oils are fairly typical of paraffinic, mature liquid hydrocarbons [8]. Gas chromatography analysis was carried out on the whole oil (C5+) fraction for both oils. The GC traces are presented in Figure 1. The whole oil gas chromatograms for Cipluk oils are characterised by a suite of normal paraffins ranging from nC5 to nC30+. The CH4 oil is characterised as a light oil with a limited normal alkane ranging from nC5 to nC24 [9]. The Cipluk oils have high pristane/phytane ratios (4.78), which suggest derivation from a parent source facies deposited in an environment under mildly oxic (sub-oxic) conditions (Type III kerogen [7]).

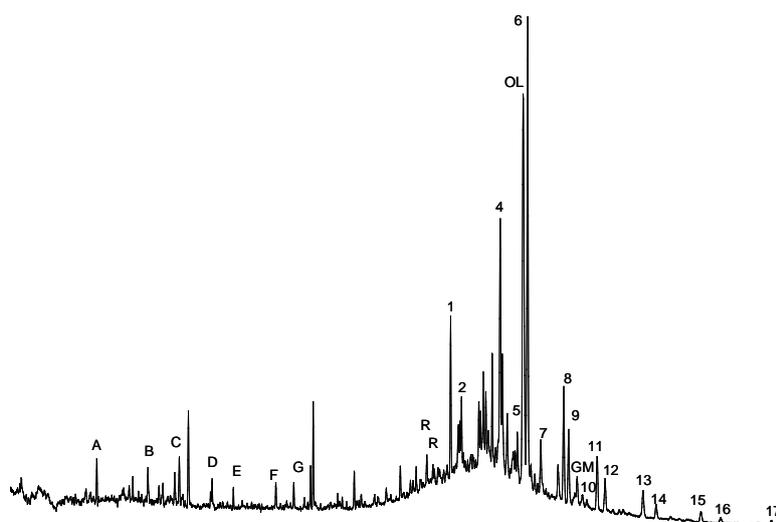


Figure 3. Fragmentogram mass (m/z 191) of oil seepage LW-05A Lawen, Banjarnegara [3].

The m/z 191 fragmentograms for the four crude samples display relatively simple distributions of bacterial-derived $17\alpha b(H)$ -hopanes which are relatively equal the C30 hopane to C29 hopane (Figure 2). This suggests these oil samples have been derived from a fluviodeltaic fair [7]. The $18\alpha(H)$ -Oleanane peak is relatively high in all samples. This compound is thought to be derived from Cretaceous (or younger) higher plant angiosperm markers [7].

The sterane distributions for the four oil samples show a full suite of normal steranes with the $C27\alpha\alpha\alpha(R)$ forms which are almost similar to Cipluk oils (30.22 %), but with relatively less abundant to the $C29\alpha\alpha\alpha(R)$ steranes (38.69). This implies a contribution of terrestrial-derived organic matter [7]. The sterane distributions of the oil sample from Cipluk oil implies a significant contribution of Estuarine or Shallow Lacustrine organic material [9]. Assessment of the thermal maturity of the oils at time of generation/expulsion has relied upon saturation and aromatic biomarker maturity specific parameters. The Methylphenanthrene Index has been calculated from the distribution of phenanthrene (m/z 170) and methylphenanthrenes (m/z 192) in the oils. The Cipluk oils show relatively high MPI-1 values (0.79) suggesting these oils were generated at mature levels based on calculated vitrinite reflectance equivalent data of 0.87 % (R_c). Based on the biomarker distributions, these oils are interpreted to have been derived from an Estuarine or shallow lacustrine source rock facies with terrestrial higher plant organic matter with some algal input [7]. A plot of the sterane distributions on Huang and Meinschein's paleoenvironment diagram can be seen in Figure 4 [8].

In Semarang area, Central Java, oil seepages are found in Bancak District, which are in Kedungjati and Bantal. Analyses done in Kedungjati were GC and GCMS for the rock extract of Pelang Formation and oil seepage and from the Kerek Formation [5]. Meanwhile, the analysis for the sample from Bantal used the GC analysis [6].

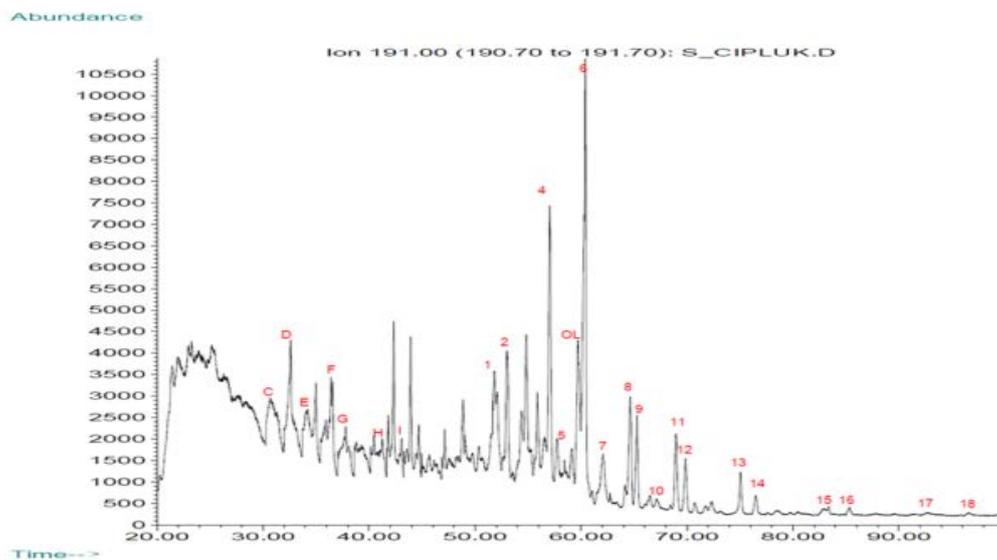


Figure 4. Fragmentogram mass m/z 191 of Cipluk oil seepage, Kendal [4].

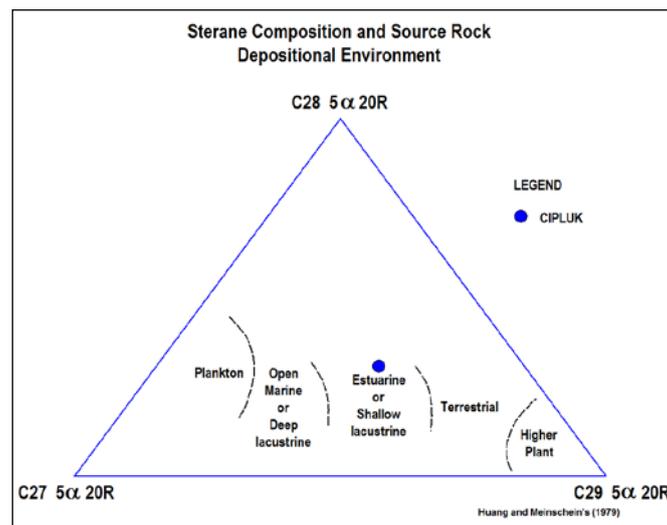


Figure 5. Sterane composition and source rock depositional environment (Huang dan Meinschein's 1979 [8]).

The chromatogram GC resulted from oil seepage of Kedungjati area [5] analysis detected the occurrence of biodegradation that is shown by the peak of n-alkana that cannot be well-separated and its n-alkane configuration is not clearly seen due to the advanced degradation. The result of GCMS of oil seepage from Kedungjati showed a sterane (m/z 217) fingerprint configuration that had been biodegraded and resulting the compound C29, C28 and C27 which are not clearly detected (Figure 6). Bisdane resin compounds are usually found in the hydrocarbon that the organic material deposited in the delta environment. Bisdane Mature Index Ratio value is 2.61 showing the oil seepage coming from the full mature source rock. Fingerprint of m/z 191 shows the present of organic materials from terrestrial higher plant organic material of the angiospermae species [7]. These organic materials were detected as oleanoide and oleanane.

The result of GC analysis of the rock extract from the Kerek Formation and Pelang Formation in Kedungjati area showing the n-alkane fingerprint configuration (Figure 6) has a unimodal character with n-C15 peak that indicated the origin of organic matter was aquatic life, the algae. The ratio of pristane and fitane shows low value ($pr/ph < 2$) that indicates the organic matter deposited in the enclosed environment has low oxygen, a characteristic of lake or marine sediments. The value of Carbon Preference Index (CPI) are 1.81 and 1.78 showing a low thermal maturity. The result of GCMS analysis of rock extract from the Kerek and Pelang Fm indicates a sterane (m/z 217) fingerprint configuration with the occurrence of high intensity of C27 sterane which shows the organic matter originated from the enclosed and very reductive marine environment. M/z 191 of the rock extract from Kerek and Pelang Fm showing the ratio of C31 22S/22R homohopane are 0.19 and 0.47, C30 22S/22R mortane/hopane are 0.44 and 0.10. Those ratio values indicate a low maturity.

The result of GC analysis of the oil seepage from Bantal area showing a fingerprint configuration of n-alkane has a bimodal character with peak at n-C8-C15 and n-C25-C29. This configuration indicates that the organic material originated from alga and high plant [11]. This conclusion is supported by the ratio of Ph/n-17 ranging from 0.61-0.94 and Ph/n-18 ranging from 0.78-0.86 that shows an organic material mixed kerogen or a mix between algal organic material and high plant organic material. Algal organic matter filled the carbon chain of C5 to C20, meanwhile the organic matter of high plant filled the carbon chain of C24 to C34, this pattern of n-alkane distribution characterizes the lacustrine oil.

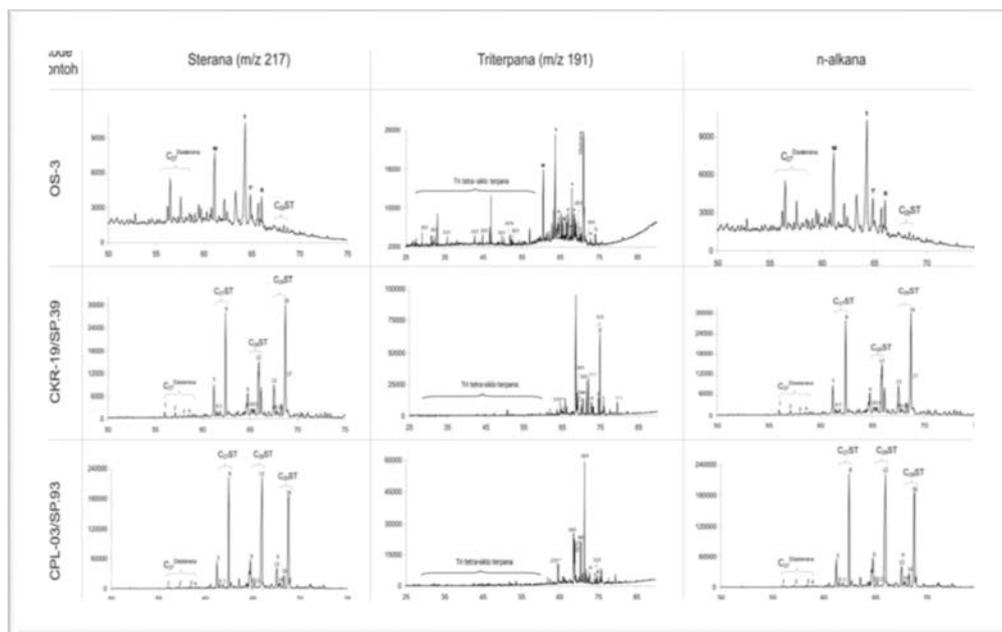


Figure 6. Fingerprint GC (n-alkane) biomarker and GCMS (Sterane and tripane) biomarker configuration of Kedungjati, Semarang [5].

3. Correlation between rock extract and oil seepage

Therefore, if reversed geochemistry proofing is done, it can be interpreted that the source rock of sample LW-05A was deposited in the relatively shallow marine, suboxic with a very high terrestrial organic material contribution and high level of maturity. The formation that is appropriate with those conditions is Totogan Formation for Banjarnegara area. For Bayat area, the appropriate formation is Wungkal Formation [10].

The correlation between oil seepage from Cipluk, Kedungjati and Bantal and the rock extract from Kerek Formation and Pelang Formation had been done by using GC and GCMS data of oil seepage and

rock extract. The result of GC and GCMS of oil seepage shows that Cipluk oil is derived from organic matter of the terrestrial plant and source rock that is categorized as mature [4]. Meanwhile, the rock extract of Kerek Formation contains aquatic organic matter (alga) that is probably originated from a marine environment with the low maturity level [5]. Different source of organic material, depositional environment and maturity level show that there is no correlation between oil seepage in Cipluk and source rock of Kerek Fm. The result of GC and GCMS analysis of oil seepage in Kedungjati shows that the organic material sourced from the terrestrial higher plant and deposited in the delta environment with a full maturity level. This data indicates that there is no correlation between Kerek Formation and Pelang Formation that have different organic material, which is aquatic (algae), deposited in the marine environment and low maturity level. The result of GC analysis of the oil seepage from Bantal, Semarang shows no correlation between Kerek Formation and Pelang Formation as there is different origin of organic material of oil seepage, which is sourced from the mixture of algae and high plant and lacustrine depositional environment.

The analysis to identify the correlation between oil seepage from Lawen, Banjarnegara and the source rock cannot be done as there is no source rock biomarker data that can be estimated as the source of the seepage. A research on the source rock biomarker is needed as an example from the Totogan Formation in the Banjarnegara and Karangsembung, Kebumen.

4. Summary

Based on the GC and GCMS analyses that show different of organic material sources, depositional environment and maturity level, it is indicated that the oil seepage in Cipluk is not correlated with the source rock of Kerek Formation. Oil seepage in Kedungjati and Bantal, Semarang is not derived from Kerek Formation and Pelang Formation based on the different in source of organic material and the depositional environment. Oil seepage in Lawen Banjarnegara is estimated to originate from Totogan Formation in Banjarnegara and Wungkal Formation in Bayat. However, analysis for oil and rock correlation in Banjarnegara cannot be done because there is no source rock geochemical data available. For that reason, biomarker analysis of source rock is needed to identify the origin of oil seepage in Lawen Banjarnegara in the Totogan Formation in Banjarnegara and Kebumen areas.

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