Origin of Oil Seeps in West Sulawesi Onshore, Indonesia: Geochemical Constraints and Paleogeographic Reconstruction of the Source Facies

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ABSTRACT

Numerous oil and gas seeps occur at onshore West and South Sulawesi. These may indicate the presence of active petroleum system in subsurface hence the area is worthy for further exploration. No discovery well so far in this area. Therefore, the seeps provide significant data to build integrated petroleum system analysis.

A number of geochemical analysis were conducted on the oil seeps and rock samples from outcrop and well cuttings to reveal the source rocks that generate the oils. Triterpane m/z 191 shows low content of tricyclic terpane, low norhopane to hopane, and abundant oleanane. Sterane m/z 217 and bicyclic alkane m/z 123 show dominant C29 sterane and bicadinane. These biomarkers indicate that the source of oils are coals and/or coaly shales deposited in fluvio-deltaic setting. Contribution from marine input is shown in Karama region to the south.

Based on stratigraphic setting of West and South Sulawesi, the best candidate for the source of oil seeps is Eocene coals or coaly shales of Toraja or Kalumpang Formation. The Eocene coal samples have been characterized and show similar GC alkane distribution with the oil seeps. Contribution from marine facies, which may age-equivalent to these coals are shown in Karama region.

Aromatic methyl phenanthrene m/z 178 and m/z 192 were also analyzed to know their maturities and they were generated at maturity level equivalent with Ro 0.8-1.0 %. Based on geochemical constraints and geologic data, a paleogeographic setting of Eocene Toraja/Kalumpang Formation was built to know better about the paleo-source facies of the oils and its geochemical characteristics.

Keywords: Biomarker, coaly shales, Toraja/Kalumpang Formation

Introduction

Numerous oil and gas seeps occur at onshore West and South Sulawesi, such as in the Kalosi, Lariang, and Karama areas (Figure 1). These may indicate the presence of active petroleum system in subsurface hence the area is worthy for further exploration. No discovery well so far in this area (Satyana et al., 2012). Therefore, the seeps provide significant data to build integrated petroleum system analysis.

Method

The main purpose of this paper is to characterize the oil seeps and to correlate them with the expected source rock located on the mainland of West Sulawesi. Characterization of the oils to infer their organic material input and depositional environment is determined by the fraction of gas chromatography and saturated biomarkers (triterpanes m/z 191, steranes m/z 217, and bicyclic alkanes m/z 123). The oil maturity is determined using aromatic biomarker (methyl phenanthrene m/z 178 and m/z 192).

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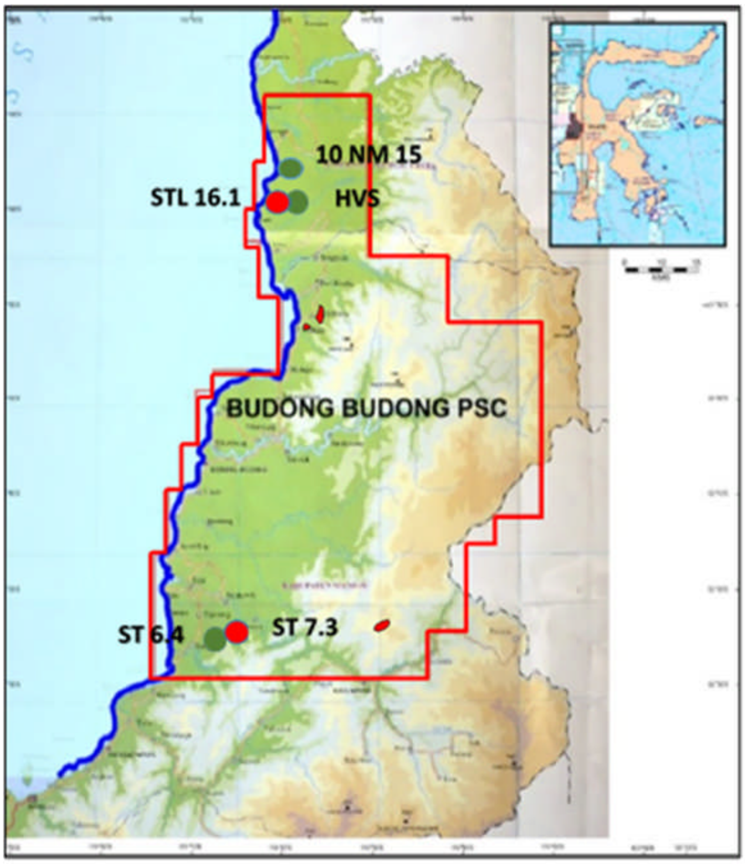

Figure 1. Location Map

RESULTS & DISCUSSION

Oil Characteristic and Source Facies

Gravity values of 10.60° to 14.80 °API suggest that these are heavy crudes, most probably due to biodegradation (Rachmalia and Jatmiko, 2011). Low wax contents (0.49 - 2.03 wt.%) and low sulphur contents (0.15-0.19 wt.%) suggest that these samples are sweet crudes.

The oil seeps that show dominance of saturate hydrocarbons (44.44 - 54.07%) with significant aromatic hydrocarbons (39.41 - 43.80%) were indicated by liquid chromatography. The polar compounds (NSO's) and asphaltene concentration are low (total 6.15 - 11.75%), typical of paraffinic mature oils (Rachmalia and Jatmiko, 2011).

According to GC traces in the gas chromatography analysis, normal paraffins are absent. Possibly due to the biodegradation has affected the crudes due to exposure at the sample sites, thus GC data and GC ratios are unreliable (Figure 2).

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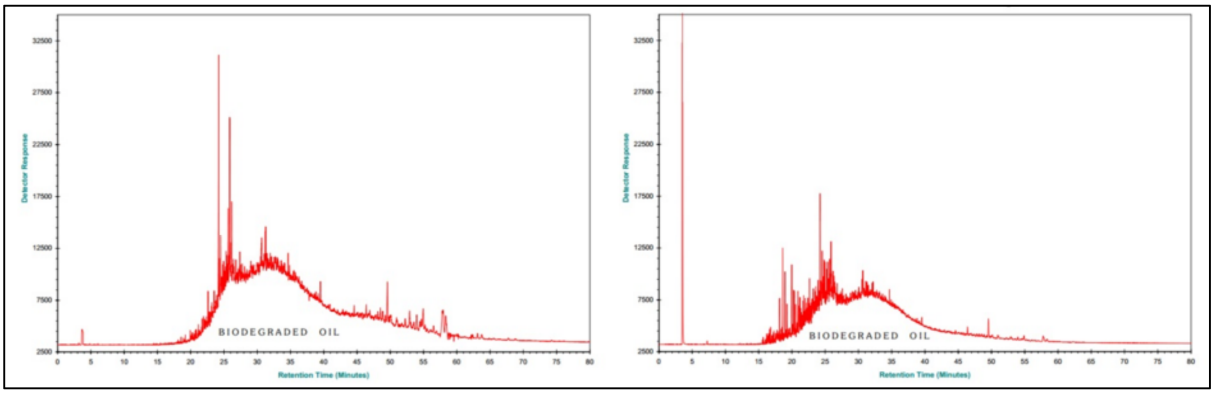

Figure 2. C5+ Whole Oil Gas Chromatogram of Oil Seeps in Lariang and Karama (Rachmalia and Jatmiko, 2011)

Triterpane m/z 191 in Lariang region shows low content of tricyclic terpane, low norhopane to hopane, and abundant oleanane (Rachmalia and Jatmiko, 2011). It displays the distributions of bacterial-derived 17αβ(H)-hopanes which are dominated by the C_{30} αβ(H)-hopane (C_{30} hopane>C_{29} hopane), suggesting the oil seeps are of clastic origins. Karama region dominated by the C_{29} αβ(H)-hopane (C_{29} hopane>C_{30} hopane), suggesting the oil seep samples show contribution of algal origin.

All oil seeps show a low abundance of the C_{23} tricyclic compounds (F) relative to the C_{21} (D). Lower abundances of tricyclic compounds (C_{19} and C_{20} tricyclic compounds, B and C respectively) is an indication of an algal origin (Rachmalia and Jatmiko, 2011). The high composition of oleanane, together with C_{30} resins (R) can be seen in Figure 3a and 3b.

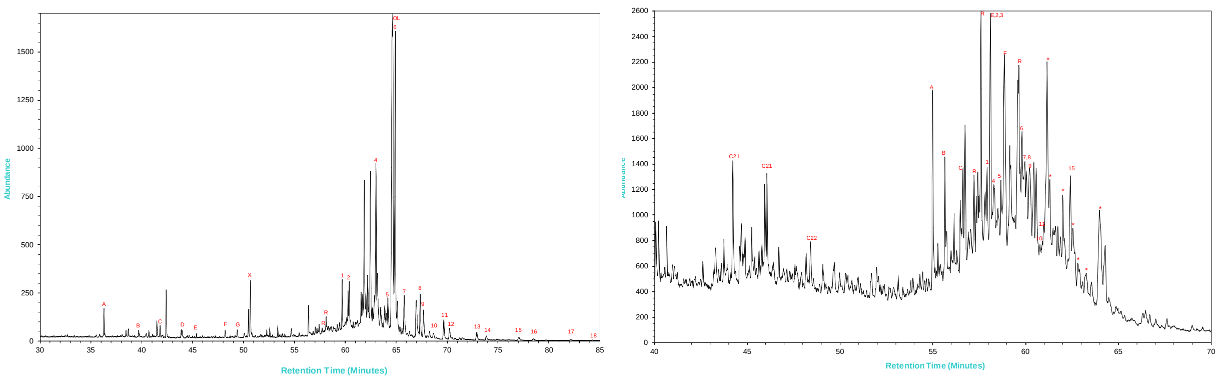

Figure 3a. GCMS Triterpanes (m/z 191) and Steranes (m/z 217) in Lariang region (Rachmalia and Jatmiko, 2011)

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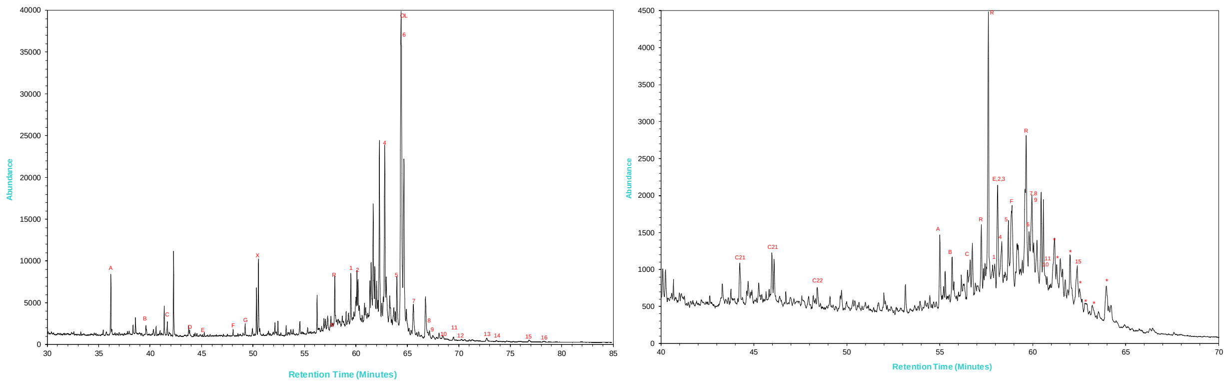

Figure 3b. GCMS Triterpanes (m/z 191) and Steranes (m/z 217) in Karama region (Rachmalia and Jatmiko, 2011)

Sterane m/z 217 and bicyclic alkane m/z 123 show dominant C29 sterane and bicadinane (Rachmalia and Jatmiko, 2011). These biomarkers indicate that the source of oils are coals and/or coaly shales deposited in fluvio-deltaic setting. In Lariang region show that $C_{29}\alpha\alpha\alpha(R)$ forms more sterane relative to the $C_{27}\alpha\alpha\alpha(R)$, defining a significant contribution of herbaceous organic material and minor algal input within the potential source rock. In the Karama region shows that the $C_{27}\alpha\alpha\alpha(R)$ forms more sterane relative to the $C_{29}\alpha\alpha\alpha(R)$, defining a significant contribution from algal derived organic matter (Figure 3a and 3b).

In the distributions of biomarker shows that the source rock facies in Lariang region contains terrestrial organic matter with some algal input. In the other hand Karama region contains a predominance algal organic matter.

Maturity

GC-MS biomarker shows that oil seeps recovered from Lariang region were generated from an organic assemblage dominated by terrestrial higher plant material with some algal input, while in Karama region the oil seeps are dominated with an algal predominance and some herbaceous organic matter.

Based on the result of GCMS in Lariang and Karama region from Robinson (1990), all of the samples proved to be extensively biodegraded with no recognizable n-alkane or isoprenoid peaks remaining on a C10 plus GC unresolved baseline (Figure 4).

The triterpene (m/z 191) profiles was also show a big amount of oleanane and bicadinane, typical of Indonesian terrestrially sourced oils (Robinson, 1990). The 4-methylsteranes are minor on m/z 231, indicate also the contribution from algal material. Vitrinite reflectance estimates based on methyl phenanthrene index (MPI) were generated at maturity equivalent with Ro 0.8-1.0%.

Expected Source

Based on stratigraphic setting of West and South Sulawesi, the best candidate for the source of oil seeps is Eocene coals or coaly shales of Toraja or Kalumpang Formation. The Eocene coal samples have been characterized and show similar GC alkane distribution with the oil seeps.

Paleogeography

Paleogeography of Kalimantan and Sulawesi during early-middle Eocene,

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affect the development of source, reservoirs and seals in Paleogene (Figure 5.).

CONCLUSIONS

1. Based on geochemical characteristics, oil seeps from onshore West Sulawesi show signatures of source facies related to terrestrial fluvio-deltaic environment of coaly source, but in Karama region the seeps show significant contribution from marine algal.
2. Based on oil to source correlation analysis, the expected source for the oil seep was Eocene coals or coaly shales of Toraja or Kalumpang Formation, but with some significant contribution from marine facies to the south in Karama region.

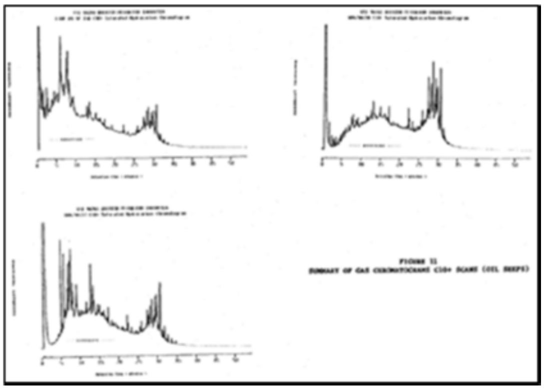

Figure 4. Summary of Gas Chromatograms C10 + scans (Robinson, 1990)

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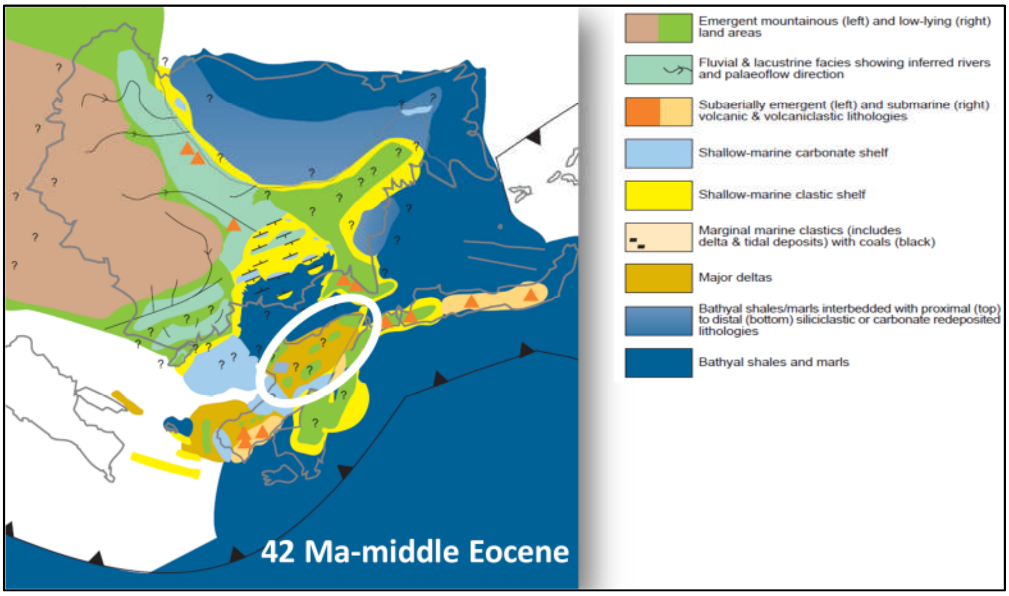

Figure 5. Paleogeography of Kalimantan and Sulawesi during early-middle Eocene (Moss and Wilson, 1998). The palaeoenvironment of area inside the white circle is fluvio-deltaic.

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