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Biomarker Characterization of Oil Seepages in Tomori Basin, Central Sulawesi, Indonesia

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Abstract. Tomori Basin is located close to the Banggai Basin which has several productive oil fields. Further investigation of the hydrocarbon potential in Tomori Basin is an important issue as potential hydrocarbon resources are indicated by the discovery of several oil seepages in the area. This study identified Tomori Basin oil seepage characteristics using a biomarker analysis approach. The Wosu and Kolo Areas were the main objectives of this study. Oil seepage characteristics were determined using Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) methods to generate biomarker data which could be analysed to identify organic matter origin, oxic and anoxic conditions, source facies, or depositional environment. Based on the GC analysis of is oprenoids, the Pristane C19/Phytane C20 ratio (Pr/Ph) of Wosu Oil was 0.75, indicating anoxic conditions typical of a hypersaline environment. Kolo Oil had a Pr/Ph ratio of 3.37 indicative of terrestrial organic input under oxic conditions. A cross plot between Pristane/nC17 and Pr/Ph ratios indicates that Wosu Oil derives from a highly anoxic environment with algae/bacterial organic matter input whereas Kolo Oil derives from a suboxic-oxic environment dominated by terrestrial organic matter input. Trycyclic terpene analysis from C19 to C25 shows Wosu Oil seepages tend to originate from an environment of mixed terrestrial and marine organic matter (transitional environment). Overall, biomarker characteristics indicate that Wosu Oil originated from organic matter in a hypersaline and anoxic environment, whereas Kolo Oil originated from terrestrial matter in a suboxic – oxic environment.

1. Introduction

The Tomori Basin is one of the basins in Indonesia with potential hydrocarbon resources. This basin is located near to the Banggai Basin which has several productive oil fields [1]. Unlike the Banggai Basin, geological and geophysical data on the Tomori Basin are still very limited. Therefore, hydrocarbon characterization of the Tomori Basin is a very interesting topic, especially since several oil seepages have been discovered in the Tomori Basin area, indicating the hydrocarbon potential of the Tomori Basin. In past hydrocarbon discoveries, the presence of hydrocarbon seepages has played a key role since the 19th century [2]. Migrated hydrocarbon from mature source rock in the subsurface to the surface is indicated by the presence of hydrocarbon seepage in the research location [2].

Biological markers or biomarkers [3] are complex molecular fossils derived from biochemical, particularly lipids, in once-living organisms. Biomarkers are very useful to provide information about the organic matter origin of source rock, an environmental condition during its deposition and burial (catagenesis), thermal maturity experienced by oil and source rock, the degree of biodegradation, some aspects of mineralogy (lithology), and age[4].

However, there is a lack of data on the geochemical characteristics of these oil seepages, particularly biomarker characteristics, in the Tomori Basin. This study would conduct an identification oil seepage characterization from Tomori Basin using the biomarker analysis approach. This study was conducted to determine the oil seepage characteristics based biomarker analysis approach. Biomarker of oil and source rock recognized to determine the depositional environment, oxic and anoxic level of depositional environment, organic matter origin, mineralogicalcharacterization of source rock [4].

2. Geological setting

Sulawesi Island consists of three distinct mega-tectonic provinces. These are: (1) The North Sulawesi Island Arc which a pure oceanic island-arc; (2) The Western Sulawesi Magmatic Arc, which is attached to the main body of Sulawesi, also called Western Sulawesi. It is a rifted part of Sundaland and a plutono-vulcanic arc or magmatic arc which is subdivided into sections by crustal faults into the North Sulawesi Segment (NW Sulawesi) in the neck area; the Central West Sulawesi Segment (CW Sulawesi); and the Southwest Sulawesi Segment (SW Sulawesi); and (3) The East Sulawesi Eastern Belt, which is the hinterland of an orogen, composed of Mesozoic autochthon and younger allochthonous metamorphic and ophiolitic rocks which are obducted over an eastern province of Australian derived microplates during the late Oligocene [5] . The stratigraphy of the Tomori Basin includes four major rock groups.: (1) Sundaland accretion boundary rocks; (2) rocks from the pieces of the Australian Continent;
(3) Neogeneous rocks after the collision between the continental strip and the eastern arm of Sulawesi (Sulawesi Molasa Group); and (4) rocks originat ing from the Pacific Ocean crust (ophiolite complex). Map of the Tomori Basin are shown Fig. 1

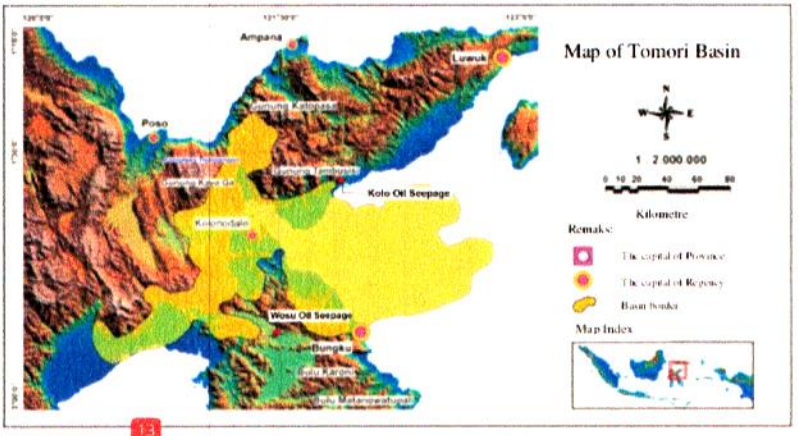

Figure 1. Map of the Tomori Basin area showing the research sites.

Regionally, Tomori Basin is composed of a microcontinent that consists of the Tokala Formation as a basement rock of this basin. The Tokala Formation consists of limestone and claystone interlayered with shale. The Tokala Formation was deposited in a shallow-deep marine environment in Late Triassic, unconformably overlain by the Early - Late Jurassic Nanaka Formation which consists of quartz sandstone, conglomerates with granite fragments, and shale. The Nanaka Formation deposited in the fluvio-deltaic environment is interfingered in the upper layer with the Tetambahu Formation which consists of a limestone unit from the Mid to Late Jurassic. The Tetambahu Formation depositional processes continued to the Late-Jurassic, in a shallow marine environment The Tetambahu Formation is unconformably overlain by pelagic sediment from the Matano Formation which was deposited in the Late Cretaceous [1].

3. Data and methods

Oil seepages were found in the Wosu Area and Kolo Area in Central Sulawesi Province (figure1). Oil

seepages found in the research area were the main objective of this study. Determination of Oil seepage characteristics was conducted using Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) methods. These methods generated biomarker data that was analysed to identify organic matter origin, oxic and anoxic conditions, source facies, and depositional environment of organic matter.

Data for the determination of organic matter origin, oxic and anoxic conditions were generated through calculation of the Pristane/Phytane ratio [6], the cross-section between Pristane (Pr)/normal alkane nC17 and Pristane (Pr)/Phytane (Ph) using Gas Chromatography (GC). Data on source facies and depositional environment of organic material were generated by determining the Sterane and Triterpene ratios using Gas Chromatography- Mass Spectrometry (GC-MS) analysis. Cross plots between the sterane ratio and the distribution pattern of triterpene provided specific information to determine the characteristics of the oil seepages in this study.

4. Results and discussion

4.1. *Gas Chromatogram (GC) analysis*

Determination of organic matter origin from oil seepages using Gas Chromatogram (GC) analysis showed that oil seepages from the Kolo area (Kolo Oil) originated from the compression of organic matter with a predominance of higher plant input in a suboxic environment, whereas the Wosu oil resulted from the compression of algal/bacterial organic matter in the anoxic-suboxic condition (figure 2). The direct pristane/phytane ratio was calculated as an indicator to aid in the determination of the depositional environment. The pristane/phytane ratio of Kolo Oil was 3.37, indicating that the Kolo oil source input was derived from a transitional depositional environment (e.g. deltaic) with a concentration of higher plant input. An average Pristane/Phytane ratio of around0.75 indicates that Wosu Oil likely originated in a hypersaline environment.

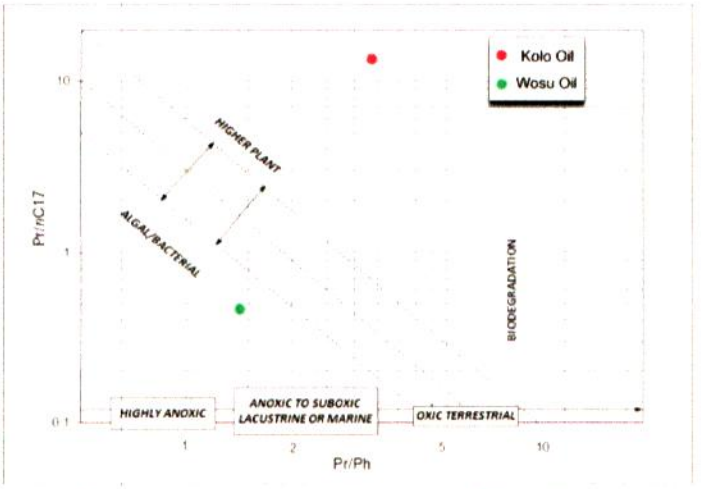

Figure 2. Cross plot between Pristane/ Phytane and Pristane/ nC17 (after Hwang, 1998) showing higher plant organic matter input in a suboxic environment for Kolo Oil, and algal/ bacterial organic matter input in an anoxic to suboxic environment for Wosu Oil.

4.2. *Gas Chromatography-Mass Spectrometry (GC-MS) analysis*

The Gas Chromatography-Mass Spectrometry (GC-MS) analysis to determine the depositional environment could not be carried out on the Kolo Oil due to technical issues, therefore only the Kolo Oil samples were analysed. Huang and Meinschein's (1979) ternary diagram of C27, C28, and C29 from m/z 217 is one of the indicators in the determination of depositional environment, to distinguished the material input and the correlation with the depositional environment[7]. The ternary diagram of C27, C28, and C29 shows that Wosu Oil originated from a transitional environment due to

the equal concentration between C27 which indicates planktonic organic input under hypersaline conditions, and C29 which indicates higher plant input in a terrestrial environment (Figure 3).

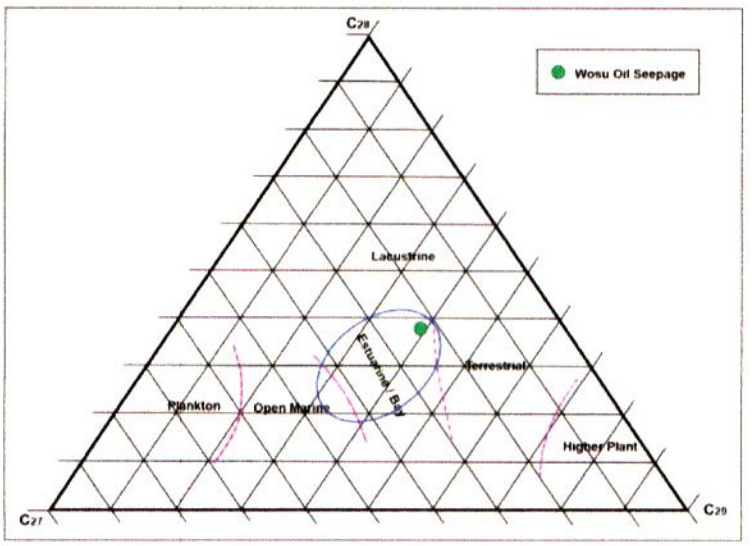

Figure 3. Ternary diagram of sterane C_{27}, C_{28}, C_{29} (after Huang and Meinschein, 1979) shows that Wosu Oil derived from an estuarine/ bay depositional environment

4.3. *Tricyclic Terpene ratio*

The Tricyclic Terpene ratio was used in this study to determine the depositional environment based on the C19 to C25 concentration in the oil samples. Determination of depositional environment based on tricyclic terpene patterns was proposed by Price, et al., 1987 [8]. The observed tricyclic terpene ratio of Wosu Oil shows a predominance of C19 and C23 which indicates that Wosu Oil originated from a mixing between organic matter from terrestrial and marine origins. The implication of this condition is we can simply determine that Wosu Oil is derived from a transitional environment (e.g. deltaic/estuarine) with a mixture of organic matter inputs.

5. Conclusion

According to the results and discussion above, we conclude that GC and GCMS analysis proved to be a good indicator for distinguishing and determining Oil seepage characteristics. Wosu and Kolo Oil have different characterization and can be distinguished using GC and GC-MS analysis. The Wosu oil seems to have originated from a hypersaline environment, from a concentration of algal/bacterial organic matter under anoxic-suboxic conditions, whereas the Kolo Oil appears to be derived from higher plant organic matter under suboxic conditions. Wosu oil originated from a transitional environment (estuarine/bay depositional environment) as indicated by the equal concentrations of C27 (Phytoplankton) and C29 (Higher Plants). The terpene tricyclic C19 and C23 predominance in Wosu Oil samples also indicates a transitional environment with mixed input from terrestrial and marine organic matter.

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