Thermogenic Hydrocarbon Potential on Two Drop Cores Samples from The Surface Geochemical Exploration Program in The Offshores Area of Yamdena Basin, Tanimbar Islands

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ABSTRACT

Seepage of hydrocarbons in near-surface sediments can be categorized into micro and macro seepage, controlled by complex geological, geochemical, and biological processes. Surface geochemical exploration programs have been widely employed to detect and analyze geochemical anomalies on the Earth's surface, which could indicate the presence of subsurface mineral or hydrocarbon deposits. This study aims to characterize two drop core samples extracted from the Yamdena Basin through organic geochemical and isotopic analysis to assess the potential for thermogenic hydrocarbons in the region. A quantitative approach was adopted, utilizing geochemical data, including stable carbon isotope analysis and organic geochemical evaluation through Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS). The samples analyzed consisted of two piston cores collected during a surface geochemical program conducted by TDI-Brooks International, Inc. This study relies on data from a previous TDI-Brooks International, Inc. survey, with data licensed from TGN-NOPEC Geophysical Company through the Migas Data Repository (MDR) – Pusdatin, focusing on the organic geochemical characterization of drop core samples from offshore Tanimbar Islands. The results indicate that Sample#1 and Sample#2 samples were deposited in a marine setting with varying terrestrial input and exhibited a low maturity level. Geochemical signatures reveal the presence of immature land-plant lipids, suggesting a low potential for thermogenic hydrocarbon generation. The findings highlight the value of surface geochemical exploration programs in mapping hydrocarbon prospects in frontier areas. Furthermore, detailed geochemical analyses can provide insights into the sources and potential of hydrocarbons, aiding in future exploration strategies.

Keywords: Surface geochemical exploration, organic geochemistry, hydrocarbon seepage, Yamdena Basin.

INTRODUCTION

Hydrocarbons have a natural property as other liquids to be migrated from subsurface accumulation to the surface. This hydrocarbon migration predominantly occurred via Darcy flow, driven by buoyancy and water flow in compacting sediment (ENGLAND et al., 1987). High pressure and under-compaction during the process of diagenesis could also create micro fissures, which eventually form interconnected pores, joints, and fractures in carrier and reservoir rocks, enabling smooth liquid-phase migration during both primary and secondary migration stages (Jiang et al., 2016). During the migration process, hydrocarbon could be migrated until reaching the reservoir rock. However, whether the seal is absent or the present seal cannot hold the hydrocarbon due to the high pressure created by the fluid or tectonic events, the hydrocarbon will continue to move and could create seepage near the surface.

The occurrence of the seepage in the near sediment could be expressed as micro and macro seepage. The micro and macro seepage is governed by complex processes influenced by geological, geochemical, and biological factors. Etiope (2015) stated that macro seepages refer to substantial gas emissions, such as oil seeps and mud volcanoes, which are generally associated with geological faults. Moreover, microseepage is a widespread gas emission across extensive areas, usually requiring advanced detection methods(Etiope, 2015). Microseeps have low concentrations of hydrocarbons and exhibit minimal geophysical anomalies, commonly occurring in regions with relict generation and extensive regional seals(Abrams, 1996). Both macro and micro seepages could provide evidence of the presence of hydrocarbon as an indication of an active petroleum system. However, there are critical differences between both seeps. The macro seepages provide direct proof of hydrocarbon existence, while micro seepages act as key exploration markers, emphasizing the importance of combining geochemical and geological methods in hydrocarbon prospecting (Etiope, 2015; Tedesco, 2012, 2021).

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A surface geochemical exploration program has been utilized to detect and analyze geochemical anomalies on the Earth's surface, which can indicate the presence of subsurface minerals or hydrocarbon deposits. The primary goal of a geochemical exploration survey is to identify the presence and distribution of hydrocarbons in a given area and, more critically, to assess the likely hydrocarbon charge to specific exploration targets and prospects (Schumacher, 2000). The geochemical exploration survey, which involves the chemical identification of surface or near-surface sediment, has been done in several areas, such as offshore Brunei, Argentina, and New Mexico (Bjorøy & L. Ferriday, 2006; Hill et al., 2006; Larriestra et al., 2013). Bernie *et al.* (2008) have also conducted a surface geochemical exploration program in fifteen frontier basins in Indonesia. The geochemical exploration program has been focused on the presence of thermogenic hydrocarbon in the area (Bernard et al., 2008). However, the detailed organic geochemical characteristics of the drop cores, especially in the offshores area of Yamdena Basin, South Tanimbar Islands, have not been discussed. Thus, this paper aimed to characterize two drop cores extracted from the Yamdena basin according to their organic geochemical and isotopic analysis to see the possibility of thermogenic hydrocarbon potential in the area.

GEOLOGICAL SETTINGS

Eastern Indonesia is situated within a highly complex tectonic zone shaped by the Neogene collision and interaction of the Australian and Eurasian (Sunda Land) continental plates and the Caroline and Philippine Sea oceanic microplates (Pacific Plate). The region has been compared to a vast jigsaw puzzle, consisting of numerous small ocean basins separated by fragments of continental crust, some of which are thickened and are ultimately expected to merge into a single intricate terrane (Baillie et al., 2003; Metcalfe, 1998; Milsom, 1991).

The study area is regarded as a zone of collision between the northern margin of the Australian Continent plate and an oceanic island arc system bordering the Sunda plate. It is assumed that the volcanic arc called the "Banda Inner Arc" developed due to the subduction of the Australian Continent plate under the oceanic island arc. Subsequently, an accretionary prism, the "Banda Outer Arc" (Seram-Kai-Tanimbar-Timor Island arc), consisting of sediments from the Australian continent plate, formed accompanied by deep-seated thrust (P. Barber et al., 2003).

The offshore Tanimbar region is situated in southeastern Indonesia, bordering Australian territory to the south. It comprises the Babar Selaru Block in the north and the Abadi Field in the south (Saputra & Ohara, 2016). Geologically, this region lies within the Banda Outer Arc, the Timor-Tanimbar Trough, and the Northern Bonaparte Basin (Figure 1). Structurally, the area of interest consists of a series of Paleozoic basins, such as the Barakan and Arafura Basins, along with elevated platform highs from the Late Paleozoic to Early Mesozoic, including the Sahul Platform and Darwin Shelf. These platforms are separated by Mesozoic depocenters like the Malita and Calder Grabens. To the northeast lies the Banda Arc, which formed during the Neogene due to the collision between the leading edge of the Australian continental plate and the East Indonesia island arc system (P. M. Barber et al., 2003). The islands reveal a stratigraphic sequence spanning from the Triassic to the present. The Triassic-Cretaceous deposits formed within and along the western flank of a large graben basin, representing the Calder Graben's northern extension on the Australian continental margin. The Paleogene to Miocene sequence consists of deepwater sediments accumulating on the Australian margin following continental breakup (Fakhruddin, 2020).

RESEARCH METHOD

The research adopted a quantitative approach that utilized the geochemical data, including the stable carbon isotope and organic geochemical analysis from Gas Chromatography (GC) and Gas Chromatography and Mass Spectrometry (GC-MS). Two piston core samples were collected during the surface geochemical program conducted by TDI-Brooks International, Inc. The detailed methodology of sample collection has been described in detail by Bernard *et al*. (2008). This research utilizes the data from the previous survey by TDI-Brooks International. Inc. with a data license from TGN-NOPEC Geophysical Company. This research was focused on the organic geochemical characterization of the two drop core samples collected in the offshores areas of Tanimbar islands close to Yamdena island (Figure 1).

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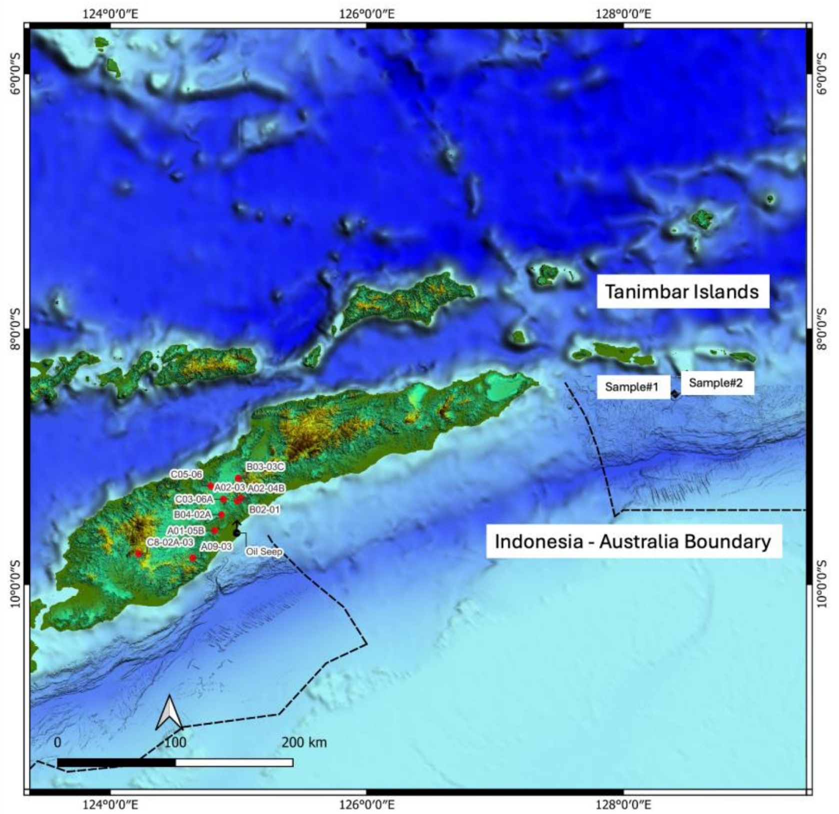

Figure 1. The location of the study area, along with the samples used in this study, was marked with labels SAMPLE# and SAMPLE#2.

Table 1. Bulk chemical analysis of the two piston core samples

No.	Sample ID	Drop cores extracts samples				Sat/Aro	n-Paraffin/ Naphtene	d13C sat	d13C Aro	CV	EOM (ppm)
		%Sat	%Aro	%NSO	%Asph						
1	SAMPLE#1	22,4	38,8	28,2	10,6	0,58	0,22	-29,86	-28,64	0,3	142
2	SAMPLE#2	39,4	32,3	14,1	14,1	1,22	0,81	-29,16	-27,41	1,3	165

Notes:

%sat	saturate fraction from isolated extract
%Aro	aromatic fraction from isolated extract
%NSO	Nitrogen, Oxygen, and Sulphur fractions from isolated extract
%Asph	asphaltene fraction from isolated extract
n-Paraffin/ naphtene	ratio of aliphatic n-alkana (paraffinic) and ratio of cylcoalkane (naphtenic)
CV	canonical variable from isotopic measurement
EOM	*Extractable organic matter*,

RESULT AND DISCUSSION

The result of bulk analysis of the two drop cores showed by Table 1. The percent of each fraction from the extract could give information related to the source lithology (Tissot & Welte, 1985). The saturate fraction of the sample#1 sample has a relatively lower composition than the other fractions, indicating the smaller amounts of aliphatic hydrocarbon contained by the sample. Furthermore, this indicates that the extract's hydrocarbon is a heavier crude oil. The

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described characteristics could also be related to biodegradation, which alters the simple hydrocarbon with low molecular weight into the heavier one (Palmer, 1993). In contrast, the TGN 153 showed relatively more dominant saturate fractions than the aromatic and NSO fractions. This refers to the higher aliphatic component of the samples, which could also be seen by a higher ratio of n-Paraffin/naphtene (Table 1).

The saturated to the aromatic ratio (sat/aro) for both samples respectively are 0,58 (Sample#1) and 1,22 (Sample#2), indicating a marine setting of the source rock. Although both samples show the possibility of marine source, they differ in the lithology in which the Sample#1 hydrocarbon was sourced from a less calcareous source than Sample#2 (Peters et al., 2005). The isotopic analysis showed that both samples have a lighter carbon isotope (-29,86 and -29,16, respectively, for the saturate fractions; -28,64 and -27,41, respectively, for the aromatic fractions). The lighter isotope contained by both samples indicates that the hydrocarbon source was deposited in the shallow water at a restricted circulated basin with a dominant organic CO_2 (Bissada et al., 1993).

The comparison between isotopic values of aromatic and saturated fractions (Fig. 2) exhibits a dominant input of the terrigenous organic matter to the samples during deposition (Sofer, 1984). The bulk analysis results also showed differences in the canonical variable (CV), which refers to the difference in the isotopic relationship. In this study, Sample#1 has a CV of 0,3 while Sample#2 has 1,3 values. The results suggest that Sample#1 has more marine organic matter characteristics than Sample#2, which received more input from terrestrial organic matter (Sofer, 1984).

The results of the GC analysis (Fig.3) revealed that the n-alkane distribution of both samples ranges from nC_6 -nC_{35} with the odd to even predominance. The predominance of odd carbon numbers of n-alkanes in high molecular weight of n-alkane suggests the input from cuticular waxes of the continental higher plant deposited in a marine setting (Tissot & Welte, 1985). Moreover, the predominance of nC_{25} – nC_{27} – nC_{29} in samples also indicates the contribution of immature land plant lipids (Tissot & Welte, 1985).

The triterpane biomarkers obtained from the fragmentogram of *m/z* 191 (Fig. 3) could also to be analyzed to obtain information related to the source of the hydrocarbon contained in the extracts. Both samples exhibit a relatively low C_{19}/C_{23} ratio with a low C_{24} tetracyclic component, indicating the deposition's marine setting (Peters et al., 2005). In addition, the distribution of sterane biomarkers (*m/z* 217, Fig.3) confirmed that both samples received dominant input from terrigenous organic matter and showed the dominance of C_{29} steranes in both samples.

Both samples showed different maturity profiles based on the C_{27} and C_{29} Ts/Tm ratios. Although both are characterized by the dominant of the less stable Tm compound, which refers to the low maturity, Sample#1 showed a higher Ts/Tm ratio. This sample also obtained a higher ratio of C_{29} sterane 20S/20R, indicating a possibility of a higher maturity stage for this sample.

CONCLUSION.

The organic geochemical analysis and the stable carbon isotopes for the two drop core samples showed that the hydrocarbon extracted was deposited in a marine setting. A strong indication of terrigenous organic matter input was also present in the samples, which refer to the shallow water depositional setting. The major distinction in the depositional settings is that Sample#1 received less terrestrial input and came from a more calcareous lithology source. The maturity of Sample#2 is also higher, indicating a possibility of migrated hydrocarbon. However, as both samples exhibit relatively low maturity in general, and the signature of immature land plant lipids is also present, the potential of thermogenic hydrocarbon is not present.

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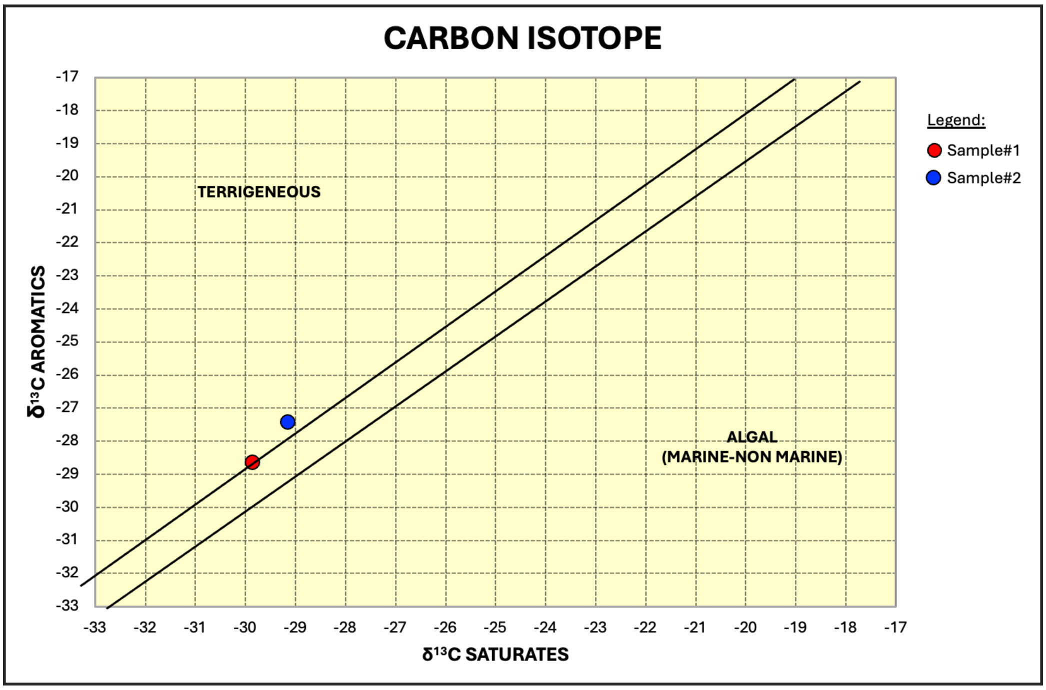

Figure 2. Carbon isotopic plots of both saturate and aromatic fractions of both samples.

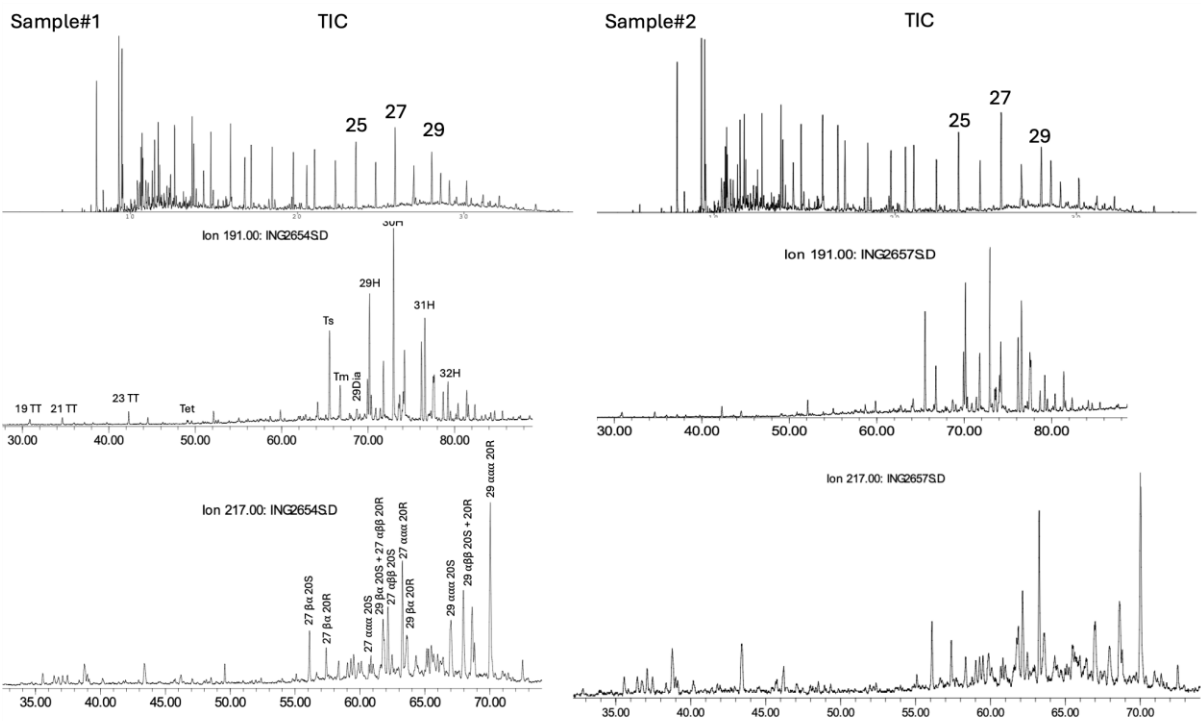

Figure 3. Chromatogram and Fragmentograms of Sample#1 and Sample#2 samples showing the distribution of n-alkanes (TIC), Triterpanes (*m/z* 191), and Steranes (*m/z* 217) biomarkers.

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