

Relationship of oil seep in Kudat Peninsula with surrounding rocks based on geochemical analysis

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Abstract: This study aims to investigate the relation of oil seepages on the Sikuati area with the surrounding rocks on Kudat Peninsula through geochemical analysis. Outcrops with highly carbonaceous laminated rocks belonging to the Sikuati Member at Kudat Peninsula indicate the presence of oil seepage in this area. A detailed geochemical analysis of the source rock samples and oil seepages from the Sikuati area was carried out for their characterization and correlation. Hydrocarbon prospective of Sikuati Member source rock is poor to good with Total Organic Carbon (TOC) value of 0.11% to 1.48%. The rocks are categorized as immature to early mature with Vitrinite Reflectance (VRo) values of 0.43% to 0.50 %Ro. Based on biomarker the distribution, from Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometry (GC-MS) analysis, the source rock sample shows Pr/Ph, CPI and WI values of 2.22 to 2.68, 2.17 to 2.19 and 2.46 to 2.74 respectively indicating the source rock is immature and coming from terrestrial environment. The source rock might be rich in carbonaceous organic matter resulting from planktonic/bacterial activity which occurred in a fluvial to fluvio-deltaic environment. Overall, the source rock from outcrop level of Kudat Peninsula is moderately prolific in term of prospective and maturity. However, deeper beneath the surface, we can expect the pressure of mature source rocks that generate and expulse of hydrocarbon from the subsurface, migrating through deep-seated faults to form oil seepages in the Sikuati area.

Keywords: Kudat Peninsula, Oil Seepage, Kampung Minyak Sikuati, Geochemical analysis

1. Introduction

This study is conducted at the Sikuati area (Figure 1), within the central part of Kudat Peninsula, Sabah, Malaysia. Sikuati is a coastal village located on the west coast of the northern tip of Borneo which is about 23 km to the south of Kudat Town. The study involves an area of approximately 12.7km x 7.2km and in total of 92km² of area.

Oil leakages had been reported since Year 1881 until present day in Kampung Minyak, Sikuati. The area has become one of the tourist attraction in Kudat. Muda, 2010 indicates that the oil seepage is in a tidal mangrove swamp surrounded by an adjacent green area of primary and secondary vegetation. The geology of the area has been mapped as being underlain by the Sikuati Member, one of the members in the Kudat Formation and dated as Early Miocene (Foo & McDonald, 1983; Hall, 2013; Hutchison, 2005; Leong, 1999; Liechti et al., 1960; Sanudin & Baba, 2007; Tongkul, 1990; Van Hattum et al., 2013).



The occurrence of oil seepage in Kampung Minyak, Sikuati has long been known but it remains unclear what had caused the seepage to leak to the surface and where is the source of the migrating hydrocarbons due to complex tectonic regime and structural framework at the northern tip of Borneo. In general, this study focuses on finding the relationship of surface oil seepages with surrounding rock formations. The main aim of this paper is find a relationship of the oil seepage in Kampung Minyak with the surrounding rocks in the area, based on the conducted geochemical analysis.

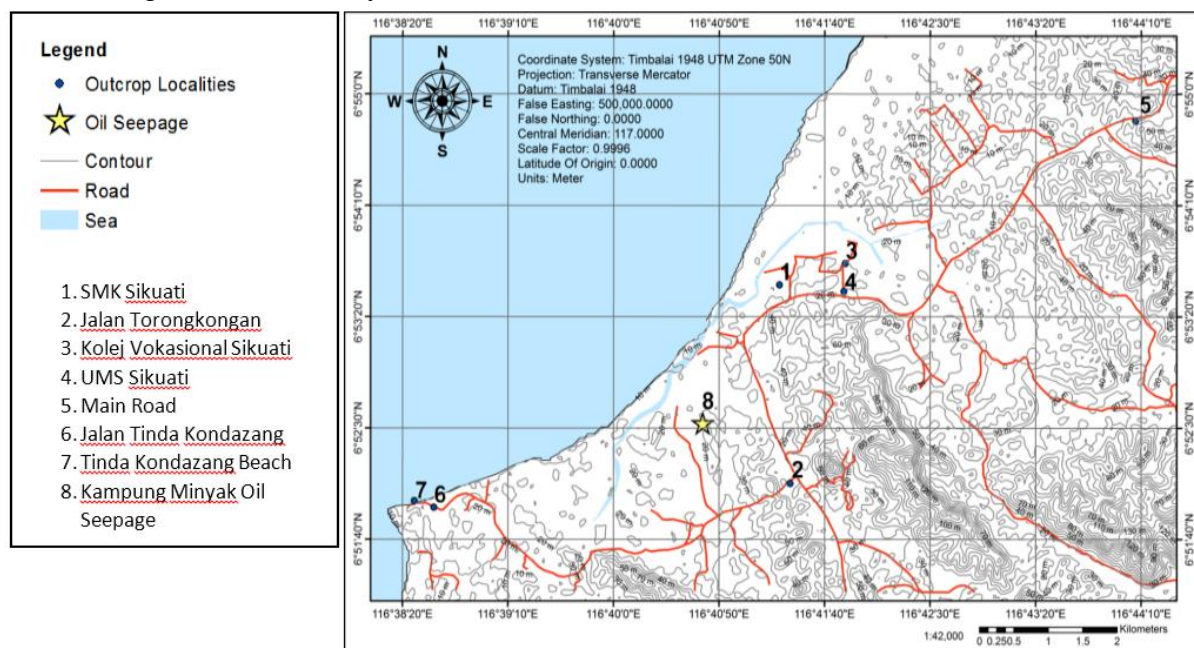


Figure 1: Map showing the location of the study area, topography and outcrop localities (with numbers) in Sikuati, Kudat.

2. Sampling and Methodology

Fieldwork was carried out on outcrops of the Sikuati Member of the Kudat Formation and West Crocker Formation. Eight (8) localities as shown in Figure 1 were visited. Thirteen (13) rock samples from the outcrops and one oil seepage from Pool 1 were collected for further analysis.

2.1 Geochemical Analysis

The geochemistry of the source rock and oil presence is a crucial element in the interpretation of the oil seepage at Kampung Minyak. The aim of this geochemistry study is to provide geochemical analyses on samples from the Sikuati region and also to enhance the result as to establish a good correlation between the Sikuati Member source rocks with the oil seepage present at Kampung Minyak. Figure 2 gives an overview of the workflow and fractionation of the samples and fluid collected during the fieldwork and analyses that have been done to achieve the objective of the study.

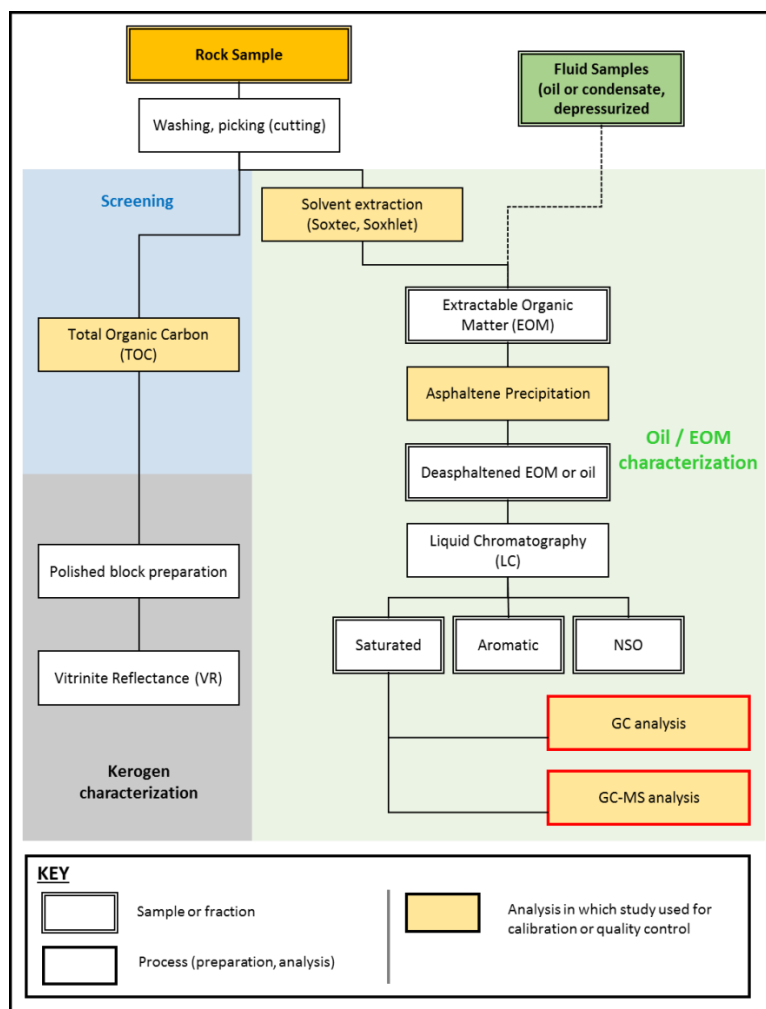


Figure 2: The flowchart showing laboratory analysis done in this study which include TOC, VR, GC and GCMS Analysis.

The samples were analysed for Total Carbon (TC) and Total Organic Carbon (TOC). The source rock samples such as shale and carbonaceous shale were crushed to analyse the carbon content using the Analytik Jena Analyzer multi N/C® 3100 instrument. Most of the samples tested for TC and TOC present some challenges due to uneven distribution of inorganic and organic carbon content within the samples.

Vitrinite Reflectance (VR) Analysis was also performed to indicate the level of maturity of the samples. Vitrinite Reflectance (VR) was performed using calibration numbers ranging from 40 to 100 due to variable amount of vitrinite clasts in the samples. Gas Chromatography (GC) and Gas Chromatography-Mass Spectrometer (GCMS) were also conducted on the samples. GC Analysis allows the calculation of mass hydrocarbon chain in the source rock and fluid from the sample was collected for geochemical characterization and correlation of the biomarker. On the other hand, GCMS Analysis helps in determining the environment of deposition and the

maturity-parameter which is dependent on the degree of microbial degradation (Waples and Machiharia, 1991).

3. Results and Discussion

3.1 Total Organic Carbon (TOC) Analysis

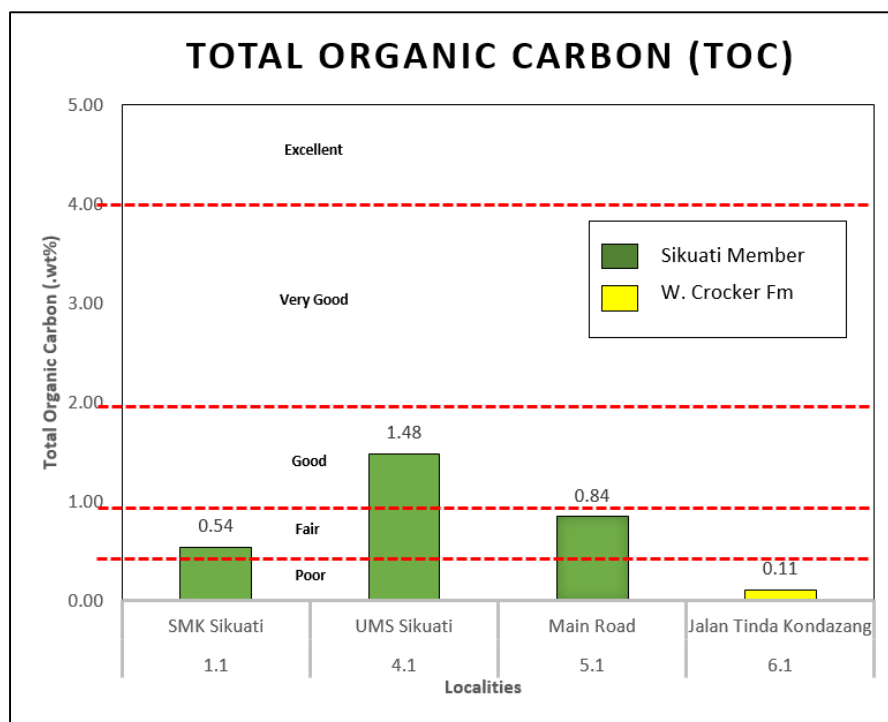


Figure 3: Total organic carbon (TOC) distribution according to localities

TOC analysis were conducted on samples collected from four localities, which are, one from the West Crocker Formation and the other three from the Sikuati Member. These samples were selected as they are shale, mudstone and carbonaceous rocks. The analysis shows that TOC for Sikuati Member varies from 0.54 to 1.48% wt and TOC from the Crocker Formation mudstone is 0.11% wt (Figure 3). The highest TOC content (1.48 % wt.) was recorded from the

UMS Sikuati mudstone (Sample 4.1). All these samples can be characterized as good source rock based on Peters and Cassa (1994). In contrast, the SMK Sikuati mudstone (Sample 1.1) and Main Road (Sample 5.1) mudstone are classified as fair source rock with a TOC of 0.54% wt and 0.84% wt respectively. On the other hand, the sample from Crocker Formation (Sample 6.1) located at Jalan Tinda Kondazang is labeled as poor source rock potential.

3.2 Vitrinite Reflectance (V_{Ro}) Analysis

Mudstone samples from the Sikuati Member which are mainly shale with carbonaceous laminae give V_{Ro} values in between 0.43% to 0.50% Ro which indicate an immature to marginally early mature oil window. These results reflect that outcrops at the Kudat Peninsula had been buried with a short intense of thermal burial history.

3.3 Gas Chromatography (GC) Analysis

Pristine to Phytane Ratio (Pr/Ph) are used to determine the depositional environment through GC analysis. Source rock sample 5.1 had recorded a Pr/Ph ratio of 2.22, 2.68 for GC and GC-MS m/z 85 indicating that rocks from the Sikwati Member was deposited in a terrigenous environment. Based on Figure 4, the cross-plot of Pr/C17 vs Ph/C18 for Main Road (Sample 5.1) shows that the Sikwati Member deposited in a mixed environment with slight or no influence of marine environment. Meanwhile, biomarker distribution of the oil seepage collected at Kampung Minyak, Sikwati (Pool 1) recorded Pr/Ph ratio of 5.63 indicating that the oil seepage deposited in oxidizing environment. In addition, the Pr/C17 vs Ph/C18 cross plot showing the oil coming from peat-coal environment (Figure 4). These results showed that the rock originated from a swampy environment. Waxiness index was used to determine the amount of land-derived organic matter in sediments, based on the assumption that terrigenous material contributes high molecular weight normal alkane components (Peters et al., 2005). Both sample from Main Road (Sample 5.1) and Pool 1 showed relatively high waxiness index varying from 2.18 to 2.74, indicating high contribution from land plants for both source rock and oil seepage

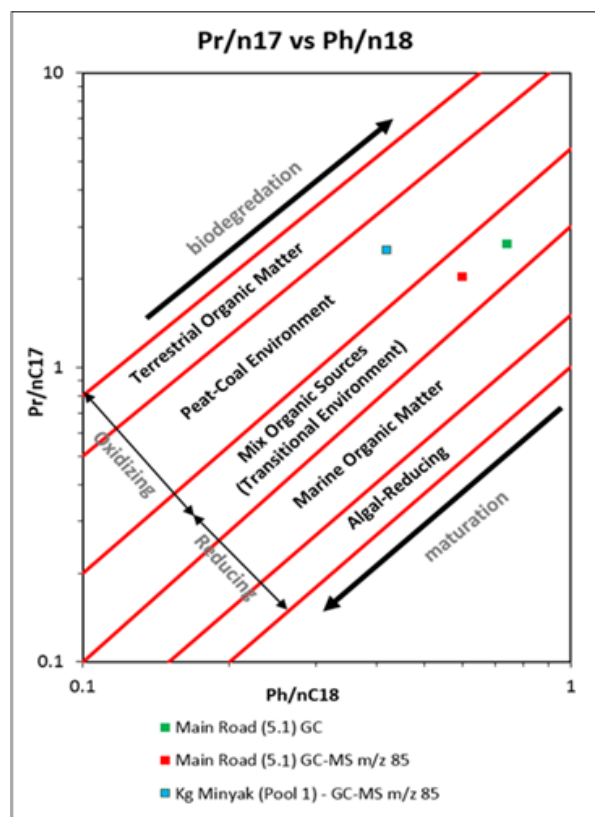


Figure 4: Cross-plot of Pr/C17 vs Ph/C18 showing depositional environment interpretation based on GC result.

3.4 Gas Chromatography- Mass Spectrometry (GCMS) Analysis

The maturity of the source rock and oil-seepage sample were tested based on GCMS Analysis. The $T_s / (T_s + T_m)$ values can be used to assess the maturity of a sample but could be influenced by maturation, organic matter typing and lithology (Moldowan et al., 1985). The ratio between T_s and T_m based on $T_s / (T_s + T_m)$ values for both samples recorded 0.08 and 0.42 respectively. The sample from Main Road (Sample 5.1) recorded a low C32-H reading of 0.39 which indicated the sample is immature. C30 M/C30 H and C23 Tri/ C30 H readings from Main Road (Sample 5.1) recorded 0.74 and 0.32 respectively. This indicates the immature condition which suggests the sample have yet to enter the oil window generation.

On the other hand, the oil seepage at Kg.Minyak recorded a C32-H reading of 0.62 indicating the sample is mature and had reached the oil window. This is suggested by C30M/C30H and C23 Tri/C30H readings of 0.15 and 0.03 respectively. Based on the source dependent parameter from the GCMS Analysis, both samples indicate that the source rocks originated from distributive fluvial system rich in organic matter.

4. Conclusion

Results gathered from geochemical analysis in this study showed that rocks from the outcrops are immature and originated from a mixed terrestrial/marine setting, but with a preponderance of terrestrial organic matter. On the other hand, oil seepages had indicated that the oil is coming from a peat-coal environment. Thus, the source rock might be rich in carbonaceous material organic matter originating from planktonic/bacterial activity which occurred in a fluvial-deltaic environment. From this study, the aim to investigate the relationship between the oil seepage in Kampung Minyak, Sikuati with the surrounding geology around the Sikuati area has been achieved. Overall, the source rock from outcrops in Kudat Peninsula are moderately prolific in terms of prospectivity and maturity. However, deeper beneath the surface, we can expect the existence of matured source rock generating and expulsing hydrocarbon from the subsurface and migrating through deep-seated faults to form oil seepages in this study area.

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