PARAMETRIC STUDY ON SOURCE ROCK POTENTIAL OF WEST CROCKER FORMATION, ONSHORE SARAWAK

Muhammad Qayyum bin Azman, Nur Shuhadah binti Japperi, and Norsyazwani binti Abdul Jalil

Faculty of Chemical Engineering, Universiti Teknologi Mara

West Crocker Formation is known with its lithologies and is described as a deep-water formation that is formed due to tectonic evolutions. Studies have show that West Crocker Formation has a good hydrocarbon generation and contain oil prone type II/III kerogen. It indicates that West Crocker Formation is a good source rock for petroleum accumulation and production. Thus, the purpose of this research paper is to determine the potential source rock of West Crocker Formation on onshore Sarawak. The methodology used in this research paper is by analyzing the source rock sample taken from the outcrop sample field using Gas Chromatographhy-Mass Spectrometry. From the result obtained, further analysis can be done in order to determine whether West Crocker Formation can be a good potential source rock or not.

Keywords— Extracted organic matter (EOR), Gas Column chromatography-mass spectrometry (GCMS), potential source rock, West Crocker formation.

I. Introduction

West Crocker Formation is a deep-water formation resulting from tectonic evolutions happened in Sabah and Sarawak. This was due to a series of tectonic event; cause continuous compression, subduction, folding and uplifting of the West Crocker Formation [1]. Various sedimentation process occurs throughout the time thus increase the source rock potential of West Crocker Formation. The West Crocker consist of four different types of lithologies; massive sandstone, thick-bedded sandstone, inter-bedded sandstone-mudstone and thick shale units.

The West Crocker Formation sandstones contain a very close relationship of diagenesis and porosity-permeability values because the sandstones had been introduced with higher degree of compaction and cementation [2]. The recorded value of both of the density and velocities of these sandstones are high [2]. The West Crocker Formation is deep water turbidites sediments. The hydrocarbon generation of West Crocker Formation shows mature to late stage from the results of vitrinite reflectance and pyrolysis Tmax values [3].

The West Crocker Formation samples have total organic carbon (TOC) level less than 1% weightage showing that the hydrocarbon generating potential is low, but if it is characterized by using mass transport deposits (MTD), it has total organic carbon (TOC) more than 2 thus possess good to excellent hydrocarbon generating potential [3]. Other than that, the study also shows that the West Crocker Formation contain oil prone type II/III kerogen in the slump deposits [4].

In this study, the potential source rock of West Crocker Formation on onshore Sarawak were evaluated by using chemical laboratory technique. The components of the samples are determined and analyzed. The samples are directly taken from the field sample of West Crocker Formation.

II. METHODOLOGY

A. *Materials*

The materials that are going to be used is the outcrop field sample that is directly taken from different location which are identified as Lawas 01, Lawas 02 and Lawas 03.

B. *Preparation of the Materials*

The rock samples collected are washed in order to remove the dirt on their surface. Then, the samples were dried inside the oven at 100°C to ensure it is entirely dry. The rock samples are then crushed into small pieces (2-3) mm by using pestle and mortar or other mechanical devices [5].

The chemicals used in this experiment will be ethyl acetate and dichloromethane. These chemicals are important as ethyl acetate are used as the solvent to extract the bitumen and dichloromethane will be the solvent used to dilute the extracted sample before undergoes further experiment.

C. *Bitumen Extraction*

The small matters of rock samples are place inside the test tube and were weighed by using weighing machine. The samples are extracted respectively by using the Soxhlet Apparatus for 72 hours.

The solvent used is ethyl acetate. After the extraction process is complete, the solvent is removed trough evaporation process under low pressure. This can be done by using rotary evaporator. The dried recover fractions are then measured by its weight and recorded as the extractable organic matter (EOM).

The yield or the mass of extractable organic matter (EOM) is obtained as follows.

$$\text{Extracted weight} = vial + extract - clean\ vial \tag{1}$$

$$\text{Organic matter (EOM)} = \frac{Extractweight}{Mass\ of\ sample\ before\ extraction} \tag{2}$$

$$\text{EOM\%} = \text{EOM} \times 100\% \tag{3}$$

D. Gas Column Chromatography-Mass Spectrometry

Further analysis of the extracted samples is conducted by using Gas Chromatography-Mass Spectrometry (GCMS). This technique is used to screen, identify, quantification of many groups of non-polar and/or semi-polar components [10]. The samples were dissolved with dichloromethane before being analyzed by GC-MS.

The Gas Chromatography is set from 40°C to 300°C (for 30 min hold) at 4°C min-1 in an oven for 95 minutes [6]. The injected samples are vaporized due to high temperature inside the Gas Chromatograph and mixed with helium or nitrogen gas as a carrier gas. The data of the separated compounds is then transferred to the mass spectrometer and ionized by the electron beam. The data is then translated and processed by using computer software.

III. RESULTS AND DISCUSSION

A. Extractable Organic Matter

A summary of extracted organic matter (EOM) are provided in the Table 4.1. The highest total amount of extracted organic matter recorded is in Lawas 03 with 0.58% g of extract. The difference between Lawas 01, Lawas 02 and Lawas 03 are significant by which the value is far from each other despite the same characteristic of reservoir. This might be because of difference outcrop sample location taken.

As compared to Lawas 01, Lawas 02 and Lawas 03 contain high amount of organic matter and they have potential to become source rock. This is because they may have sufficient amount of organic matter required to be a source rock.

Due to the small amount of extracted organic matter, the separation process cannot be done. The extracted materials might be totally evaporated or lost during the process.

Table 1: Extracted organic matter from the samples

Samples	Before Extraction (g)	After Extraction (g)	Extracted Weight (g)	EOM %
Lawas 01	90.951	90.871	0.080	0.088
Lawas 02	99.946	99.639	0.307	0.307
Lawas 03	95.077	94.523	0.553	0.582

B. Trace of GCMS

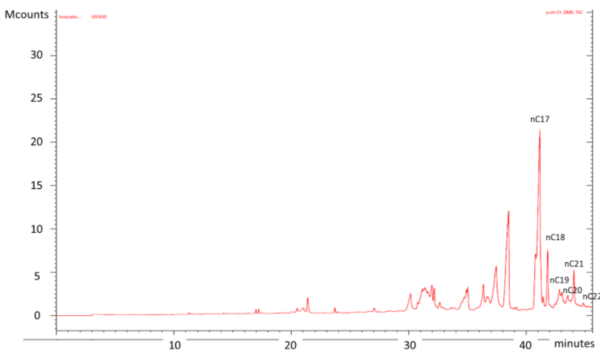

Figure 1: Result of GCMS data for Lawas 01

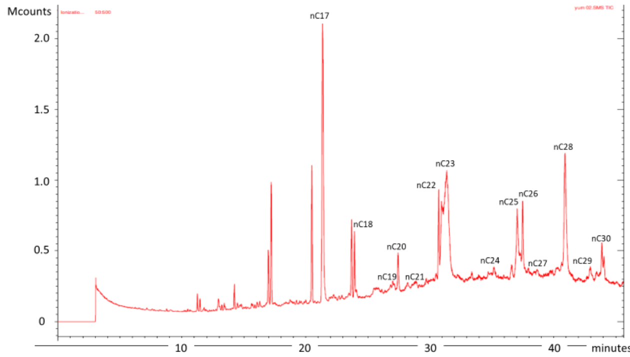

Figure 2: Result of GCMS data for Lawas 02

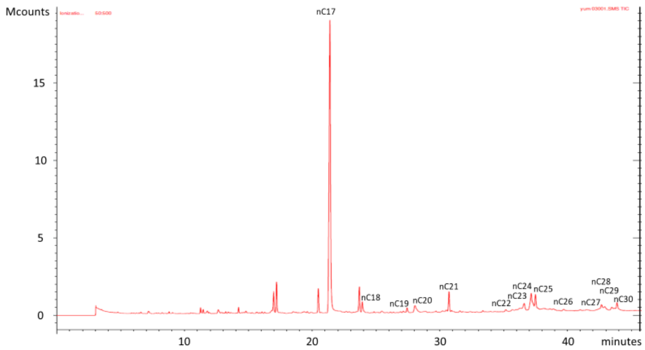

Figure 3: Result of GCMS data for Lawas 03

Based on the chromatogram plot, the depositional environment of Lawas 02 and Lawas 03 can be interpreted as a marine environment. The evaluation from the shape of chromatogram plot is supported by the dominance of short chain n-alkanes (n-C_{15} to n-C_{19}) over long chain n-alkanes (n-C_{25} to n-C_{30}). The short chain n-alkanes (n-C_{15} to n-C_{19}) is the derivation from the marine algae.

However, in Lawas 01, further analysis cannot be done due to minimal information present on the chromatogram plot. Lawas 01 contains a very short straight n-alkane chain (n-C_{10} to n-C_{20}) which it suggests that there is no specific marker present to determine the source of organic matter.

C. n-Alkanes and Isoprenoids

The pristane (Pr) and phytane (Ph) are the most important acyclic isoprenoid hydrocarbon in determining the redox potential of the depositional environment. The existence of both pristane and phytane allowed further interpretation of the palaeoenvironmental conditions of the source rock samples and they are considered as a measure for redox conditions during sedimentation and diagenesis [4]. The type of depositional settings can be identified based on the Pr/Ph ratio values. If the Pr/Ph values are greater than 3.0, it indicates oxic conditions. The values between 0.6 to 3.0 indicate a suboxic condition and if the ratio values are lower than 0.6, it indicates that it is anoxic depositional setting.

Table 2: Results of Pr/Ph ratio values

Sample	Pr (cm)	Ph (cm)	Pr/Ph	Condition
Lawas 01	2.2	0.4	5.5	Oxic
Lawas 02	6.5	3.6	0.4	Anoxic
Lawas 03	1.2	1.2	1.0	Suboxic

Based on Table 2, the result shows different condition for each sample even though they are from the same type of reservoir. As per previous analysis, the West Crocker formation is interpreted to contain marine depositional environment. This does not well correspond with data obtained from redox condition evaluation trough Pr/Ph ratio value. There are some researcher believes that the value of Pr/Ph ratio varies because of the alteration between oxic and anoxic conditions during depositions [4]. Other than that, there are some arguements in using Pr/Ph ratio value as the redox interpretation because the results may be altered due to different source of organic matter. There is other solution in interpreting the redox conditions which is by combining both isoprenoid and normal alkanes to provide more accurate information about the organic matter, organic facies, biodegradation and maturation levels [8]. These information can be obtained trough plotting a graph of Pr/n-C_{17} versus Ph/n-C_{18}.

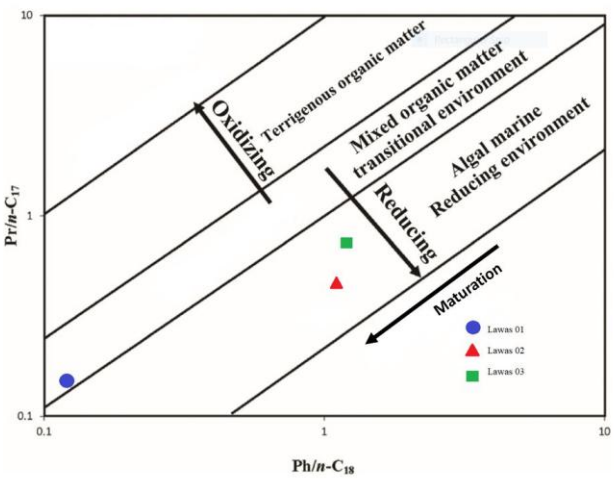

Figure 4: A graph plot of Ph/n-C_{18} Versus Pr/n-C_{18} ratios

Based on Figure 4, it shows the dominance of anoxic conditions trough Lawas 02 and Lawas 03. Only Lawas 01 shows suboxic conditions. The plot also sway towards marine organic matter suggesting that it is deposited under anoxic depositional environment. Other than that, the maturity level of hydrocarbon generations can be interpreted as mature. This can be seen trough the dominance of the samples position in the middle of the plotted graph. These findings are supported by other study which the hydrocarbon generation of West Crocker Formation matures trough the results of vitrinite and pyrolysis T_{max} values [6].

As compared to both redox condition evaluation methodology, it is found that the results obtained are differs from each other and are not well consistent. By using Ph/Pr ratio values, all three samples which are Lawas 01, Lawas 02 and Lawas 03 shows different conditions and are not accurate enough to interprete the depositional environment of West Crocker formation. However, by using a graph plot of Ph/n-C_{18} Versus Pr/n-C_{18} interpretation, the results are more accurate in terms of interpreting the depositional environment, source organic matter and the maturity levels of the hydrocarbon generation.

D. Carbon Preference Index (CPI) ratio

Carbon Preference Index (CPI) ratio is the analysis involves in defining the maturity level of the hydrocarbon generations. It is also known as the maturity parameter. The value of CPI is significant in measuring the level of maturity [4]. If the CPI above 1.0, it indicates thermally immature and with value approaching 1.0 it suggests that they are thermally mature. In this study, further evaluation of maturity levels is conducted to compare with the result obtained from previous analysis and to determine the most accurate analysis to be used in determining the maturity level in hydrocarbon generation of West Crocker formation.

Table 3: Results of Carbon Preference Index (CPI)

Sample	CPI
Lawas 01	-
Lawas 02	0.916
Lawas 03	0.963

Based on Table 3, the reading of CPI from Lawas 01 cannot be obtained. This is due to absence of long straight n-alkane chains in the chromatogram plot. However, in Lawas 02 and Lawas 03, both reading of CPI value is approaching 1.0. This suggest that Lawas 02 and Lawas 03 are thermally mature. This is supported by the study that stated the hydrocarbon generation of West Crocker formation are thermally mature by using the same method of analysis [4].

Thus, the result obtained from the evaluation shows that the West Crocker Formation contain thermally mature hydrocarbon generation. The results are then compared with the previous analysis, which is by using a graph plot of Ph/n-C_{18} Versus Pr/n-C_{18} interpretation and it is found that both of the results are tally and well correspond. This suggests that both of the analysis are accurate in terms of interpreting the maturity level of hydrocarbon generation.

E. Triterpane Distributions

Triterpanes can be found commonly in marine and terrestrial environment due to their original form from algae and bacteria [7]. They are also representing a marker for high salinity depositional environment. In this study, the ratio of C29 norhorpane/ C30 hopane are calculated to differentiate between clay-rich or carbonate rich [9].

Table 4: Results of C_{29} norhorpane/ C_{30} hopane ratio

Sample	C_{29} norhorpane/ C_{30} hopane
Lawas 01	-
Lawas 02	0.4
Lawas 03	0.3

Based on Table 4, the ratio for both Lawas 02 and Lawas 03 is less than 1. This shows that the sample is rich with clay.

IV. Conclusion

In conclusion, Lawas 01, Lawas 02 and Lawas 03 have a potential to become a good source rock. This is supported by high yield of extracted organic matter obtained from bitumen extraction indicates that the samples possess sufficient amount of organic matter to become a source rock.

Other than that, based on analysis using biomarker application, it has been found that the samples have marine organic matter deposited under anoxic depositional environment. The samples also contain thermally mature hydrocarbon generation which indicate that the samples have good hydrocarbon potential generation. Moreover, the samples have been identified as a clay-rich.

Acknowledgment

The research paper compiled here is due to immense support provided by individuals whose inspiration, ideas, time, funding, and love were instrumental in its completion.

I want to thank my supervisor Madam Shuhadah Japperi for enormous guidance throughout my research process and writing. A deep gratitude also i wish to my parents for both of their support mentally and physically, and my friends for their understanding and helping me on completing the research paper entirely.

Finally, I would like to thank god for His blessings to make all these happen. Alhamdulillah.
This research paper is dedicated for all of them.

References

[1] Mohamed, A. Rahman and M. Ismail, "Sedimentary Facies of the West Crocker Formation North Kota Kinabalu-Tuaran Area, Sabah, Malaysia", *IOP Conference Series: Earth and Environmental Science*, vol. 30, p. 012004, 2016.

[2] T. Y. Jia, “Characteristics of Sedimentary Facies and Reservoir Properties of Some Tertiary Sandstones in Sabah and Sarawak, East Malaysia,” no. October, p. 24, 2007.

[3] W. H. Abdullah et al., “Hydrocarbon source potential of Eocene-Miocene sequence of Western Sabah, Malaysia,” Mar. Pet. Geol., vol. 83, pp. 345–361, 2017.

[4] “Petroleum Source Rock Potential of Submarine Fan and Deltaic Cenozoic Sequences of Western Sabah and Sarawak, Malaysia Togunwa Serifat Olayinka Department of Geology Faculty of Science University of Malaya Kuala Lumpur,” 2015.

[5] W. G. Akande, “A review of experimental procedures of gas chromatography-mass spectrometry (gc-ms) and possible sources of analytical errors,” *Earth Sci.*, vol. 1, no. 1, p. 1, 2012.

[6] W. H. Abdullah *et al.*, “Hydrocarbon source potential of Eocene-Miocene sequence of Western Sabah, Malaysia,” *Mar. Pet. Geol.*, vol. 83, pp. 345–361, 2017.

[7] S. M. El-sabagh, A. Y. El-naggar, M. M. El Nady, M. A. Ebiad, A. M. Rashad, and E. S. Abdullah, “Distribution of triterpanes and steranes biomarkers as indication of organic matters input and depositional environments of crude oils of oilfields in Gulf of Suez, Egypt,” *Egypt. J. Pet.*, 2018.

[8] O. Access, “We are IntechOpen , the world ’ s leading publisher of Open Access books Built by scientists , for scientists TOP 1 % Hydrocarbon Generation.”, 2018.

[9] W. Basin, M. Obermajer, K. G. Osadetz, M. G. Fowler, and L. R. Snowdon, “Light hydrocarbon (gasoline range) parameter refinement of biomarker-based oil – oil correlation studies: an example from Light hydrocarbon (gasoline range) parameter re ® nement of biomarker-based oil ± oil correlation studies: an example from Williston Basin,” no. October, 2000.

[10] H. McNair and J. Miller, “Gas Chromatography–Mass Spectrometry (GC–MS),” *Basic Gas Chromatogr. Second Ed.*, pp. 419–473, 2007.