Petroleum and Coal

Article **Open Access**

Total Organic Carbon (TOC) Distribution of the Jurassic – Cretaceous Continental Deposits in Central Pahang, Malaysia

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Received February 17, 2020; Accepted April 29, 2020

Abstract

Samples from outcrops of the Jurassic-Cretaceous continental sediments of Central Pahang, Malaysia were analysed for their total organic content. This study aims to identify and highlight the distribution of organic content of these continental deposits and its link to its inferred depositional environment. Results from TOC concentrations in the studied samples varied between 0.399 to 6.16 wt.% showing ranges of poor to excellent hydrocarbon source rock potential. In Kuala Tahan, the TOC values range from 0.405 to 0.474 wt% in the gravel braided river system while it is 0.559 to 0.887 wt.% in the floodplain environment. TOC values range from 0.399 to 0.495 wt.% in the anastomosing river of Jerantut while it ranges from 0.405 to 3.94 wt.% in the anastomosing river of Maran. Meandering river of Jengka records TOC values ranging from 0.598 to 6.16 wt.%. Low TOC values are often associated with fine-grained sandy deposits while high TOC values are associated with samples containing in-situ coaly/carbonaceous material. High variations on distributions of TOC values are often associated with areas with high TOC values while areas with low TOC values have a lower variation on its TOC value distribution. The variations and values of TOC could be linked to the different sub-environments of the fluvial system governed by localized energy and process of deposition.

Keywords: *Fluvial, Total organic carbon; Jurassic-Cretaceous; Central Pahang; Tembeling Group.*

1. Introduction

Total Organic Carbon (TOC) measurement serves as one of the screening tools for assessment of potentiality of sediments to generate hydrocarbons [1]. A study has been conducted to analyse the TOC distribution in the Jurassic-Cretaceous continental sediments of Central Pahang and to relate the TOC value with its corresponding depositional environment. The interpretation of depositional environment is based on earlier studies [2-10] and interpretation from facies analysis by the author. The distribution of organic matter relating to depositional environment in continental setting is still poorly understood. Hence, this paper presents the findings of a systematic research to quantify the organic content of these sediments by statistical methods and relating it with its corresponding depositional environment.

2. Methodology

Some thirty-one (31) surface samples of sandy–fine grained sediments from the continental Upper Jurassic- Late Cretaceous succession were collected from outcrops along the road of Felda Sungai Retang – Padang Piol, Jalan Jerantut-Benta and road of C19 and C108 in Central Pahang. The samples were analyzed for its total organic carbon (TOC) content. Samples are named based on their locality and strata where capital letters each correspond to a large area as shown in the Table 1.

Table 1.

Abbreviation	Area	Abbreviation	Area
KT	Kuala Tahan	J	Jengka
JB	Jerantut	M, C19	Maran

Coaly samples are noted as 'coal' right after the locality area name (e.g., JBCoal corresponds to coaly sample from the Jerantut area). Subsequent number after the area code corresponds to the locality number of the sample taken (e.g., KT1 corresponds to sample from the first locality of the Kuala Tahan area) and where present, subsequent capital letters represent number of samples taken from the locality (e.g., KT7A corresponds to the first sample from seventh locality of Kuala Tahan area).

Whole rock samples of carbonaceous mudstones, shales and sandstones were crushed to fine powder. The crushed samples were weighed and treated with 10% hydrochloric acid (HCl) to take off the inorganic carbon and carbonate minerals. TOC content was then analyzed by using Analytickjena HT 1300 Solids Carbon Analyzer in Universiti Teknologi PETRONAS. TOC percentage measurements were obtained using the direct method proposed by Dow and Pearson [11].

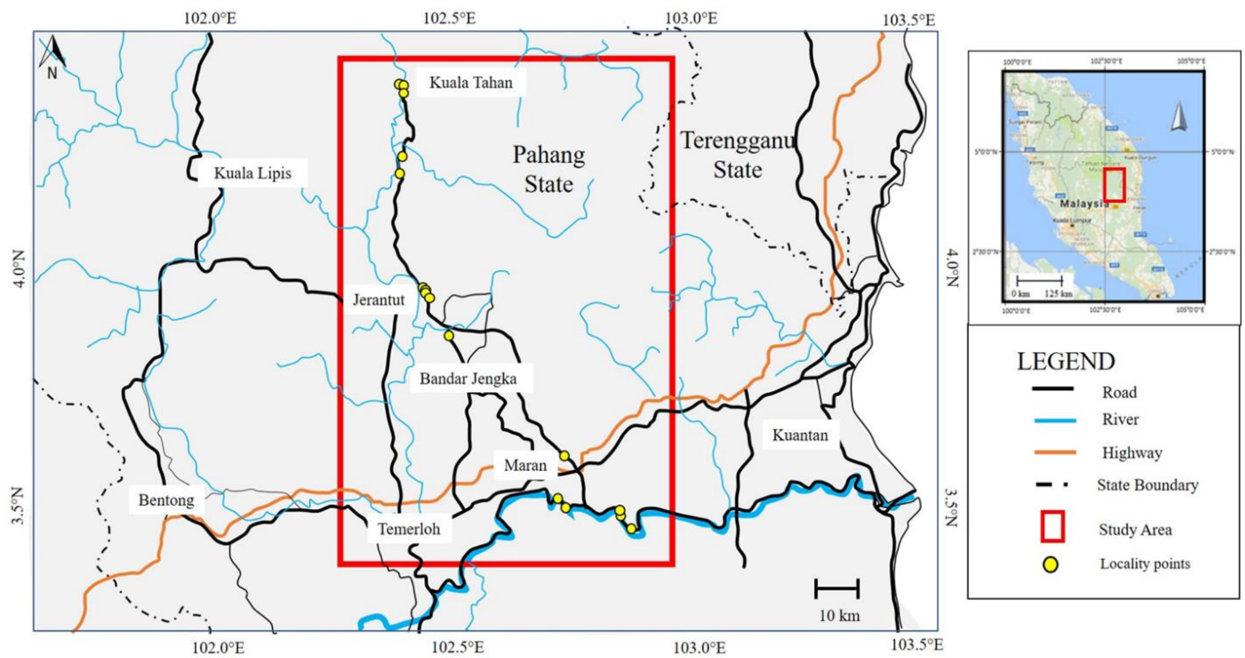

Fig. 1. Map showing the location of the study area and the exposed outcrops (A)The research area is in Central Pahang, Malaysia, (B) The localities map of the research area from the current exposed outcrops

3. Results and discussion

3.1. TOC values

Table 2 shows the TOC values of the samples with its corresponding lithology. Colored rows int Table 2 are samples with TOC values of greater than 0.5 weight percent (wt%.).

The minimal initial organic matter concentration necessary for effective hydrocarbon source rocks in shales is usually taken at 0.5% TOC (various researches as cited by Tyson [7]).

From the results shown in Table 1, fourteen out of thirty-one samples recorded TOC value of more than 0.5 wt%. The breakdown of samples according to area are : i) four (4) samples from Kuala Tahan, ii) three (3) samples from Jengka, and iii) seven (7) samples from Maran. None of the samples from Jerantut shows TOC value of more than 0.5%. Table 2 shows the range of TOC values and the source rock potential based on Peters and Cassa [12].

Table 2. Total organic carbon (TOC) content (wt%) of the samples

No	Sample name	Lithology	Wt %
1	KT1	Red crystal lithic tuff	0.471
2	KT5	Greywacke	0.474
3	KT6B	Light grey shale	0.405
4	KT7A	Carbonaceous shale	0.794
5	KT7B	Carbonaceous shale	0.887
6	KT7C	Carbonaceous shale	0.559
7	KT8	Light purplish grey mudstone with carbonaceous lamination	0.634
8	JB1A	Purplish grey silty sandstone	0.495
9	JB1B	Purplish red mudstone	0.448
10	JB2A	Purplish grey mudstone	0.454
11	JBCoal1	Coal	0.461
12	JB2C	Dark grey and red mudstone	0.465
13	JBCoal2	Coal	0.444
14	JB2E	Ferruginous red mudstone	0.414
15	JB2G	Dark grey & red mudstone	0.41
16	JB5A	Dark red mudstone	0.399
17	JL	Coaly mudstone	1.56
18	Jcoal	Coal	6.16
19	JR	Coaly mudstone	0.598
20	M2A1	Indurated dark grey shale	1.03
21	M2B	Black mudstone	0.786
22	M5A	Light grey shale	0.497
23	M5C	Light grey shale with sandstone interbed	0.48
24	M6A	Dark grey mudstone	0.516
25	M6C	Carbonaceous mudstone	2.87
26	M7A	Grey indurated mudstone	0.789
27	M7D1	Coaly mudstone	3.94
28	M7D2	Extracted coal	2.17
29	C19A1	Dark reddish black mudstone (bottom)	0.405
30	C19A2	Dark reddish black mudstone (top)	0.405
31	C19B	Grey mudstone	0.409

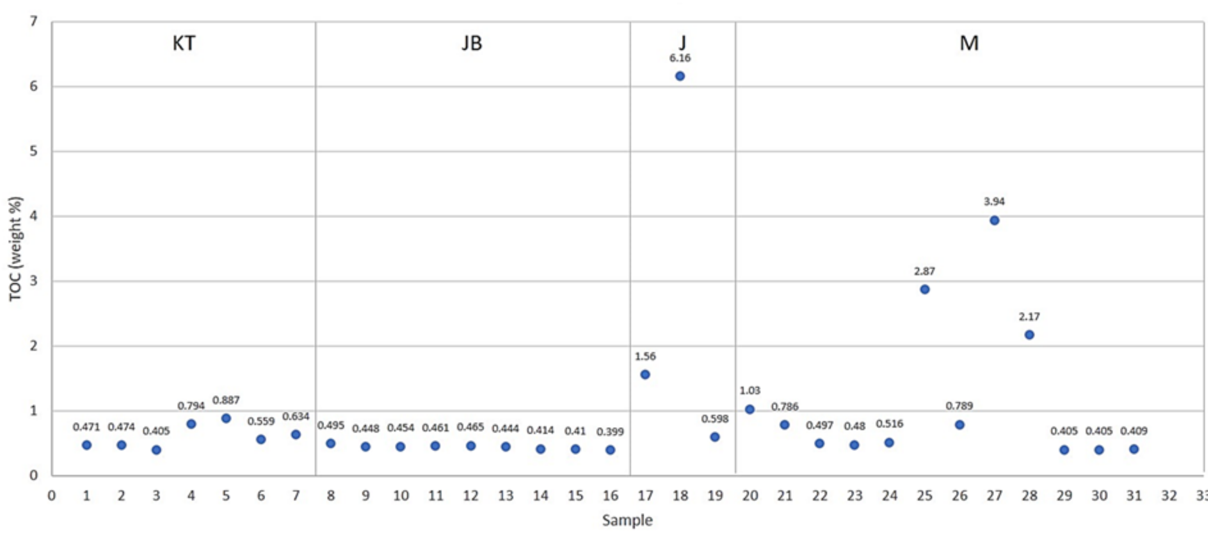

Fig. 2. Graph showing the overall values of TOC by samples following the sample numbering in Table 2

3.2. Individual value plot (IVP)

Individual Value Plot (IVP) is created to assess and compare sample data distributions. An IVP shows a dot for the actual value of each observation in a group, making it easy to spot outliers and see distribution spread.

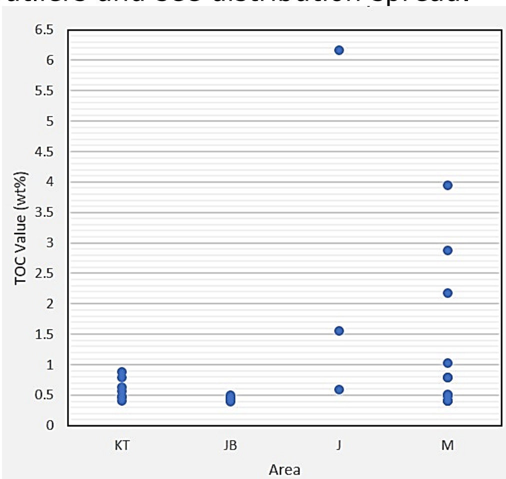

Fig. 3. Individual value plot of TOC by area

An IVP works best when the sample size is less than approximately 50. Like a boxplot, an IVP helps to identify possible outliers and visualize the distribution of data. However, unlike a boxplot, an IVP displays each value separately. Separate values are especially useful when there are relatively few observations or when it is important to assess the effect of each observation

The IVP in Figure 3 shows the TOC values from the four areas. The sample sizes for KT, JB, J and M are seven, nine, three and twelve respectively.

3.3. Spread and distribution

The spread of data at KT and JB is comparatively short, meaning that most of the TOC values are at high level of agreement with each other as compared to TOC values in J and M where the data in the IVPs are more spread out, suggesting a variation in the distribution of its TOC values. The values of KT and JB are less than 1 wt% while J and M values are more than 1 wt%. The more clustered spreading of KT and JB data indicates normal distribution while the spreading of data from M is concentrated at low values, where this indicates right skewness.

Values of TOC at M are more concentrated at less than 2 wt% and only a few values recorded at more than 2 wt%. Distribution of values at J are insignificant as the data are too low. TOC values at Kuala Tahan and Maran recorded similar TOC values, whereas in Jerantut and Jengka, it differs highly, apparent by the median value. The median TOC value is centred around 0.559 in Kuala Tahan, 0.448 in Jerantut, 1.56 in Jengka and around 0.651 wt% in Maran (refer Table 3).

Table 3. TOC range and classification for the areas

Area	TOC (wt%) range	TOC% classification
KT	0.405 - 0.887	Poor - Fair
JB	0.399 - 0.495	Poor - Fair
J	0.598 - 6.16	Fair - Excellent
M	0.405 - 3.94	Poor - Very good

TOC% Classification is based on Peters and Cassa [12]

Given the large spread of TOC values in Jengka and Maran, we can interpret a high variation in the amount of TOC while in Kuala Tahan and Jerantut, the TOC values center more towards average. The TOC values are quite even in Kuala Tahan and Jerantut but not as much as in Jengka and Maran suggesting a rather inhomogenous distribution of organic matter rich lithologies or a more localized organic matter concentration in Jengka and Maran.

Table 4. Statistical values of TOC (wt%) data by area

	KT	JB	J	M	All
Min	0.405	0.399	0.598	0.405	0.399
Q1	0.4725	0.414	1.079	0.46225	0.446
Median	0.559	0.448	1.56	0.651	0.495
Q3	0.714	0.461	3.86	1.315	0.7915
Max	0.887	0.495	6.16	3.94	6.16

3.4. Relationship between TOC and depositional environment

The sediments of the study area are part of the Jurassic – Cretaceous continental strata [13]. In Kuala Tahan, the sediments are inferred to belong to the Kerum Formation, as correlated to a study by Khoo [5] while outcrops from Jerantut, Jengka and Maran are correlated to belong to the Mangking Sandstone and Termus Shale [4, 8-9, 13].

Facies analysis on the studied portion of the Kuala Tahan area by the author has inferred the depositional environment to be of two separate fluvial styles; i) gravel braided with sediment-gravity flows and ii) broad floodplain. TOC values are well below 0.5 wt% for the gravel braided environment represented by samples KT1, KT5 and KT6B. On the other hand, the broad floodplain environment represented by samples KT7A-C and KT8 recorded high TOC values of more than 0.5 wt%. The depositional process of the gravel braided river in this study is well associated with high depositional energy while the floodplain is of low depositional energy and with abundance of carbonaceous material, a highly vegetated environment is inferred. Correlating the recorded organic content to the inferred depositional environment, we can assume that in Kuala Tahan, high energy environment have a low depositional rate of organic content while low energy environments, together with adequate supply of organic matter deposits higher organic content.

Previous studies have suggested a braided-meandering or a low-sinuosity river depositional environment for the Mangking Sandstone while current study by the author has inferred the depositional environment of studied section in Jerantut to be of anastomosing river with minor tidal influence. Occurrences of red beds, fluctuating energy deposits with conglomeratic scours and lateral accretion surfaces among other findings were observed here. The low value of organic content in the sediments in the Jerantut area which is well below 0.5 wt%, correlated to its depositional environment of anastomosing river could be attributed to high fluctuations of energy, making it difficult to deposit high volumes of organic matter, evident by the presence of coal clasts and rapid changing of flow regime deposits. Oxic environment, evident by the red colour oxidizes the organic matter, making it difficult for organic matter preservation. Changes in current energy resulted in the preservation of organic matter to be periodical and in low volume. Hence, with low TOC values and a high agreement on the values distribution, we can conclude that organic matter preservation and distribution is low throughout the system in Mangking Sandstone in Jerantut.

In the studied portion of the Jengka area, most of the samples are coaly, and relating to its depositional environment of meandering river [4], the rocks where the samples are taken are highly likely to be deposited in a vegetated swamp sub-environment. The values of organic content in Jengka are the highest among all the samples with values ranging from 0.598 to 6.16 wt%. Low energy of deposition along with the presence of vegetation can be suggested to contribute to the high concentration of organic matter in this deposit.

The depositional environment for the sediments in the Maran area, when correlated to studies by Konjing *et al.* [8], Malihan *et al.* [9] and Said *et al.* [10] is of a braided-meandering river system. Current study has inferred the studied portion of the Maran area correspond to an anastomosing river with broad floodplain environment which is slightly different with previous studies. In comparison with samples from Jerantut, the TOC values for Maran samples shows higher TOC values ranging from 0.405 to 3.94 wt% even with the same inferred depositional environment. The samples were less weathered than the samples from Jerantut and this could contribute to the higher TOC values. Plant fossils were also found thr ughout the strata where the samples were taken which could infer to a vegetated low-energy sub-environment for the Maran sediments.

4. Conclusion

The TOC values of the samples from the study area range from 0.399 to 6.16 wt%. In Kuala Tahan, the TOC values range from 0.405 to 0.474 wt% for the gravel braided river system and 0.559 to 0.887 wt.% for the floodplain environment. TOC values range from 0.399 to 0.495 wt.% in the anastomosing river of Jerantut however, the values range more wider from 0.405 to 3.94 wt. %. in the anastomosing river of Maran. Meandering river of Jengka showed higher and wider range of TOC values ranging from 0.598 to 6.16 wt.%. Low values of organic content are recorded in fine-grained sandy and oxidized (red) sediments while higher values are recorded in finer-grained (mudstone/shale) and coaly/ carbonaceous sediments. High variations in the distributions of TOC values are often associated with areas with high TOC values and vice-versa. Weathering and grain size affect the preservation of organic matter in sediments as well as the energy of deposition where low-energy sediments have a higher rate of organic carbon preservation.

5. Future works

Selected samples with TOC values of greater than 0.5% will be sent for palynofacies and pyrolysis analysis to further characterize the organic geochemical properties of the sediments. Discussion on the linkage between total organic content and its depositional environment can be made with more confidence and in depth with results from the proposed analyses.

Acknowledgement

The author would like to thank Shale Gas Research Group (SGRG) for providing financial support throughout the research through the PRF Shale Gas grant 0153AB-A33

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