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PETROLEUM POTENTIAL OF MAE TEEP ORGANIC SEDIMENTS, NORTHERN THAILAND

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ABSTRACT: The selected 7 organic sediment samples (3 oil shale samples from Upper Oil Shale, Lower Oil Shale and Oil Shale in Coal A sub-unit, 3 coal samples from Coal A, Coal B and Coal C sub-unit and 1 leonardite sample from Leonardite sub-unit) collected at the northern wall of Mae Teep coal mine were conducted the Hydrocarbon Analyzer with Kinetics (HAWK) pyrolysis in order to assess their petroleum source rock potential. The calculated HI, OI, PI, S2+S3 and R_o were then used to classify the kerogen type and to evaluate the thermal maturity stage of these 7 studied organic sediment samples. Results of the study indicate that all of the organic sediment sub-units of Mae Teep organic sediments have good to excellent hydrocarbon generation potential. HI vs T_{max} and HI vs calculated R_o cross-plots results indicate that organic sediments of Coal A, Coal B, Coal C, Oil Shale in Coal A and Upper Oil Shale sub-unit are in the thermal immature stage, while the organic sediments of Lower Oil Shale and Leonardite sub-unit are in the early thermal mature stage. Mae Teep organic sediments are considered to be the high potential hydrocarbon source rock since they have high kerogen yield (S2) (21.49 - 69.8 mg HC/g rock) and their total hydrocarbon generation potential (S1+S2) are also high (22.13-72.12 mg HC/mg rock). These may contribute them to be a good to very good source rock if their maturity reaches the thermal mature stage.

Keywords: Kerogen, Vitrinite reflectance, Pyrolysis, Source rock

1. INTRODUCTION

Most of petroleum production in Thailand has been obtained from Tertiary basins. The main petroleum producing areas in 4 geological terrains of Thailand are Gulf of Thailand, onshore Northern and Central, onshore Northeastern)Khorat basin(and Mergui basin of Andaman Sea [1] and especially in northern Thailand there are more than 40 basins [2]. The basins developed during this age have been recognized as Cenozoic rift basins. They are very important resources for their deposited oil shales and coals throughout northern Thailand. Many of these northern Thailand basins have already generated petroleum such as Sirikit and Fang oil field. However, there are many of these basins which are uplifted and exposed their content of coals and oil shales association such as Wiang Haeng, Mae Chaem)Na Hong(in Ching Mai province, Ban Pa Kha, Li, Mae Than and Mae Teep in Lampang province, Mae Tun and Mae Lamao in Tak province. A well-known oil shale area is Mae Sot basin in Tak province [3,4].

Mae Teep basin is a small and isolated Tertiary basin in northern Thailand. It is located about 80 kilometers northeast of Lampang city, Ngao district, Lampang province (Fig 1). The basin trends north-northeast – south-southwest direction and it is situated between Ngao and Phrae basin. The valley of the basin has flat-rolling topography with the elevation of 220 – 280 m msl. and the surrounding mountains rise to nearly 1200 m. msl.

The main objective of this study is to assess the petroleum source rock potential of Mae Teep organic sediments by the pyrolysis analysis technique.

2. GEOLOGICAL BACKGROUND

Mae Teep basin is about 3 km wide and 10 km long, trends north-northeast – south-southwest direction, situated between the Ngao and Phrae basins [5].

Results from fieldwork indicate that the main rock units in the Mae Teep coal mine consist of Tertiary sequences, which are overlain by Quaternary deposits. Quaternary sediments are unconsolidated sediments including gravel, sand, silt, clays, mud, and lateritic soil with the total thickness about 5 meters. The Tertiary sediments deposit in Mae Teep coal mine can be classified based on their distinguished characters into 3 main depositional environments (Fluvial, Lacustrine and Swamp) [7], 5 rock units (Fluvial sequences, Fine-grained sedimentary sequences, Oil Shale, Coal, and Leonardite), and 7 sub-units (Upper Oil Shale, Lower Oil Shale, Oil Shale in Coal A, Coal A, Coal B, Coal C, and Leonardite) as showed in Table 1.

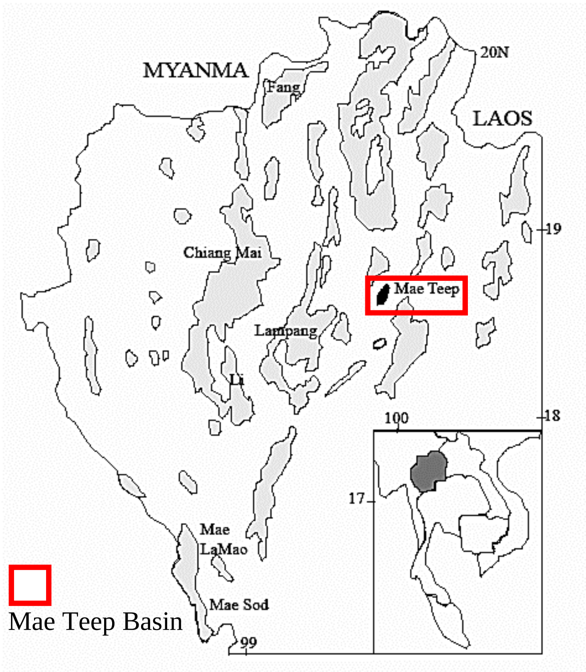

Fig. 1 Map of Tertiary basins and study area of Mae Teep basin in northern Thailand (modified after [6]).

Table 1 Rock units according to the depositional environments of Mae Teep deposit.

Environments	Unit	Sub-unit	Thickness (m)
Fluvial	Fluvial sequences		65.50
Lacustrine	Fine-grained sedimentary sequences		5.50
	Oil Shale	Upper Oil Shale	3.14
		Lower Oil Shale	2.16
Swamp	Coal and Leonardite	Oil Shale in Coal A	1.13
		Coal A	9.26
		Coal B	3.95
		Coal C	4.65
		Leonardite	>3.00

3. RESEARCH METHODOLOGY

Research methodology of this study comprises organic sediment collection and preparation, pyrolysis analysis, and source rock quality and petroleum potential analysis.

3.1 Organic sediments samples collection and preparation

A total of 44 organic sediment samples (14 oil shale, 26 coal and 4 leonardite samples) were collected from a vertical sediment succession at the northern wall of Mae Teep coal mine. Fresh rock samples about 5 kg from each sampling point were collected following the ASTM D 4596 – 09 standard [8] and stored in plastic bags. All of samples required air drying before feeding properly through the crushing, washing and dividing equipment. The air- dried samples were then prepared following the standard practice for preparing coal samples for geochemical analysis of ASTM D2013/D2013M-11 and Practice D346 – 04 [9].

3.2 Pyrolysis analysis

The selected 7 organic sediment samples (3 oil shale samples from Upper Oil Shale, Lower Oil Shale and Oil Shale in Coal A sub-unit, 3 coal samples from Coal A, Coal B and Coal C sub-unit and 1 leonardite sample from Leonardite sub-unit) were sent to the Energy Resources Consulting Pty. Ltd. , Australia, to conduct the Hydrocarbon Analyzer with Kinetics (HAWK) pyrolysis analysis. The HAWK pyrolysis was conducted in this study in order to determine values of total organic carbon)TOC, wt.%(, the quantity of the free hydrocarbons present in the sample before the analysis or hydrocarbon yield)S1, mg HC/g rock), the volume of hydrocarbons that formed during thermal pyrolysis of the sample or kerogen yield)S2, mg HC/g rock), the CO_2 yield during thermal breakdown of kerogen)S3, mg CO_2/g rock(and the temperature at which the maximum rate of hydrocarbon generation occurs in a kerogen sample during pyrolysis analysis (the temperature at the time the S2 peak is recorded during pyrolysis) or maximum temperature)T_{max}, ^{o}C(of the studied organic sediment samples. During the HAWK pyrolysis analysis, the number of hydrocarbons of the studied samples were measured by a flame ionization detection)FID(, while CO and CO_2 were measured by an infrared)IR(detector cell of the HAWK instrument during the temperature was elevated at each step.

3.3 Source rock quality and petroleum potential analysis

In this study the results from HAWK pyrolysis analysis were then used for calculating [10] the amount of hydrogen relative to the amount of organic carbon present in a sample or hydrogen index (HI, mg HC/TOC(and the amount of oxygen relative to the amount of organic carbon present in a sample or oxygen index (OI, mg HC/TOC(by using Eq. (1) and Eq. (2).

$$\text{Hydrogen Index (HI)} = (S2*100)/TOC \quad (1)$$

$$\text{Oxygen Index (OI)} = (S3*100)/TOC \quad (2)$$

In addition, production index (PI) which can be calculated by Eq. (3) was then used to assess source rock quality and hydrocarbon potential of the studied organic sediment samples [10].

$$\text{Production Index (PI)} = (S1/(S1+S2)) \quad (3)$$

The maturation of the studied organic sediment samples can be determined by using the vitrinite reflectance)R_o(which present in the unit of %R_o [11 – 13]. Jarvie [14] proposed the correlation between T_{max} and vitrinite reflectance as presented in Eq. (4).

$$\text{Vitrinite reflectance } (R_o) = 0.018(T_{max}) - 7.16 \quad (4)$$

Therefore, T_{max} resulted from the HAWK pyrolysis analysis were then used to calculate vitrinite reflectance of the studied organic sediment samples and named calculated R_o.

4. RESULTS AND DISCUSSIONS

The results from the HAWK pyrolysis analysis of studied organic sediments samples from each sub-unit including S1, S2, S3, TOC and T_{max} are presented in Table 2 and the calculated S2+S3, HI, OI, PI, and R_o are presented in Table 3 respectively.

Table 2 HAWK pyrolysis analysis results of the studied organic sediment samples.

Sub-units	S1	S2	S3	TOC	T_{max}
		(mg/g)		(wt%)	(°C)
Upper Oil Shale	0.96	40.39	1.19	7.57	425
Lower Oil Shale	0.58	42.59	0.72	5.98	434
Oil Shale in Coal A	1.49	67.80	5.25	19.13	422
Coal A	2.19	69.77	12.30	46.65	427
Coal B	2.32	69.80	8.88	36.43	424
Coal C	2.11	59.14	9.35	39.18	426
Leonardite	0.64	21.49	1.33	6.37	432

Hydrocarbon yield)S1(of all samples are less than 3 mg HC/g rock and vary from 0.58 to 2.32 mg HC/g rock. S1 of the Coal B sub-unit sample is the highest, while S1 of the Lower Oil Shale sub-unit sample is the lowest.

Kerogen yield)S2(of all samples are vary from 21.49 to 69.80 mg HC/g rock. The highest S2 value is of the Coal B sub-unit sample, while Leonardite sub-unit sample has the lowest S2 value.

CO_2 content (S3) of all samples are less than 13 mg/g. The highest CO_2 content is of the Coal A sub-unit sample (12.30 mg CO_2/g rock), while the lowest CO_2 content is of the Lower Oil Shale sub-unit sample (0.72 mg CO_2/g rock).

Total organic carbon (TOC) (wt.%) of all samples are vary from 5.98 to 46.65 wt.%. TOC of the Coal A sub-unit sample is the highest, while TOC of the Lower Oil Shale sub-unit sample is the lowest.

The maximum temperature (T_{max}) of all studied sample vary from 422 to 434 ºC. The highest T_{max} is of the Lower Oil Shale sub-unit sample, while the lowest T_{max} is of the Oil Shale in Coal A sub-unit sample.

The total hydrocarbon generation potential (S1+S2) of the studied organic samples are between 22.13 mg HC/mg rock (Leonardite sub-unit sample) and 72.12 mg HC/mg rock (Coal A sub-unit sample). These values indicate that all of the studied organic samples have high potential for hydrocarbon generating [15 – 19].

The cross-plot between S2 and TOC indicate that the studied samples have very good to excellent hydrocarbon generation potential (Fig. 2).

The maturation of the organic source rock can be estimated by the maximum temperature (T_{max}) and vitrinite reflectance (R_o). In general, a T_{max} of 430 ºC is the boundary between immature and mature stage (oil production zone) [21 – 23].

The petroleum build-up that the effective oil window is estimated to occurs at 0.7 %R_o for type I, 0.5 %R_o for type II and 0.6 %R_o for type III and kerogen type I and II are early 0.5%R_o for generating dry gas [24,25].

Several studies reported that the limit of maximum value of HI about 370 at vitrinite reflectance~ 0.6% R_o or a Tmax of~ 430 ºC is increasing maturity whereas the lower limit in coals about HI 110 – 120 at a T_{max} of~455ºC [26,15,16].

The vitrinite reflectance of 0.4 %R_o (or T_{max} of~ 420 ºC) is onset of petroleum generation [27,16]. In this study, the calculated vitrinite reflectance are between 0.436 and 0.652 %R_o (Table 3).

Therefore, the organic source rock maturation based on the calculated R_o, kerogen type and T_{max} for each studied organic sediment from each sub-unit can be estimated and showed in Table 3.
Consequently, result of the source rock maturation study based on kerogen type, T_{max} and calculated vitrinite reflectance (%R_o) indicate that all of organic sediment sub-units of the Mae Teep organic sediment succession are in between immature and early mature stage. This is coincident to the calculated PI values of the studied organic sediment samples which are all less than 0.1 and indicate the thermal immature stage of these samples [28,10].

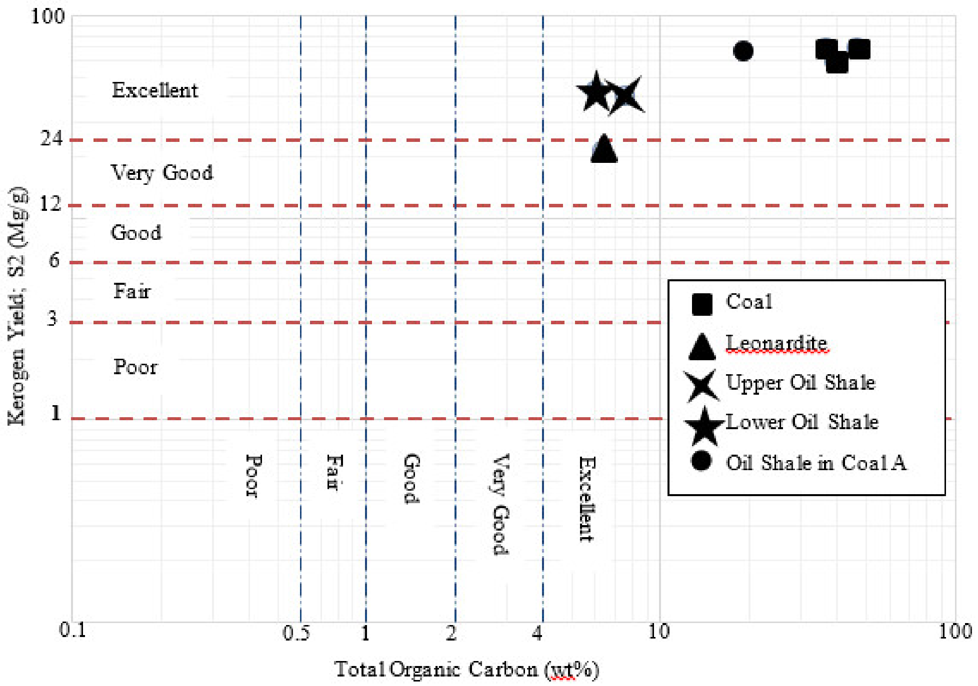

Fig. 2 Cross-plot of S2 vs TOC show good to excellent potential hydrocarbon generation of the studied samples (modified after [20]).

Table 3 The studied organic source rock thermal maturation estimation based on kerogen type, T_{max}, and calculated R_o.

Sub-unit	Kerogen Type	Total Hydrocarbon Generation Potential (S1+S2)	Hydrogen Index (HI)	Oxygen Index (OI)	Production Index (PI)	Ro (%)	Thermal Maturation
Upper Oil Shale	II	41.35	533	15	0.02322	0.490	Immature
Lower Oil Shale	I	43.17	712	12	0.01344	0.652	Immature to Early Mature
Oil Shale in Coal A	II and III	69.29	371	31	0.02150	0.436	Immature
Coal A	III	71.96	149	26	0.03043	0.526	Immature to Early Mature
Coal B	III	72.12	191	24	0.03217	0.472	Immature
Coal C	III	61.25	150	23	0.03445	0.508	Immature to Early Mature
Leonardite	II and III	22.13	337	20	0.02892	0.616	Early Mature

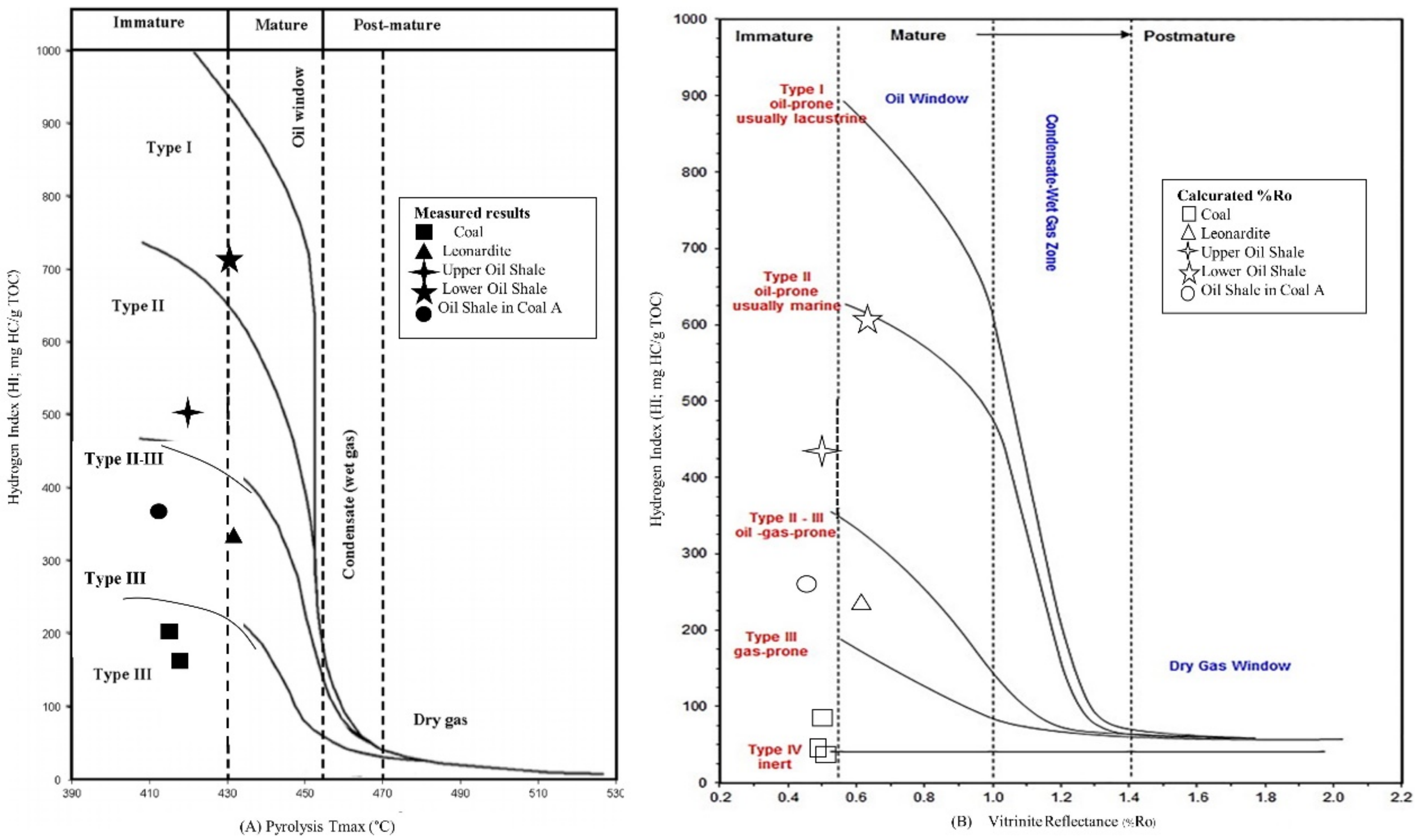

Fig. 3 Thermal maturity stage evaluation and kerogen type classification of the studied organic samples based on HI vs T_{max} cross-plot (A) and HI vs calculated R_o cross-plot (B) [29,27,16].

In this study the calculated HI was plotted versus pyrolysis T_{max} [29] and calculated R_o [27,16] to evaluate thermal maturity stage and to classify kerogen type of the studied samples as showed in Fig. 3A and 3B respectively. Results of the HI vs T_{max} and HI vs calculated R_o cross-plots clearly indicate that organic sediments of Coal A, Coal B, Coal C, Oil Shale in Coal A and Upper Oil Shale sub-unit are in the thermal immature stage, while the organic sediments of Lower Oil Shale and Leonardite sub-unit are in the early thermal mature stage.

Results of the plots also indicate that the organic sediment sample of the Lower Oil Shale sub-unit is Type I kerogen, the organic sediment sample of the Upper Oil Shale sub-unit is Type II kerogen, the organic sediment sample of the Oil Shale in Coal A and Leonardite sub-unit are Type II-III kerogen, while the organic sediment sample of the Coal A, Coal B and Coal C sub-unit are Type III kerogen respectively.

5. CONCLUSION

Based on the results from HAWK pyrolysis analysis, all organic sediment sub-units of Mae Teep organic sediments have good to excellent hydrocarbon generation potential. According to HI vs T_{max} and HI vs calculated R_o cross-plots, the thermal maturity stage and kerogen type of the studied organic sediments can be evaluated and classified respectively.

Results of the plots indicate that organic sediments of Coal A, Coal B, Coal C, Oil Shale in Coal A and Upper Oil Shale sub-unit are in the thermal immature stage, while the organic sediments of Lower Oil Shale and Leonardite sub-unit are in the early thermal mature stage. Results of the plots also indicate that the organic sediment sample of Lower Oil Shale sub-unit is Type I kerogen, the organic sediment sample of the Upper Oil Shale sub-unit is Type II kerogen, the organic sediment samples of the Oil Shale in Coal A and Leonardite sub-unit are Type II-III kerogen, while the organic sediment samples of the Coal A, Coal B and Coal C sub-unit are Type III kerogen respectively.

Though the results of pyrolysis analysis of the studied organic sediment samples from every sub-units show low hydrocarbon yields (S1) (0.58 – 2.32 mg HC/g rock), they are still considered to be the high potential hydrocarbon source rock since they have high kerogen yield (S2) (21.49 - 69.8 mg HC/g rock) and the total hydrocarbon generation potential (S1+S2) of all studied organic sediments are also high (22.13-72.12 mg HC/mg rock). These may contribute them to be a good - very good source rock if their maturity reaches the thermal mature stage.

6. ACKNOWLEDGMENTS

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