

## ABSTRAK

Arang Batu Formasi Tanjong berusia Tertiar yang berada di blok tengah barat Pinangah, bahagian selatan Sabah dianalisis berdasarkan teknik petrologi organik dan geokimikal organik. Sediman di Tanjong Formasi diendapkan dalam sekitaran air payau berdasarkan data yg diperolehi daripada biostratigraphi analisis (Collenette, 1965). Arang batu Tanjong Formasi adalah bersifat humik dan umumnya didominasi oleh makeral vitrinit, liptinit dan sedikit kuantiti inertinit. Kandungan jumlah karbon organik ialah daripada 51.2 sehingga 77.7 wt%, dan nilai pengeluaran bitumen ialah daripada 57300 hingga 140000 ppm, iaitu mencapai tahap minimum batuan sumber dan juga berpontensi cemerlang sebagai generatif hidrokarbon. Arang batu Tanjong Formasi mempunyai potensi generatif yang baik sebagai cecair hidrokarbon berdasarkan kandungan liptinit (>15%). Ini disokong oleh indeks hidrogen yang tinggi iaitu melebihi 300 mg HC/g TOC, selaras dengan kerogen Jenis II dan campuran Jenis II-III. Sampel arang batu mempunyai nilai pantulan vitrinit iaitu dari 0.42%-0.66 Ro%, dan ini menunjukkan arang batu Tanjong Formasi kurang matang hingga awal matang untuk generatif hidrokarbon. Nilai pantulan vitrinit ini juga menunjukkan arang batu Tanjong Formasi adalah dari sub-bituminus B-A dan tinggi wap bituminous C. Nilai Tmax ialah dari 419°C to 451°C dan selaras dengan data dari pantulan vitrinit. Ini juga disokong oleh parameter kematangan biomarker iaitu oleh C<sub>32</sub> homohopan. Pecahan tepu arang batu Tanjong Formasi dicirikan dengan didominasi nombor ganjil karbon n-alkana (n-C<sub>23</sub> to n-C<sub>33</sub>), tinggi nisbah Pr/Ph tinggi (8–18), tinggi nisbah Tm/Ts (6–28), dan kandungan utama C<sub>29</sub> steran. Polen yang hadir dalam sampel arang batu ialah *Rhizophora*, *Cassuriana*, *Dactylocdalus* and *podocarpus*. Diagram indeks pengawetan berlawanan indeks gelifikasi menunjukkan sampel arang batu diplotkan dalam sekitaran paya terbuka sehingga sungai dalam kawasan dataran delta rendah. Ini disokong oleh keputusan

palinologi. Semua parameter biomarker dan keputusan palinologi menunjukkan kandungan organik adalah berasal dari terrestrial dan diterapkan di bawah pengaruh marin diantara kondisi suboxic dalam delta rendah.

## ABSTRACT

The Tertiary Tanjong Formation coals exposed in the west middle block of the Pinangah Coalfield, central part of southern Sabah were analysed based on organic petrological and organic geochemical methods. The sediments of the Tanjong Formation were deposited in brackish water condition, based on limited biostratigraphic data (Collenette, 1965). The Tertiary Tanjong coals are humic and generally dominated by vitrinite, with significant amounts of liptinite and low amounts of inertinite macerals. Total organic carbon contents (TOC) of the coals range from 51.2 to 77.7 wt. %, and yield of bitumen values ranging from 57300 to 140000 ppm, which meet the standard as a source rock with excellent hydrocarbon-generative potential. Good liquid hydrocarbons generation potential can be expected from the Tanjong coals based on significant liptinitic content (> 15%). This is supported by their high hydrogen index up to 300 mg HC/g TOC, consistent with Type II and mixed Type II-III kerogen. The coal samples have vitrinite reflectance values in the range of 0.42%-0.66 Ro%, indicating immature to early mature stage for hydrocarbon generation. These vitrinite reflectance values also indicated that the Tanjong coals are within sub-bituminous B-A and high volatile bituminous C rank. Tmax values ranging from 419°C to 451°C are in good agreement with the vitrinite reflectance data. This is supported by biomarker maturity parameters as suggested by the C<sub>32</sub> homohopane. The saturated fraction of the Tanjong coals are characterized by dominant odd carbon numbered n-alkanes (n-C<sub>23</sub> to n-C<sub>33</sub>), high Pr/Ph ratios (8–18), high Tm/Ts ratios (6–28), and predominant of C<sub>29</sub> regular sterane. *Rhizophora*, *Cassuriana*, *Dactyloctenium* and *podocarpus* are the types of pollen present in the analysed coal samples. Preservation Index versus Gelification Index facies diagram show coal samples fall within the depositional open marsh to fluvial environment on the lower delta plain field. This is supported by

palynology result. All biomarker parameters and palynology result clearly indicate that the organic matter were derived from terrestrial inputs and deposited under marine influenced within suboxic condition on the lower delta plain.

## TABLE OF CONTENTS

Abstrak.....	i
Abstract.....	iii
List of Figures.....	x
List of Table.....	xii
List of Plates.....	xiii
Acknowledgements.....	xiv

### CHAPTER 1: INTRODUCTION

1.1	Introduction.....	1
1.2	Objective.....	3
1.3	An introduction of Sabah.....	3
1.4	Location of study area.....	4

### CHAPTER 2: GENERAL GEOLOGY OF SABAH

2.1	Introduction of Sabah.....	6
2.2	Tectonic evaluation and Basin development in Sabah.....	7
2.2.1	Early Cretaceous- Eocene.....	7
2.2.2	Oligocene- Early Miocene.....	9
2.2.3	Early Miocene .....	9
2.2.4	Early- Middle Miocene.....	10

2.2.5	Pliocene.....	11
2.3	Stratigraphy of the Sabah.....	12
2.4	Tanjong Formation.....	13

### **CHAPTER 3: LITERATURE RIVIEW**

3.1	Introduction.....	15
3.2	Defination of sedimentary facies and coal facies.....	16
3.3	Coal Depositional Environment.....	17
3.4	Fluvial sedimentation and sedimentary structure.....	19
3.5	Coalification of coal.....	21
3.6	Organic Petrology	
3.6.1	Characteristic of Macerals.....	22
3.6.2	Vitrinite Group.....	22
3.6.3	Liptinite/ exinite Group.....	23
3.6.4	Inertinite Group.....	23
3.6.5	Vitrinite reflectance.....	25
3.7	Organic geochemistry	
3.7.1	Biomarkers (Biological markers).....	27
3.7.2	Biomarker as a maturity Indicator.....	30
3.7.3	Biomarker as Organic Facies Indicator.....	32
3.7.4	The Principle of Source Rock Evaluation.....	35
	3.7.4.1 Quantity of Organic Matter.....	35

3.7.4.2 Quality of Organic Matter.....	36
3.7.4.3 Maturity of Organic Matter.....	36
3.7.4.4 Vitrinite Reflectance.....	37

## **CHAPTER 4: METHODOLOGY**

4.1	Introduction.....	39
4.2	Fieldwork.....	40
4.3	Laboratory Analysis.....	42
4.4	Organic Petrology.....	43
4.4.1	Polish Block Preparation.....	43
4.4.2	Vitrinite Reflectance.....	44
4.4.3	Maceral Analyses.....	45
4.4.4	Tissue Preservation Index and Gelification index of petrological analysis	46
4.4.5	Palynology.....	46
4.5	Organic Geochemistry	
4.5.1	Source Rock Analysis (SRA).....	47
4.5.2	Biomarkers.....	48
4.5.2.1	Sample extraction.....	49
4.5.2.2	Column Chromatography.....	49
4.5.2.3	Gas Chromatography- Mass Spectrometry (GCMS).....	50

## CHAPTER 5: RESULT & DISCUSSION

5.1	Introduction.....	52
5.2	Sample description.....	52
5.3	Sedimentary description for BDD 30.....	60
5.3.1	Lithofacies Description.....	62
5.4	Organic Petrology Analyses	
5.4.1	Vitrinite Reflectance Data .....	65
5.4.2	Tellocollinite versus Desmocollinite.....	67
5.4.3	Maceral Analyses.....	68
5.4.4	Interpretation of Macerals and Kerogen Assemblage.....	73
5.4.5	Coal facies.....	80
5.4.6	Palynology.....	83
5.5	Organic Geochemical Analyses.....	89
5.5.1	Result of Source Rock Analysis	
5.5.1.1	Generative Potential.....	89
5.5.1.2	Total Organic Carbon.....	89
5.5.1.3	Thermal maturity of organic matter (Tmax).....	91
5.5.1.4	Types of organic matter.....	91
5.5.2	Extractable organic matter.....	94



5.5.3	Biomarker Distribution Result	
5.5.3.1	The n-Alkanes Distribution (GC).....	96
5.5.3.2	Isoprenoid.....	97
5.5.3.3	Triterpanes Distribution.....	104
5.5.3.4	Sterane Distribution.....	112
5.6	Integration of organic petrological and organic geochemical data	
5.6.1	Thermal maturity.....	115
5.6.2	Liquid hydrocarbon generation potential.....	117
5.6.3	Organic Matter Input and depositional environment.....	119
5.7	Conclusion.....	123

## LIST OF FIGURES

Figure 1.1	Map locations of the study area.....	2
Figure 1.2	Location map of the Sabah, Malaysia.....	5
Figure 2.1	Schematic NW- SE cross- sections across Sabah (Cretaceous- Eocene)....	8
Figure 2.2	Schematic NW- SE cross- sections across Sabah (Oligocene- Early Miocene).....	9
Figure 2.3	Schematic NW- SE cross- sections across Sabah (Early Miocene).....	10
Figure 2.4	Schematic NW- SE cross- sections across Sabah (Early- Middle Miocene)	10
Figure 2.5	Schematic NW- SE cross- sections across Sabah (Miocene- Pliocene)....	11
Figure 2.6	The stratigraphy of the southern Sabah .....	13
Figure 3.1	The diagram shows suberially depositional of modern peatland area...	18
Figure 3.2	The illustration of sedimentary structure.....	20
Figure 3.3	Chemical structures of hopanoid and sterol.....	29
Figure 4.1	Sample of coals collected from Pinangah prepared.....	41
Figure 4.2	Coal samples dry overnight .....	42
Figure 4.3	Microscope model, Leica DM6000M.....	45
Figure 4.4	Source Rock Analyzer (SRA).....	48
Figure 4.5	Sample preparation of GC-MS and GC analysis.....	51
Figure 5.1	The location of twelve coal outcrop in the study area.....	53
Figure 5.2	Stratigraphy log for the BDD 30 coal outcrop, Pinangah Sabah.....	61
Figure 5.3	The value of tellocollinite and desmocollinite reflectance of the..... coal samples analyses.	67
Figure 5.4	Two subgroup of vitrinite maceral: tellocollinite and..... Desmocollinite	68

Figure 5.5	The ternary diagram of maceral composition coals in study area.....	72
Figure 5.6	Pie chart show the maceral component (%) on each maceral in coal samples from Pinangah Sabah.....	75,76
Figure 5.7	Photomicrograph of macerals in Pinangah coals, Sabah under reflected white light and blue light excitation.....	77
Figure 5.8	Photomicrograph of macerals in Pinangah coals, Sabah under reflected white light and blue light excitation.....	78
Figure 5.9	Photomicrograph of macerals in Pinangah coals, Sabah under reflected white light and blue light excitation .....	79
Figure 5.10	Coal Facies (GI vs TPI), proposed by Diesel (1986) .....	82
Figure 5.11	Photomicrograph of palynomorph in coals sample in study area of Pinangah Sabah.....	87,88
Figure 5.12	Pyrolysis S <sub>2</sub> versus total organic carbon (TOC).....	92
Figure 5.13	Plot of hydrogen index (HI) versus pyrolysis Tmax.....	93
Figure 5.14	The typical n-alkanes and isoprenoids distributions of GC..... Chromatograms.	100,101
Figure 5.15	Graph of CPI.....	102
Figure 5.16	Plot of pristane/n-C <sub>17</sub> vs. Phytane/n-C <sub>18</sub> .....	103
Figure 5.17	The typical m/z 191 fragmentograms (terpane distributions) for analyses Coal samples from Pinangah, Sabah area.....	108-110
Figure 5.18	The typical m/z 217 fragmentograms (sterane distributions) for analyses coal samples from Pinangah, Sabah area.....	113, 114
Figure 5.19	Cross- plot of two biomarker parameters sensitive to thermal maturity of the Pinangah sediments (modified from Peters and Moldowan, 1993).....	116

Figure 5.20	Ternary diagrams of regular steranes (C <sub>27</sub> -C <sub>29</sub> ).....	121
-------------	---	-----

**LIST OF TABLE**

Table 3.1	Classification of coal macerals into subgroups and groups.....	24
Table 3.2	Coalification stages according to the German and North American classificatio.....	26
Table 3.3	Vitrinite reflection value for maturity.....	27
Table 3.4	Parameter of Source Rock Potential by Peter and Cassa, (1994).....	38
Table 5.1	Organic petrology data summary for vitrinite analysis for tellocollinite and desmocollinite reflectance.....	66
Table 5.2	Organic petrology data for vitrinite analysis and maceral analysis.....	67
Table 5.3	The composition of maceral (%) based on petrology data.....	74
Table 5.4	Palynomorf data for coal samples in Pinangah, Sabah .....	85,86
Table 5.5	Bulk geochemical results of pyrolysis analysis.....	90
Table 5.6	Data for extraction analysis of extractable organic matter.....	95
Table 5.7	Bitumen extraction and normal alkane parameters.....	99
Table 5.8	Terpane and sterane data of coal samples in study area.....	107
Table 5.9	Peak assignments for alkane hydrocarbon (I) m/z 191 mass chromatograms and (II) m/z 217 mass chromatograms .....	111

**LIST OF PLATE**

Plate 5.1 Field photograph of the coal outcrop..... 55

Plate 5.2 Field photograph and stratigraphy log for the coal outcrop BDD 2..... 57

Plate 5.3 Outcrop section show the coal outcrop at the BDD 30..... 60

Plate 5.4 Photograph of the sedimentary structure..... 63

Plate 5.5 Photograph of the sedimentary structure..... 64

## ACKNOWLEDMENT

First of all I want to praise to our creator Allah S.W.T for his mercy and guide to finish up my thesis during the time of my research. Many thank to my parents for their trust and moral support during the time of my study.

The author would also like to thank Prof Wan Hasiah Abdullah, Dr Ralph L. Kugler and Dr Mohammed H. Hakimi for all their generous supervision and patience over the last two years. I also would like to thank Dr M.Pearson for his valuable comments. Special thank to staff of Jabatan Mineral & Galian (JMG) Sabah for provide a transport, accommodation, facilities and guidance during the fieldtrip at the research study area.

Support receive from all the laboratory assistant staff of the University of Malaya geochemistry and petrology lab, are very much appreciate. To my friends, Mohd Harith Azhar, Mohd Fadzly Mislán and Patrick Gou thanks a lot for everything during all of this time.

Finally, many thank to University of Malaya for giving me this opportunity to continue my study for the Master of Science and also providing Research Grant No PS363 2009c.