CONTENTS

		Page
Abstract		i.
Abstract		v
List of Tables		xvi
List of Plates		xix
List of Figures		xxiv
Glossary		xxxi
Acknowledgements		xxxii
CHAPTER 1	INTRODUCTION	1
1.1.1	Preface	1
1.2	Purpose of study	1
1.3	Location and accessibility	2
1.4	Geography	2
1.4.1	Drainage	2
1.4.2	Vegetation and Land use	4
1.5	Geomorphology	5
1.5.1	Topography	5
1.5.2	Karst Topography	6
1.5.3	Sink holes	6
1.6	Previous Geological work	6
1.7	Regional Geology	8

1.7.1	Outlines on the tectonics of South East Asia	8
1.7.2	General Geology	10
1.7.2.1	Geological outline of peninsular Malaysia	10
1.7.2.2	General Geology of the study areas	10
1.7.2.2.1	Geology of the Central Pahang	10
1.7.2.2.2	Geology of the Panching - Sg. Lembing Area	12
1.7.2.2.3	Geology of the Bt. Pak Sagor	13
1.7.2.2.4	Geology of the Kemaman	13
1.7.3	Paleozoic Rocks of Peninsular Malaysia	14
1.7.4	Triassic Rocks in Peninsular Malaysia	16
CHAPTER 2	SAMPLES AND METHODS OF STUDY	17
2.1	Location os sample	17
2.2	Methods of study	21
2.2.1	Inorganic Methods	21
2.2.1.1	Minerological and clay Minerals Analysis	21
2.2.1.2	Geochemical Analysis	22
2.2.1.2.1	Glassy disks	22
2.2.1.2.2	Pressed sample powder pellets	22
2.2.1.3	Loss on Ignition (L.O.1)	22
2.2.1.4	Grain-size analysis	23
2.2.2	Organic Methods	23
2.2.2.1	Petrology	23

2.2.2.1.1	Polished blocks	23
2.2.2.1.2	Microscopic Examination and vitrinite reflectance	25
2.2.2.2	Geochemistry	25
2.2.2.2.1	Total Organic Carbon (TOC)	25
2.2.2.2.2	Biomarker Extraction	25
2.2.2.2.3	Column Chromatography	27
2.2.2.2.4	Gas chromatography (GC) and Gas chromatography	
	-Mars spectrometry (GC-MS)	29
CHAPTER 3	PETROGRAPHY AND CLAY MINERALOGY	32
3.1	Introduction	32
3.2	Field observation and Samples description	32
3.2.1	Semantan Formation Samples	32
3.2.2	Permian sequence Samples	33
3.2.3	Charu Samples	33
3.2.4	Panching Limestone Samples	40
3.2.5	Sagor Samples	45
3.2.6	Kemaman (Chukai) metasediments Samples	47
3.3	Clay minerals investigations	51
3.4	Clay mineralogy	51
3.4.1	Illite	51
3.4.1.1	Crystallinity of illite	53
3.4.1.2	Crystallite size determination	78

4.2.1.3	Fe ₂ 0 ₃ total content	118
4.2.1.4	Magnesium content (MgO)	120
4.2.1.5	Calcium content (CaO)	120
4.2.1.6	Sodium content (Na2O)	121
4.2.1.7	Potasium content (K2O)	121
4.2.1.8	Titanium content (TiO2)	123
4.2.1.9	Manganese content (MnO)	123
4.2.1.10	Phosphours content (P2O5)	124
4.2.1.11	Loss on ignition (L.O.I)	124
4.2.1.12	Sulphur content (S)	125
4.2.2	Minor Elements	126
4.2.2.1	Ba content	126
4.2.2.2	Cobalt (Co) content	127
4.2.2.3	Chromium (Cr) content	128
4.2.2.4	Gallium (Ga) content	128
4.2.2.5	Niobium(Nb) content	129
4.2.2.6	Rubidium (Rb) content	129
4.2.2.7	Strontium (Sr) content	130
4.2.2.8	Zirconium (Zr) content	131
4.3	Relationship between chemical composition	n
	and grain-size	131
4.3.1	Interpretation	133

3.4.1.2.1	Introduction	78
3.4.1.2.2	Measurement of average crystal size of illite	78
3.4.1.2.3	Interpretation of Results	79
3.4.2	Kaolinite	81
3.4.2.1	Kaolinite Crystallinity	83
3.4.3	Chlorite	86
3.5	Pyrophyllite	86
3.5.1	Introduction	86
3.5.2	Identification of Pyrophyllite	87
3.6	Non Clay minerals	92
3.7	Indicator of very low grade metamorphism	104
3.8	Diagenesis	107
3.8.1	Illite diagenesis	108
3.8.2	Diagenesis of Kaolinite	108
3.9	Interpretation and discussions	108
3.10	Conclusion	110
CHAPTER 4	GEOCHEMICAL ANALYSIS	111
4.1	Introduction	111
4.2	Results and Discussion	111
4.2.1	Major Elements	111
4.2.1.1	Silica content (SiO2)	111
4.2.1.2	Alumina content (Al ₂ O ₃)	117

4.4	Interpretation of Geochemistry for the environment	
	of deposition.	143
4.5	Diagenesis and interrelationship between organic	
	and inorganic reactions.	148
4.6	Summary of the results.	150
CHAPTER 5	ORGANIC GEOCHEMISTRY	153
5.1	Background of study	153
5.1.1	Introduction	153
5.1.2	Hydrocarbon compounds in sediments	153
5.1.3	Types of organic matter	154
5.1.4	Variety and characteristics of Hydrocarbons	155
5.1.4.1	Saturated hydrocarbons	156
5.2	Results	157
5.2.1	Petrography	157
5.2.2	Interpretation of vitrinite reflectance	159
5.2,3	Fluorescence Microscopy	159
5.2.4	Total organic carbon (TOC)	166
5.2.5	Normal alkane and acyclic isoprenoids	174
5.2.5.1	Pr/Ph ratio	180
5.2.5.2	Carbon preference index (CPI)	181
5.2.6	Gaschromatography- Mars spectrometry	
	(GC-MS)	182

5.2.0.1	Theyene and tetracyclic terpanes (M/Z. 191)	18.
5.2.6.2	Pentacyclic terpanes	19
5.2.6.2.1	Hopane	19
5.2.7	Steranes M/Z 217	19
5.3	Discussion	193
5.3.1	Maturity	192
5.3.2	Type of organic matter	197
5.3.3	Depositional environment	199
5.4	Conclusions	201
APPENDIX A	Preparation of clays for X-ray diffraction	
	examination.	203
APPENDIX B	X-ray fluorescence spectrometry method	
	of analysis and sample preparation.	205
APPENDIX C	Determination of loss on ignition (L.O.1).	207
APPENDIX D	Maximum and minimum vitrinite reflectance	
	measurements.	208
REFERENCES		210

LIST OF TABLES

3.1	Distribution of clay minerals in the sediments	
	studied.	52
3.2A	The behaviour of basal reflections of illite upon	
	treatments (bulk analysis).	60
3.2B	The behaviour of basal reflections of illite upon	
	treatments $\leq 2\mu m$ fractions.	61
3.2C	The behaviour of basal reflections of illite upon	
	treatments (bulk analysis) of Kemaman samples.	62
3.2D	The behaviour of basal reflection of illite upon	
	treatments $\leq 2\mu m$ fractions of Kemaman samples.	63
3.3	Crystal-size measurements of illite.	79
3.4A	The behaviour of basal reflections of kaolinite	
	(<2μm fractions) after being treated.	82
3.4B	The behaviour of (001) basal reflections of	
	kaolinite after being treated (bulk analysis).	82
3.4C	The behaviour of (001) reflections of kaolinite	
	after being treated (clay-sized fractions) in the	
	Kemaman samples.	83
3.5	The behaviour of (002) and (004) basal reflections	
	of pyrophyllite in the Kemaman samples.	87
3.6	Metamorphic grade for very low grade	
	metamorphism for Kemaman samples	107

4.1	Major, minor and trace chemical analysis of the	
	carbonaceous sediments, in the studied areas,	
	major elements in % and minor elements in	
	10-6.	112
4.2	Major, minor and trace chemical analysis of the	
	Kemaman carbonaceous sediments, major	
	elements in % and trace elements in 10 ⁻⁶ .	113
4.3	Major, minor and trace chemical composition	
	(average) of carbonaceous sediments. Major	
	elements in % and trace elements in 10 ⁻⁶ .	114
4.4	Parameters of grain-sized distribution of the	
	carbonaceous sediments in the study areas	
	sediments.	132
4.5	An average values of Al ₂ O ₃ : TiO ₂ ratio in the	
	carbonaceous sediments of the study area.	144
4.6	The Sr and Ca relationship with Rb and K	
	in the carbonaceous sediments of the study area.	146
5.1	Vitrinite reflectance values (%Ro) for the studied	
	sediments.	158
5.2	TOC %.	166
5.3	Identification for mass fragmentograms in	
	M/z 217.	189
5.4	Identification of peaks in M/z 217.	189

5.5	Organic geochemistry data.	194
5.6	Biomarker parameters for selected rock extracts	
	in the area of study.	195

LIST OF PLATES

2.1	Master grain size machine	24
2.2	Soxhlet apparatus	- 26
2.3	Column chromatography	28
2.4	Buchi evaporation	30
3.1	Handspecimen show sharp contact between	
	tuffaceous sandstone and alternating shale-	
	mudstone beds. Semantan Formation.	34
3.2a	Graded tuffaceous sandstone handspecimen	
	Semantan Formation.	35
3.2b	Tuffaceous sandstone show layer of mudstone.	
	Semantan Formation.	36
3.3	Permian limestone handspecimen show small	
	joints and fracture distributed randomly filled	
	with secondary calcite. "Jengka Pass"	37
3.4	Carbonaceous shale hand specimen illustrate	
	plant remains, "Permian Formation".	
	Location Jengka Pass.	37
3.5	Black shale show lamination with alternation	
	dark and grey color. Permian sequence at	
	Jengka Pass.	38
3.6	Weathered black shale of Charu Formation which	
	change to friable soil (28 km to Kuantan town)	30

3.7	Black shale in Charu Formation show thinly beds	
	of coaly shale (28 km to Kuantan town).	41
3.8	Coaly shale hand specimen from Charu Formation	
	sample Ch ₄ . (28 km to Kuantan town)	42.
3.9	Black shale in Charu Formation show dark and	
	light lamination. (28 km to Kuantan town)	43
3.10	Dark grey limestone show small joints and fracture	
	distributed randomly, filled with secondary calcite	
	(sample Pa ₁ ; Bt. Panching)	44
3.11	Light grey color limestone show fracture filled	
	with secondary calcite, botlom side right red color	
	due to weathering of hematite grains (sample Pa2	
	Bt Panching).	44
3.12	Handspecimen of black shale show fissibility	
	(sample Sa2, Bt. Sagor).	46
3.13	Plant leaf fragment preserved between bedding	
	planes of the carbonaceous shale (sample Sa ₄ ,	
	Bt. Pak Sagor).	46
3.14	Photograph of Bt. Tg. Mat Amin (Chukai).	48
3.15	Handspecimen show rock cleavage and silky	
	sheen in black slate (sample Km3 Bt. Tg.	
	Mat Amin).	49

3.16	Phyllite show marked luster due to high content	
	of carbon in the form of graphite. (sample Km4,	
	Bt. Tg. Mat Amin).	49
3.17	Photograph show repeation of strata by folding	
	Bt. Tg. Mat Amin (Chukai).	50
3.18A	Scanning electron micrograph of (sample Ch4)	
	illustrate flacky platelets illite.	64
3.18B	Scanning electron micrograph of (sample Per2)	
	display flacky platelets illite.	66
3.18C	Scanning electron micrograph of (sample Tr ₃)	
	show flacky platelets illite.	68
3.18D	Scanning electron micrograph of (sample Sa ₄)	
	show flacky platelets illite.	70
3.19	Scanning electron micrograph of sample Ch4	
	show kaolinite.	84
3.20	Scanning electron micrograph of (sample Perı)	
	showing framboids pyrite.	99
3.21	Scanning electron micrograph show rhombic	
	morphology of calcite (sample Per3).	101
3.22	Scanning electron micrograph of show calcite	
	mineral (sample Perı).	102

5.1a and b	Photomicrographs showing dark brown bitumen	
	staining occurring within a ground mass with	
	fine grained, highly reflecting vitrinite particles,	
	inertinite quartz and clay matrix. Reflected white	
	light; field width = 0.21mm.	167
5.2	Photomicrograph showing yellow orange	
	fluorescencing bitumen staining. Same view as	
	plate 5.1b under blue light exitation.	168
5.3 a and b	Photomicrographs showing possible poorly,	
	preserved graphitized plant remains. Reflected	
	white light; field width = 0.21mm.	169
5.4	Photomicrograph showing a particle with distinct	
	cellular structure of unknown identity. Reflected	
	white light; field width = 0.21 mm. Sample Km_2	
	phyllite, location Bt. Tg. Mat Amin (Chukai).	170
5.5a and b	Photomicrographs showing amorphous organic	
	matter. Reflected blue light; field width	
	= 0.21mm.	171
5.6a and b	Photomicrographs showing yellow orange	
	fluoresencing bitumen occurring within ground	
	mass of unrecognisable macerals. Reflected blue	
	light; field width $a = 0.65mm$ and $b = 0.21mm$.	172

Scanning electron micrograph show cellular carbonaceous wood fragments preserved in Sample Km4 (phyllite). Location; Bt. Tg. Mat Amin (Chukai).

173

LIST OF FIGURES

1.1	Location map showing areas surveyed	3
1.2	Setting of the Eastern Peninsular Malaysia in	
	the tectonic of South East Asia.	9
1.3	Location of the three geological belts in	
	the West Malaysia.	11
2.1a	Sampling localities of the Kuantan Group.	18
2.1b	Sampling Localities of the Permian and	
	Semantan formations.	19
2.1c	Sampling localities of the Kemaman (lower	
	Carboniferous age) carbonaceous sediments.	20
2.2	Scheme for extraction and analysis geochemical	
	Fossils.	31
3.1A	X-ray diffraction pattern of untreated sample	
	$Chs \leq 2\mu m$	54
3.1B	X-ray diffraction pattern of untreated sample	
	$Sa_4 \le 2\mu m$	55
3.1C	X-ray diffraction pattern of untreated sample	
	$Tr_1 < 2\mu m$	56
3.1D	X-ray diffraction pattern of untreated sample	
	$Per_1 \le 2\mu m$	57
3.1E	X-ray diffraction pattern of untreated sample	
	Km ₃ < 2μm	58

3.1F	X-ray diffraction pattern of untreated sample	
	$Km_4 \leq 2\mu m$	59
3.2A	Energy Dispensive X-ray spectrum (EDX)	
	of illite sample Ch4	65
3.2B	Energy Dispensive X-ray spectrum (EDX)	
	illite sample Per3	67
3.2C	Energy Dispensive X-ray spectrum (EDX)	
	of illite sample Tr3	69
3.2D	Energy Dispensive X-ray spectrum (EDX)	
	of illite sample Sa4	71
3.3A	X-ray diffraction pattern of sample Chs	
	after being glycolated.	72
3.3B	X-ray diffraction pattern of sample Chs	
	after being heated.	73
3.3C	X-ray diffraction pattern of sample Sa ₄	
	after being glycolated.	74
3.3D	X-ray diffraction pattern of sample Sa ₄	
	after being heated.	75
3.3E	X-ray diffraction pattern of sample Peri	
	after being glycolated.	76
3.3F	X-ray diffraction of sample Peri	
	after being heated	77

3.4	Average crystallite size as a function of peak	
	width at half height (After Grilfin 1971)	80
3.5	Energy Dispersive X-ray spectrum (EDX)	
	of kaolinite sample Ch4	85
3.6A	X-ray diffraction pattern of sample km3	
	after being glycolated.	88
3.6B	X-ray diffraction pattern of sample km3	
	after being heated.	89
3.6C	X-ray diffraction pattern of sample km 4	
	after being glycolated.	90
3.6D	X-ray diffraction pattern of sample km4	
	after being heated.	91
3.7A	X-ray diffraction pattern of untreated	
	sample chs bulk analysis.	93
3.7B	X-ray diffraction pattern of untreated	
	sample Sa4 bulk analysis.	94
3.7C	X-ray diffraction pattern of untreated	
	sample Perı bulk analysis.	95
3.7D	X-ray diffraction pattern of untreated	
	sample Trı bulk analysis.	96
3.7E	X-ray diffraction pattern of untreated	
	sample bulk analysis.	97

3.7F	X-ray diffraction pattern of untreated sample km4	
	bulk analysis phyllite sample.	98
3.8	Energy Dispensive X-ray spectrum (EDX)	
	of pyrite sample Perı	100
3.9	Energy Dispensive X-ray spectrum (EDX)	
	of calcite sample Per3	103
3.10	First illite basal reflection sample km3(slate).	
	Location Bt. Tg. Mat Amin (Chukai).	105
3.11	First illite basal reflection sample km4 (phyllite)	
	Location Bt. Tg. Mat Amin (Chukai).	106
4.1	Major elements composition of the carbonaceous	
	Sediments of the Charu, Sagor, Permian, Semantan	
	formations and Kemaman metasediments.	115
1.2a	Cumulative frequency curve of sample Ch ₄	134
1.2b	Cumulative frequency curve of sample Ch2	135
1.2c	Cumulative frequency curve of sample Sai	136
1.2d	Cumulative frequency curve of sample Peri	137
1.2e	Cumulative frequency curve of sample Per2	138
1.2f	Cumulative frequency curve of sample Tri	139
1.2g	Cumulative frequency curve of sample Tr2	140
.2h	Cumulative frequency curve of sample Km2	141
.2i	Cumulative frequency curve of sample Km12	142

4.3	Scheme illustrate diagenetic reactions and origin	
	of the ions forming the diagenetic minerals.	149
5.1A and B	Vitrinite reflectance histograms. A) sample Ch2;	
	B) sample Ch4. Location: Charu Fm. Pahang.	160
5.2A and B	Vitrinite reflectance histograms. A) sample Sai;	
	B) sample Sa4. Location : Bt. Pak Sagor.	161
5.3A and B	Vitrinite reflectance histograms. A) sample Per2;	
	B) sample Pers. Location : Jengka Pass.	162
5.4A and B	Vitrinite reflectance histograms. A) sample Tri;	
	B) sample Tr ₂ . Location : Semantan Fm.	163
5.5A and B	Vitrinite reflectance histograms. A) sample Km9	
	(slate); B) sample Km_2 (phyllite). Location : $Bt.Tg.$	
	Mat Amin, Chukai.	164
5.6	Vitrinite reflectance histograms of the Panching	
	Limestone (Pai). Location : Bt. Panching.	165
5.7	Gas chromatograms of saturated hydrocarbons	
	A) Charu Fm (Ch4); B) Panching	
	limestone Fm. (Pa1).	175
5.8	Gas chromatograms of saturated hydrocarbons	
	A) Sample Ch1; B) Sample Ch2; Charu Fm.	176
5.9	Gas chromatograms of saturated hydrocarbons	
	A) Sample Tra: B) Sample Tra: Semantan Em	177

5.10	Gas chromatograms of saturated hydrocarbons	
	A) Sample Sa ₂ ; B) Sample Sa ₄ ; Sagor Fm.	178
5.11	Gas chromatograms of saturated hydrocarbons	
	Sample Peri ; Jengka Pass.	179
5. 12A and B	(M/Z 191) mass chromatograms showing the	
	relative distribution of terpanes and triterpanes	
	released from the Charu Fm. A) sample Chi;	
	B) sample Ch ₄	183
5.13	(M/Z 191) mass chromatograms showing the	
	relative distribution of terpanes and triterpanes	
	released from A) Panching Fm.(Pa1);	
	B) Sagor Fm (Sa ₂)	184
5.14	M/Z 191 mass chromatograms showing the relative	
	distribution of terpanes and triterpanes released	
	from A) Permian Fm. (Per1);	
	B) Semantan Fm (Tr ₂).	185
5.15A and B	Sterane M/Z 217 distributions from rocks	
	extracts of the Charu Fm. A) sample Ch1;	
	B) sample Ch ₄	186
5.16	Sterane M/Z 217 distributions from rocks extracts of	
	A) The Panching limestone (Pa1);	
	B) The Sagor Fm (Sa ₂)	187

5.17	Sterane M/Z 217 distributions from rocks extract	
	A) The Permian Fm (Perı);	
	B) The Semantan Fm (Tr2)	188
5.18	Structures of commonly occuring biomarkers	
	in the samples studied.	190

GLOSSARY

Malay		English
Bukit	Bt.	hill
Gunung	G.	mountain
Kampung	Kg.	Village
Kuala	K.	mouth of river
Pulau	P.	island
Sungai	Sg.	River
Tanjung	Tg.	cape