General Geology of Kampung Pahit, Gerik, Perak with the emphasis on The Occurrences of Graptolites and Other Fossils

By

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15080

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31750, Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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(Dr Mohd Suhaili Ismail)

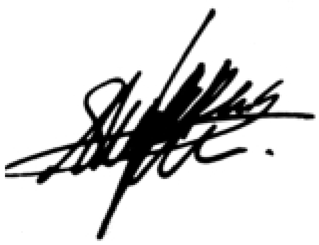
UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2014

Certification of Originality

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecific source or persons.



(KEE SHOOK PENG)

ABSTRACT

Kampung Pahit is located in the northern area of the state of Perak, where part of Pengkalan Hulu Formation are exposed on the surface. Low grade metamorphic rocks and argillaceous facies of the formation are found in the study area. Previous studies had been done by Jones (1970) and The Thai-Malaysian Working Group (2009) in Baling-Pengkalan Hulu area. Studies done are on a bigger scale to study geology the area of Northern Perak, however a study based solely in the area of Kampung Pahit have not been conducted. This project is conducted to study the general geology of the area with the emphasis of occurrences graptolites and other fossils. Several suitable methodologies had been used for the study. Low grade metamorphic rocks, carbonaceous rocks and calcareous shale are found in the study area. The depositional setting is deep marine and the depositional environment is slope apron. The discovery of *Spirograptus* sp leads to the confirmation of depositional environment. The age of the study area is Lower Palaeozoic, specifically from Later Ordovician to Early Silurian. Most of the rocks in the study area has good hydrocarbon reservoir potential as their total organic carbon content is high.

Acknowledgement

Foremost, I would like to express my sincere gratitude to my supervisor, Dr Mohd Suhaili Ismail for the continuous support of my research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this dissertation. I could not have imagined having a better mentor.

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Lastly, I would like to thank my friends for being there for me when I needed any assistance. The knowledge and skills shared make this thesis possible. The moral support and encouragement given is one of the forces that keep me moving and progressed.

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CHAPTER 1

INTRODUCTION

1.1 Background

Palaeozoic rocks are mostly found in the Western Belt of Peninsular Malaysia. These rocks are found commonly in the state of Perak, Selangor, Negeri Sembilan and Melaka. In the state of Perak, these Palaeozoic rocks can be found in Gerik area. Within Gerik area, these rocks can be found as part of the Pengkalan Hulu Formation.

The Pengkalan Hulu Formation has fossiliferous Mudstone/Shale outcrop (The Malaysian-Thai Working Group, 2009). Fossil especially graptolites are commonly found in these metamorphic rocks.

Several species of graptolites, brachiopods and trilobites have been discovered at the outcrops in Kampung Pahit area suggesting that the rocks in this Locality are formed in the Palaeozoic era. The graptolites, *Spirograptus* sp was found in the lower part of the rock sequence. In the upper part of the sequence, brachiopods, trilobite and bryozoan was observe in the fossilliferous mudstone/shale outcrop.

This project attempts to provide a close up review of the geology of this area, with emphasis of graptolites occurrences as well as the occurrences of other fossils. Several methods are used to produce results that could enhance the geological and palaeontological knowledge of this locality.

1.2 Problem Statement

Previous studies covered the geology of Gerik on a larger scales, however a study based specifically focused on the geology of Kampung Pahit, Gerik had not been conducted before. Regional scale studies might miss out important geological details. A detailed study on geology and fossil occurrences will provide a new or additional information on the geology as well as the stratigraphy of the rocks in the area.

1.3 Objectives and Scope of Study

The objectives are listed as below:

1.3.1 General Objectives

The general objective of this project is to study the general geology of Kampung Pahit area. Analysis on the structural, sedimentological and mineralogical studies of its outcrops will be conducted.

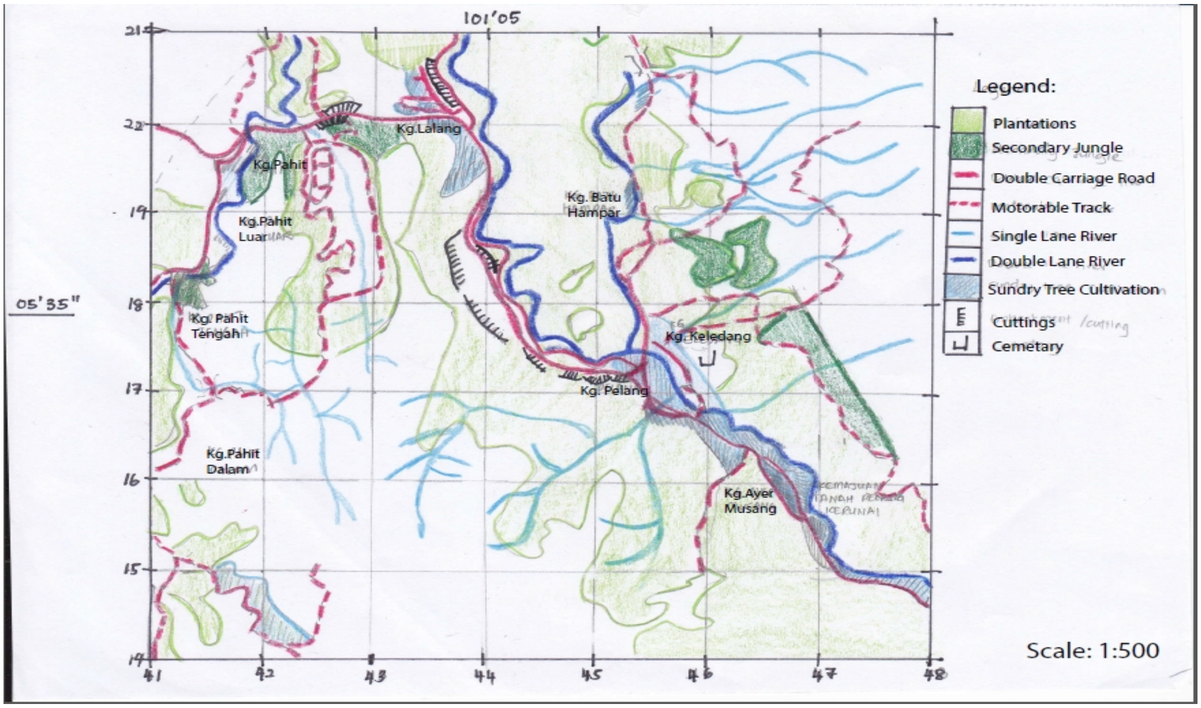
1.3.2 Specific Objectives

a. To locate more fossils to confirm the age of the rocks in the study area
b. To determine the age of the rocks in the area
c. To evaluate the depositional environment of the area based on palaeontological and geological aspect

1.4 Scope of Study

The area of the study focused in the Kampung Pahit area, which includes Kampung Pahit Luar. The samples used for analysis and further studying are limited to those in the geological time of Palaeozoic era.

1.5 Location Map of Study Area



.Figure 1: Study area traced from the geological map

1.6 Gantt Chart

Gantt chart please refer to Appendices 1

CHAPTER 2

LITERATURE REVIEW/THEORY

2.1 General Geology of Perak

Peninsular Malaysia is made up of three main belts: the Western Belt, Central Belt and Eastern Belt. Perak is located in the Western belt (as circled in Figure 2).

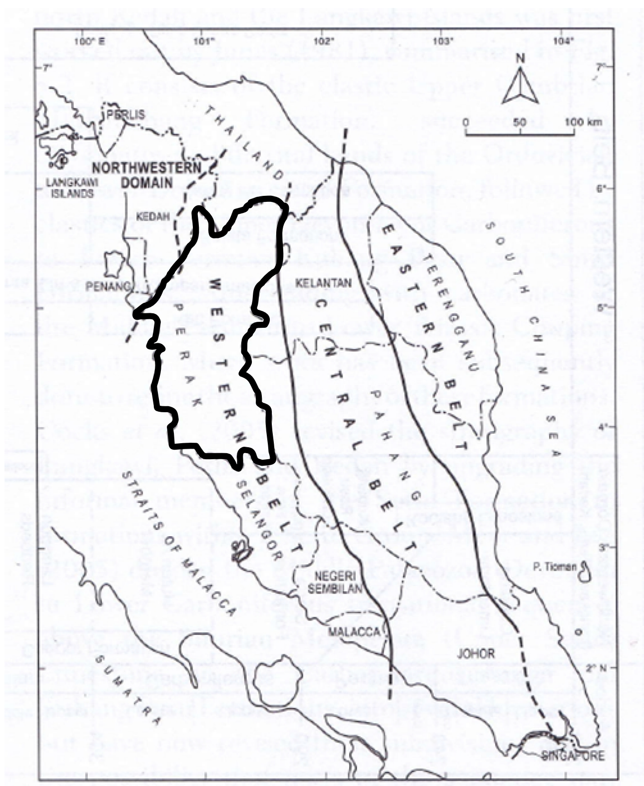


Figure 2: The 3 belts of Peninsular Malaysia

(Adapted from C.S.Hutchinson and D.N.K. Tan, 2009)

Limestone hills and caves are common geological features in the state of Perak, especially in the Ipoh area. Due to the granitic intrusion, minerals such as cassiterite is found abundantly in this area. Cassiterite is the source for tin. The discovery of cassiterite initiated the tin mining business in Perak during the Malaya colonial times. The abundant of limestone hills had caused the marble industry to bloom as well.

The other type of rocks found in the Perak includes granite, argillaceous, metamorphic, and volcanic rocks. These rocks can be found in the a few formations (which includes the Pengkalan Hulu Formation) as highlighted below:-

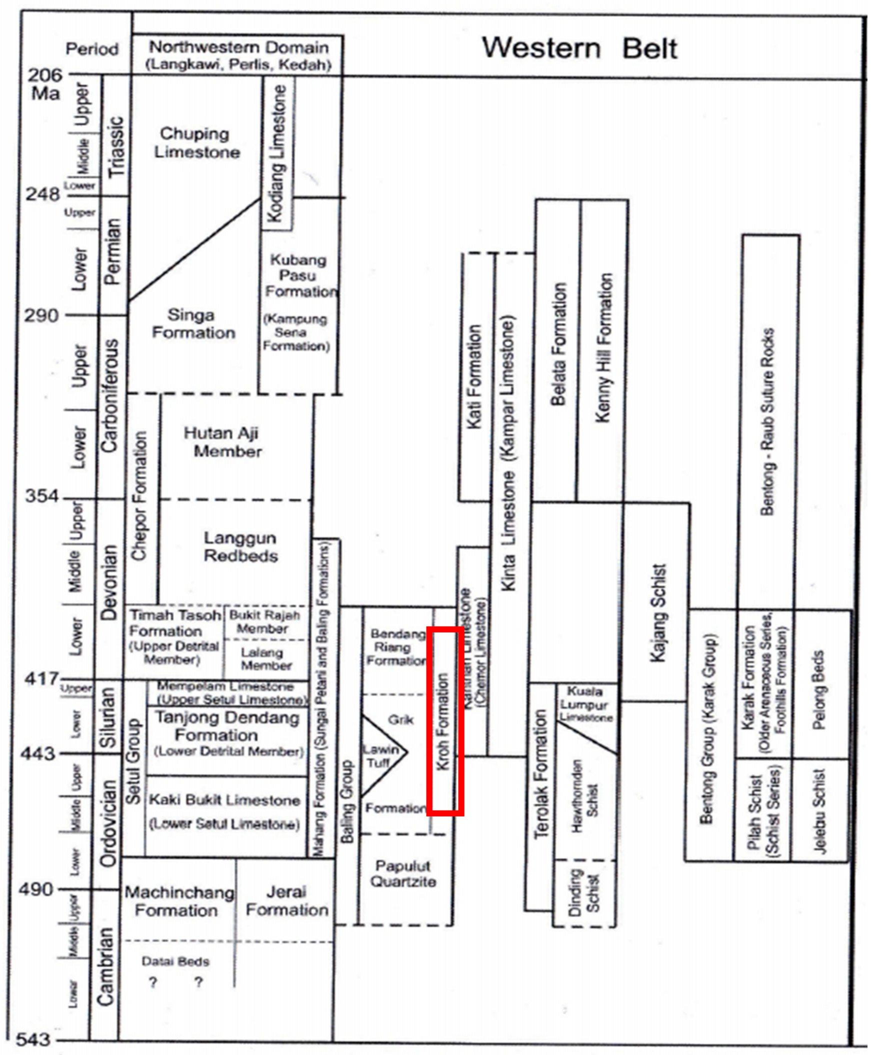


Figure 3: Stratigraphy of Palaeozoic Rock in Peninsular Malaysia

(Adapted from C.S.Hutchinson and D.N.K. Tan, 2009)

Pengkalan Hulu Formation (formerly known as Kroh Formation, as circled in red) can be found partly in Kampung Pahit, Gerik, and Perak.

2.2 General Geology of Study Area

The geology of the Kampung Pahit area consist of a rock that made of the Pengkalan Hulu Formation (formerly known as Kroh Formation) which is of Palaezoic age. Pengkalan Hulu formation is actually part of the larger Baling Group.

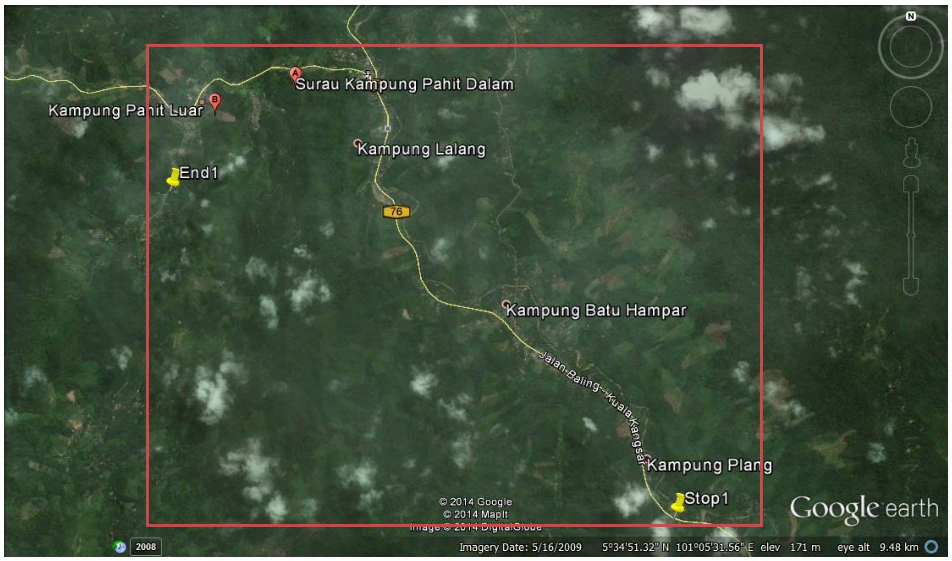
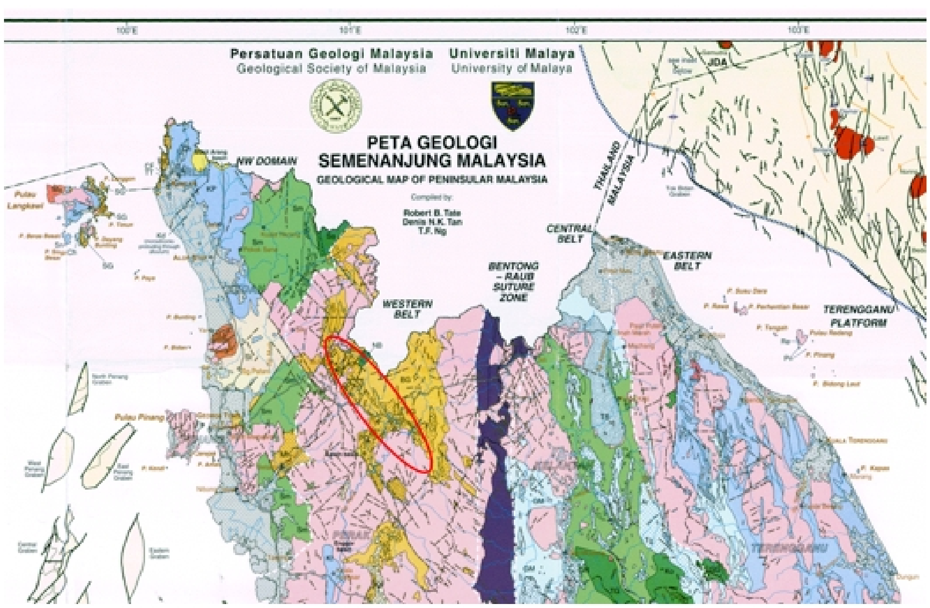


Figure 4: Study area (in red square) as shown in Google Earth



Scale: 1: 1,000,000 (Source: Universiti Malaya and Geological Society of Malaysia, 2009)

Figure 5: Geological sketch map of Gerik with study area highlighted in red circle

(Source: Geological Society of Malaysia, University Malaya , 2009)

2.2.1 Baling Group

2.2.1.1 Lithology

Baling Group includes all the pre-granitic sedimentary rocks around the Main Range, including the pyroclastic stratas. These pyroclastic facies is known latter a Grik pyroclastic member. The sediments are south-easterly extension of the strata in Baling, Kedah. The group has several facies, which are arenaceous, argillaceous and calcareous facies. Pyroclastic facies are seen in this formation as well; however it is difficult to determine the contacts between the sedimentary facies and the facies of the volcanic origin as the detrital sediments are increasingly contaminated by tuffaceous materials. The entire sequence has been affected by both dynamic and thermal metamorphism.

According to Jones (1970), calculation of thickness of the sedimentary part of the group in Gerik area is difficult as folding, possible faulting, and the lateral discontinuity of individual horizons are present. The maximum thickness between 8,000 to 9,000 feet of arenaceous, argillaceous, and calcareous strata however does not take into account the possible effect of fractures occurred to the area.

The Baling Group show rapid lateral and horizontal sediment variations. Generally, the lower part of the group consists of arenaceous strata, while the upper portion is made up of argillaceous rocks. Calcareous facies also developed more strongly in the argillaceous portion of the group. In the Baling area (Burton, in Jones, 1970) 4 main facies, namely arenaceous, argillaceous, calc-silicate, and calcareous can be distinguished.

Facies	Sub-Facies
Argillaceous	Shale, Phyllite, Mudstone, Siltstone, Hornfels, Schist,
Calcareous	Limestone, Calc-Sillicate Hornfels
Arenaceous	Subgreywacke, Schist and Hornfels, Conglomerate

Table 1: Lithological classification of the sediments the Baling group in Gerik

(Modified from Jones, 1970)

The order of deposition of the strata in the Baling area has been postulated by Burton (1970) as follows:-

5. Limestone and Hornfels
4. Siltstones
3. Quartzite, Limestone and Hornfels
2. Quartzite and Limestone
1. Hornfels and Phyllite.

In Gerik area, the lower part of the sequence consists of mainly quartzite lenses of shale and limestone whereas the upper portion is made up of shale and phyllite with thin lenticular developments of limestones. Quartzite, schist and siltstone are found at the upper part of the sequence as well.

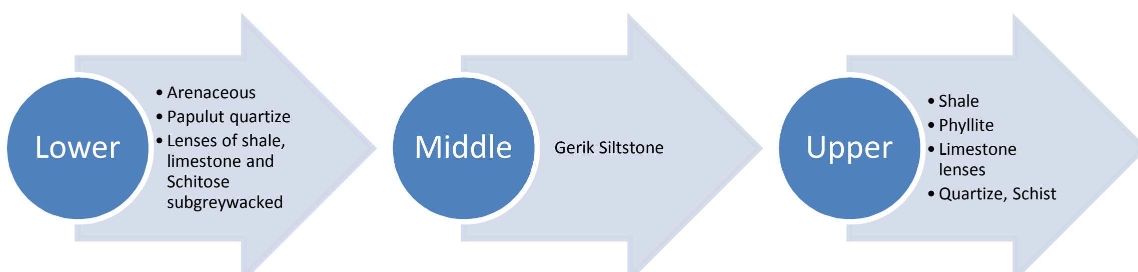


Figure 5a: Stratigraphic sequence of Sediments in Gerik area

(Modified from Jones, 1970)

The wide range of lithofacies represented in the sedimentary portion of this formation reflects that there were various environments where the sediments were deposited. The succession indicated that there was a change from shallow water deposition to deep water deposition

Volcanic fragments were deposited coexist and are closely associated with the detrital strata of Baling formation. These pyroclastic rocks lie approximately between the lower arenaceous and the upper argillaceous of the formation. Shale had been found amongst the pyroclastic rocks, and this provides a good preservation place for fossils such as graptolites, trilobites and brachiopods.

2.2.1.2 Structural Geology

The geological structure of Gerik is in generally conformity with the regional tectonic patterns of Malay Peninsular. The deformation undergone by the Lower Palaeozoic rocks have led to the complex development of structures. Firstly, the Lower Palaeozoic rocks of the Gerik area are folded into series of structures which are characterized by steeply dipping limbs. Minor folding can be seen superimposed on primary structures. The most significant structure is the synclinal axis extending southwards. The core of this syncline is occupied by argillaceous rocks.

Regional shearing is prominent in Gerik area as well. Shear directions recorded are 010, 060, 110 and 160 degrees. The main shearing have occurred parallel to the bedding. The main shearing stresses might be in a north-south direction.

Faulting might have taken place although no continuation has been found. Jointing can be found in all the consolidated rocks, however it is most striking in granite. The joints are normally vertical or steeply inclined.

2.2.1.3 Metamorphism

The pyroclastic-sedimentary sequence has been affected by thermal and dynamic metamorphism as well. Thermal metamorphism has produced low grade metamorphic rocks. Cleavage and foliation are developed from dynamic metamorphism, has also enable shale metamorphosed to phyllite, and the limestone strata has the platy structure due to elongation of mineral grains. Despite all this changes, the most intensely affected of all is still the Gerik pyroclastic member.

2.2.1.4 Economic Geology

Cassiterite (SnO_2) is the main mineral to the economic interest in Gerik area. Minor minerals such as sulphides, iron oxides, and tungsten minerals are found but the quantity is not sufficient to produce in large scale. Monazite and gold occur alongside cassiterite in the alluvium and could be produced as alluvial tin-mining operations.

Minerals occurrences and ore deposits are related to acid intrusive. Possible economic interest normally found along the contact zone, where quartz-rich, late phase magmatic effluents have deposited them in both marginal granite and the intruded strata. (Jones, 1981).

Besides metalliferous resources, limestone, sand, quartz and ballast can be used in many ways as well. Quartz sand or gravel can be used to made concrete aggregate. Limestone can be used in house constructions and flooring.

2.2.2. Pengkalan Hulu Formation

2.2.2.1 General Geology

This formation extent from Malaysia to Thailand, including the Transect area. In Malaysia, this formation is extensively exposed in the Pengkalan Hulu, Kelian Intan and Kerunai areas in Northen Perak, This formation terminates at its southern limit where the Main Range granite meets Bintang batholiths. It is composed of black shale, arenite, calcarous shale and limestone. In some areas, there are low grade metamorphic rocks which are near to the contact with main range granite. The presence of strong isoclinals folding, faulting, and the lenticular shape of the rocks units make it difficult to establish the order of rock succession (The Malaysia-Thai Group, 2009).

Generally, the lithology of the Pengkalan Hulu formation are divided into four main facies: argillaceous, calc-silicate, calcareous and minor arenaceous facies. Argillaceous facies covers major part of the Pengkalan Hulu-Baling area of Pengkalan Hulu Formation. Rocks such as shale and mudstone are often metamorphosed to slate, phyllite, pelitic hornfels, meta-mudstone and quartz-mica schist are common in these formations. Lenticular bodies of impure limestone with considerable amounts of carbonaceous content occurred within the predominant argillaceous rocks at several localities, which include Kampung Pahit Dalam in Pengkalan Hulu (The Malaysia-Thai Group, 2009). Fresh argillaceous rocks are dark grey to black in colour. This may be due to high carbonaceous content and iron sulphide.

The arenacreous facies composed of mainly metasandstone with subordinate metargillite beds. It is found as small isolated lenticular bodies in the argillaceous facies of the formation. The calc-silicate facies rock unit is made up of calc-silicate hornfels and impure limestones. Calcareous argillites metamorphosed and formed these facies, and it is often associated with granite intrusion. It is dark grey in colour and often banded with siliceous materials.

The calcareous facies is made up of lenticular bodies of limestone. It is usually dark grey in colour, thick bedded to massive with large quantity of non-carbonate impurities. It is found platy and bedded owing to the post-depositional segregation of argillaceous impurities from the carbonate. Karst topography was insufficient in development but minor karst topography still can be seen in Tanah Hitam, Belukar Semang and Kampong Pong areas. (The Malaysia-Thai Group, 2009)

2.2.2.2 Depositional Environment

Fine-grained materials which indicate long distance transportation suggest the deposition happened in deep marine environment. This interpretation is supported by the fact that widespread argillaceous facies with carbonaceous material, which suggests that the deposition of this rock occurred in anoxia marine environment

2.3 Occurrences of Graptolites

Graptolites (or Graptolithina) are an extinct group of fossils found commonly in marine environment. They are colonial animals that have skeletons built from proteins. The earliest graptolites recorded are from Middle Cambrian, which is benthic. During Ordovician, benthic graptolites diversified into a few forms, such as tuboids, cystoids, camaroids and crustiods. Planktonic graptolites appeared in early Ordovician, becoming abundant in Ordovician and Silurian.

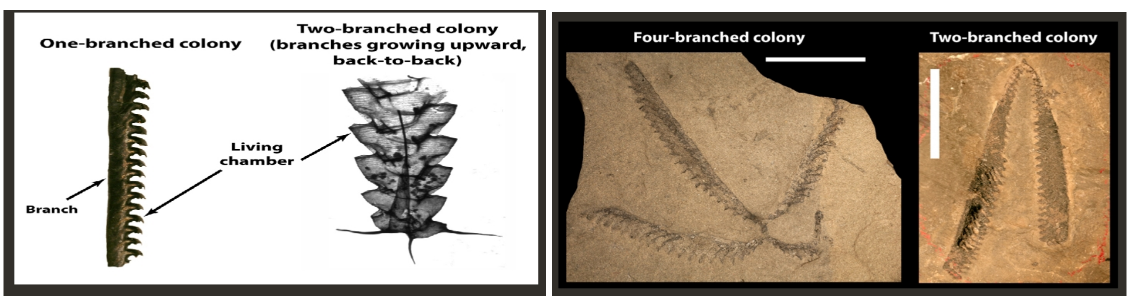


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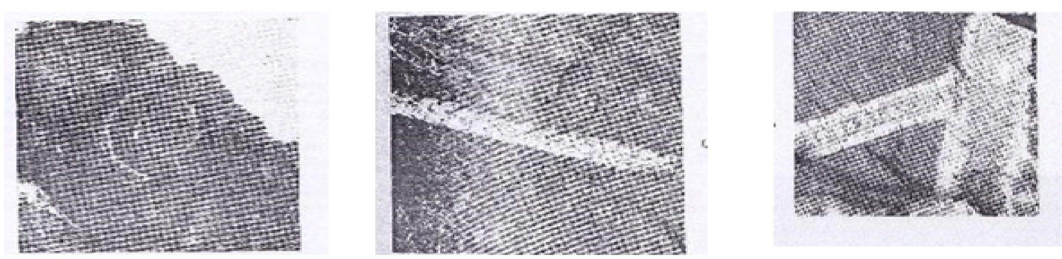
Figure 5b: (A) Graptolites with different number of Branching (B) Graptolites on rocks

(Source: http://commonfossilsofoklahoma.snomnh.ou.edu/graptolites)

Benthic Graptolithina are less common as compared to planktonic ones. Macrozooplankton Graptolites are extinct during the middle Devonian, and benthic graptolites survived until the late Carboniferous. Mitchell et al (2013) through phylogenetic method had proven that Rhadbupleura, modern pterobranch hemichordates is an extant of Graptolites group.

Graptolites are good index fossils. To classify an index fossil, the said fossils have to be wide spread, abundant and short life span. Graptolites are abundant during the Ordovician-Silurian age (Rickards, 1978), their morphology changed during their presence on earth from Cambrian to Late Carboniferous. The major change in morphology is when benthic graptolites adapt to the surrounding environment, and evolve slowly into planktonic graptolites.

Graptolithinas were reported in some localities around Kampung Pahit , Gerik, Perak which is located in between Gerik and Pengkalan Hulu. Mohd Badzran et al (1993, in The Malaysian-Thai Working Group, 2009) mentioned that graptolites were found in the argillite near Kampung Pahit. The graptolites discovered were *Monograptus* sp. and *Spirograptus* sp. Similarly, Jones (1973a,b, as cited in Lee, 2009) found graptolites belonging to Linnaei, Minor, Crispus, Griestoniensis, Spiralis and Grandis zone between Gerik and Pengkalan Hulu (formerly known as Kroh) , which confirms the age of the outcrops in the area to be Early Silurian.



Coiled valve of a gastropod in Limstone from Sungei Kerunei

Monograptus sp in carbonaceous shale from Sungai Rui

Diplograptus sp in carbonaceous shale from Sungai Rui

(Source: The Geology and Mineral Resources of the Grik Area, Upper Perak, 1970)

Figure 5c: Graptolites from Kampung Pahit

The graptolites found in the study area are distributed in Pengkalan Hulu Formation and Baling Group. *Monograptus* sp. and *Spirograptus* sp are found in the argillaceous facies of the Pengkalan Hulu Formation.

2.4 Other Fossils

Apart from graptolites, other fossils such as brachiopods, trilobites and bryzoan are also found in the lower part of the argillaceous rock sequence.

Brachiopods are marine shellfish which survive the whole of Phanerozoic. They are mostly surface dwellers, with complex mechanism housed within hinged calcareous shell. Brachiopods have two halved-shells which is not similar. Brachiopods are less common and less diverse since the mass extinction in the Permian. During the Palaeozoic, brachiopods achieved their peak in diversity, monopolising the shallow marine environment of the early and late Palaeozoic. It is one of the index fossils for Palaeozoic periods too.

Figure 5d: Assemblages of Brachiopods

(Source: www.britannica.com)

Trilobites are yet another important fossils for Palaeozoic rocks. Trilobites are mainly characterized by their exoskeleton, which is divisible into three sections or lobes. Most of the trilobite fossils are moults, as their soft tissues decomposed easily. It is commonly found in shallow marine facies such as limestones, shales and sandstones. Trilobite-derived trace fossils can be found in Palaezoic shallow marine sequences.

Figure 5f: Assembleges of Trilobites

(Source: www. encina.pntic.mec.es)

Bryozoans are aquatic, colonial organisms which consists of several individuals housed within a calcareous skeleton. Majority of the bryozoans are marine, although some brackish or freshwater forms are known as well. They are important components of both Palaeozoic and Modern evolutionary faunas. Bryozoans first appeared in early Ordovician which then quickly diversified to become dominant in Palaeozoic. They live in water with salinity ranged from fresh water to hypersaline and mostly diverse in depths of 20-80 meters.

Figure 5g: Bryozoan

(Source: www.ucmp.berkeley.edu.)

Tentaculites are also found along the Thailand-Malaysia border, which indicates the age of the formation to be Lower Palaeozoic. The discovery of *Stylolina* sp. at 0.8km southeast of Kampung Pahit confirms the age of the formation. The depositional environment of Pengkalan Hulu Formation is interpreted to be deep marine due to the lack of benthos fossil and the undisturbed sediments, which suggest a calm environment.

Figure 5f: Tentaculites from the argillaceous facies in Pengkalan Hulu formation

(Source: The Malaysia-Thai Working Group, 2009)

Jones (1970) discovered Coniconchids including *Homoctenus* sp that occurs with trilobites and brachiopods at a Locality close to the present study area. The Locality is in the Baling Group. All the fossils were found in brown silty shale.

The occurrences of graptolites, trilobites and brachiopods, give the formation of Lower Palaeozoic age. The graptolites yielded from the formation are of Lower Palaeozoic age. The age of the Baling Group is further confirmed by the discovery of the Ordovician trilobites and Devonian tentaculites (Jones, 1968). The similarities of Baling Group and Pengkalan Hulu Formation in terms of lithologies and fossils present showed the consistency between the researchers working on these areas.

The above findings confirm that the age of the rocks in northern Perak range from Late Ordovician to Early Silurian.

CHAPTER 3
RESEARCH METHODOLOGY

Several Methods are used to complete this study and they are listed as below:-

3.1 Mapping

Fieldtrip to the study area will be conducted, with road traversing. Global Positioning (GPS) reading served as a guide to identify the position of the outcrops on the map.

In order to obtain rock samples, geological hammer is used. The hardness of the rock is being tested with the geological hammer too. To identify the minerals present, hand lens are used to magnify the grains. Diluted hydrochloric acid (HCI) is used to test the presence of calcareous minerals. Data such as GPS coordinates of the outcrop, onsite observations and strike/dip measurements using Brunton compass are recorded.

Samples of rocks are taken at selected sites depending on the variations of lithology and the availability of graptolites.

3.2 Thin Section/Petrography studies

Selected rock samples are abstracted from the samples collected and made into thin section for further petrography analysis to determine the mineralogy of the rock, species of graptolites present, energy of depositional environment and depositional environment.

3.3 X-Ray Diffraction (XRD) Analysis

XRD tests are ran on selected rock samples to determine their mineral compounds. By identifying the compounds in a rock, the type of the rock can be known and classified accordingly. The results from XRD are compared to results of petrographic studies to confirm the rock type.

3.4 Total Organic Carbon (TOC)

Total Organic Carbon (TOC) is conducted to check the percentage of carbon in the rock. These percentage would be used to analyse the reservoir potential of the as well as to determine the depositional environment of the study area.

3.5 Fossils Identification

Rocks are cuts into slabs of 1cm width parallel to the rock surfaces. These rock slabs are observed under a binocular microscope to locate fossils possibly preserved in the rocks

CHAPTER 4
GENERAL GEOLOGY OF STUDY AREA

4.1 Rock Types

Geological mapping was carried out in the study area. The rocks in the area had undergone low grade metamorphism which changed the shale, a sedimentary rock into slate and phyllite. Limestone is observed in Kampung Pahit as well, in contact with the shale.

4.1.1 Shale

Shale is a fine-grained sedimentary rocks. It is formed from the compaction of silt and clay type mineral particles. There are 2 types of shale in the study area. Grey shale is found in Locality 1 and Locality 2 whilst calcareous shale is found in Locality 7 and 8.

Figure 6: Outcrop at Locality 1.

Figure 7: Grey Shale

Grey shale in the Locality 1 is thinly laminated and fissile. The colour of the rock is grey. Orange-red stains are found on the rock indicating the presence of iron oxide. Alternating silty and muddy shale are found throughout the outcrop.


Figure 8: Calcareous shale in Locality 8 Figure 9: Calcareous shale in Locality 7

Calcareous shale have significant amount of calcium carbonate. They are found in Locality 8 and 7 in the study area. The shale are grey in colour and there are abundance of calcite joints on the face of the outcrop. The grain size ranged from muddy to very fine. From the XRD analysis both clay and calcareous minerals are abundant in the samples extracted from both localities. Clay minerals are dominant minerals in the samples from these 2 localities, and the other 30 percent of the minerals are calcareous (as shown in table 1 and 2). Locality 7 has approximately 53 percent of clays whilst Locality 8 is composed of 40 percent clay.

In Locality 8, the rocks are arranged in a specific orientation that formed due to the alignment of clay mineral during the formation of rocks. The source of the calcite is the limestone where this rock formation are in contact with. The calcite are deposited into shale. The grain size of calcareous shale from this outcrop varies from silt to muddy.

S7	Amount	Percentage
Corrensite	2	11.7647059
Smectite	3	17.6470588
Gypsum	3	17.6470588
Illite	2	11.7647059
Calcite	4	23.5294118

Dolomite	1	5.88235294
Plagioclase Feldspars	2	11.7647059
TOTAL	**17**	**100**

S8A	Amount	Percentage
Smectite	3	15.00
Illite	2	10.00
Kaolinite	3	15.00
Orthoclase	2	10.00
Plagioclase Feldspars	5	25.00
Dolomite	3	15.00
Calcite	2	10.00
TOTAL	**20**	**100.00**

Table 2 & 3: Amount and percentage of each mineral in each samples from Locality 7 and Locality 8

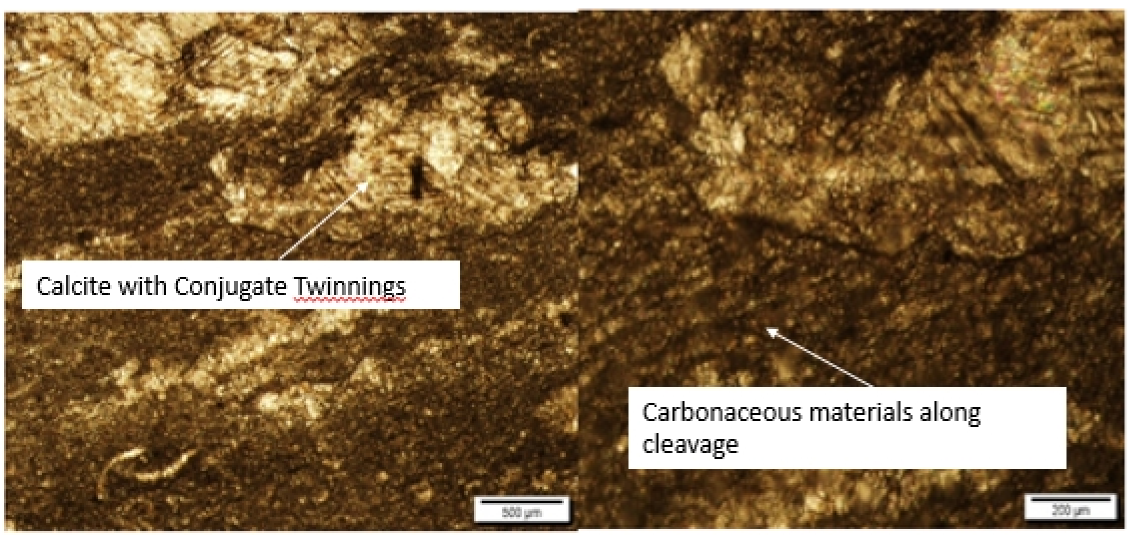
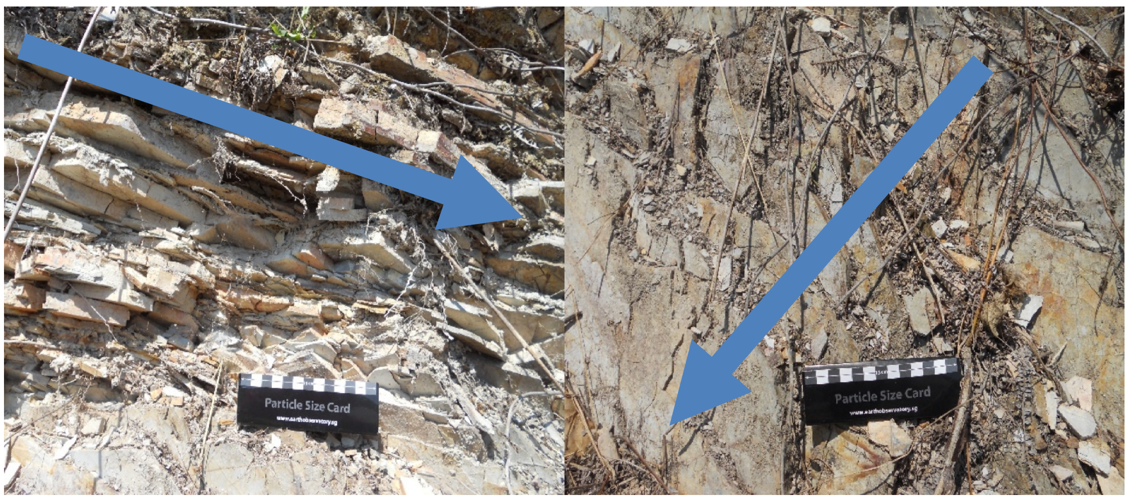


Figure 10: 4x Cross Polarized images

Figure 10 shows small calcite crystal in the 4x and 10x magnification crossed polarized plane for sample from Locality 8. The clays are arranged in a certain orientations with limited amount of carbonaceous material deposited along the cleavage planes and are in sub-parallel alignment. Calcite phenocryst are surrounded by the feldspar. Conjugate sets of deformed twinning in the calcite crystal are seen as well which indicate some deformation in the minerals as well. There are no fossils found in this thin section.

4.1.2 Slate

Slate is a common metamorphic rock in the study area, especially in Locality 3, 4 and 9. The presence of slate indicate the area has undergone low grade regional metamorphism process, most probably due to thermal metamorphism. Most of the slate are black in colour. The lamination thickness ranged from 1 to 4 centimetres. The weathering degree are mostly moderate to high.



A B

Figure 11: (A) Top of the outcrop (B) Bottom of the outcrop

The lamination in Locality 3 is thicker as compared to the shale in Locality 1. The bedding strata on the top is different from the bottom. The upper bed is dipping to the West (show by blue arrow indicates in figure 11) and the bottom strata is dipping to the East (show by blue arrow indicates in figure 11). Tectonic induced inclinal folding causes the top part of the bed to tilt. The tilting could also be a form of angular unconformity. The grain size is silt.

Slate in Locality 9 is more weathered as compared to Locality 3. Muddy and silty slate are common in this area. The area is highly fractured with multiple joints. The laminations have thickness about 1 centimetre. Slate in Locality 9 is highly weathered as compared to Locality 3.

A B

Figure 12: (A) Slate outcrop in Locality 9 (B) Closer view of weathered slate as outcrop in Locality 9

Figure 13: Slate (as circled) in Locality 4

Slate in Locality 4 is found on the right side of the outcrop (as circled in black in figure 13), underneath the folding. The approximate height of the outcrop in Locality 4 is 200 metres. Locality 4 is made up of mostly slate and phyllite (phyllite is discussed in details in the next part). The XRD data of the sample for slate in Locality 4 is as below

S4R	Amount	%
Mica	2	7.41
Smectite	6	22.22
Vermiculite	1	3.70

Plagioclase Feldspars	10	37.04
Orthoclase	2	7.41
Illite	1	3.70
Kaolinite	2	7.41
Gypsum	1	3.70
Muscovite	2	7.41
TOTAL	**27**	**100.00**

Table 4: Amount and percentage of mineral in sample from Locality 4

Slate from Locality 4 made up of mostly plagioclase feldspars (37 percent), with other minerals as minor elements. The clay content in Locality 4 ranges from 43 to 50 percent.

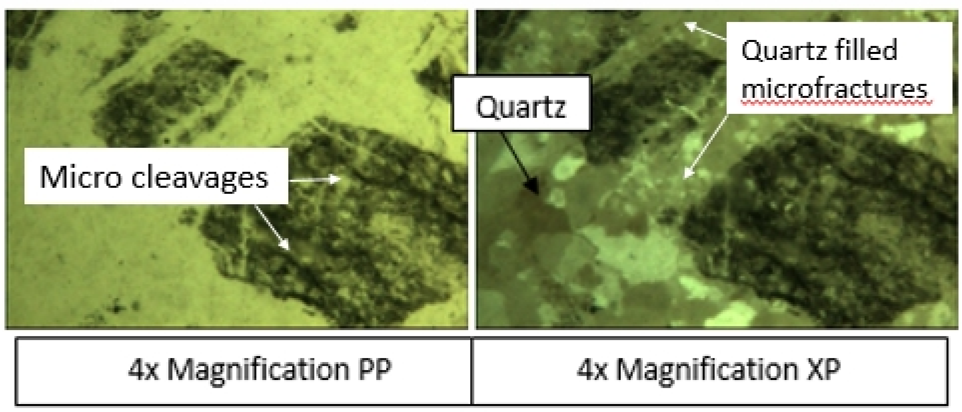


Figure 14: Thin sections of S4(R)

S4(R) is folded slate. As seen in figure 14, the rock contains layers of carbonaceous materials which is deposited on the cleavage of the slate. The cleavage can be seen but very fine. Quartz crystal are seen in the microfracture, as these joints show birefringence when the table is rotated. Opaque carbonaceous material are observed as well. This sample has mostly quartz-filled micro-fractures.

4.1.3 Phyllite

Phyllite is a fine-grained and highly foliated metamorphic rock. It usually has fine-grained mica flakes that formed foliation. The parent rock is shale. Phyllite is found in Locality 4, 5and 6.

In these 2 localities, regional folding, faulting and metamorphism can be clearly seen. It is believed that the dynamic metamorphism causes the shale in this area to metamorphose. The presence of faults (would be discussed further in next chapter) also further induce the metamorphism processes.

B

Figure 15: Phyllite in Locality 4 in detail

Phyllite in Locality 4 are located at the left side of the outcrop. It is carbonaceous as it is black in colour. It does not have the slatty cleavage and is harder as compared to the slate. The XRD data for phyllite in Locality 4 is as below:-

S4L (Phyllite)	Amount	%
Smectite	2	7.14
Vermiculite	1	3.57
Muscovite	1	3.57
Gypsum	1	3.57
Plagioclase Feldspar	12	42.86
Montmorillonite	3	10.71
Orthoclase	2	7.14
Quartz	5	17.86
Kaolinite	1	3.57
TOTAL	**28**	**100.00**

Table 5: Amount and percentage of each mineral of sample in Locality 4L

The amount of feldspars are increasing from 10 (in S4R) to 14 in S4L. However, the percentage of clay minerals are decreasing, indicating the presence of phyllite. The quartz are mostly found as infill for joints in the outcrop. The grain size is muddy.

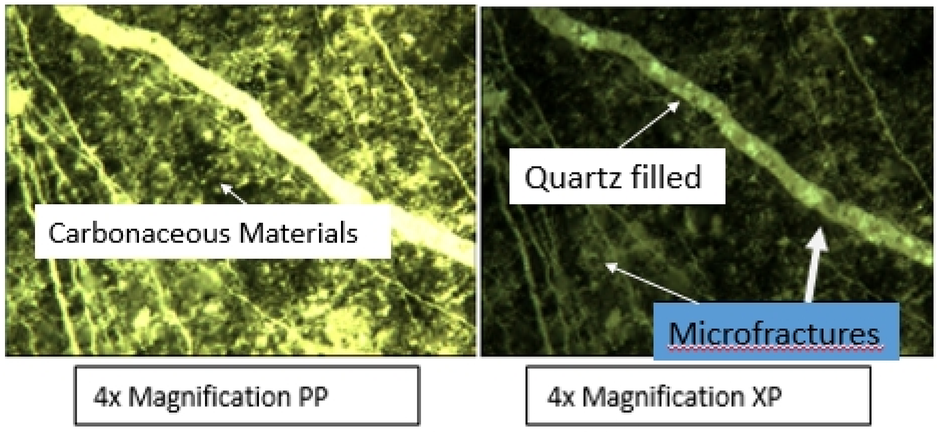


Figure 16: Thin Section of S4 (L)

Based on the thin section, the rock S4(L) is more compacted as compared to S4(R). The groundmass feldspars are align in an orientation, with a few phenocryst quartz crystal. Quartz are present in the joins as they show birefringence when the turn table is rotated. There are small opaque mineral which indicates carbonaceous material (which do not show any extinction). Micro fractures are seen as well. This rock experienced higher metamorphism, becoming more phyllite-like, thus classified as phyllite. Twinnings are not found in this thin section.

Figure 17: Phyllite in Locality 5

Phyllite in Locality 5 is carbonaceous. The slatty cleavage is not easily seen and it is easily broken when hammered. The total clay percentage in Locality 5 is approximately 65 percent. The XRD data for phyllite in this locality is as below:

S5	Amount	Percentage
Smectite	4	16.00
Iliite	3	12.00
Plagioclase Feldspar	14	56.00
Mica	1	4.00
Gypsum	1	4.00
Kaolinite	2	8.00
TOTAL	**25**	**100.00**

Table 6: Amount and percentage of mineral of sample in Locality 5

The majority content of this sample is clay. While carbon content is high (Refer to Organic Carbon Content section), carbon was not detected in the XRD.

Locality 6's outcrop is a small block beside the Pengkalan Hulu-Baling highway. Quartz joints are abundant in this small block. It is carbonaceous and create sparks when hammered.

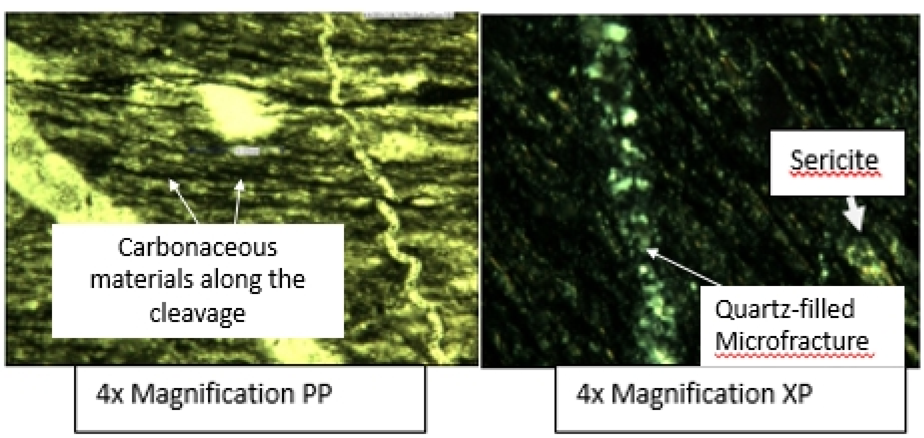


Figure 18: Thin Sections for Locality 6

Figure 18 shows parts of the rock under the microscope. The cleavage is clearly seen in the 4x magnification plane polarized image. Groundmass clay minerals are aligned in a single orientation. The presence of carbonaceous material is obvious, as they appeared as opaque mineral along the cleavage plane. Quartz is present in the rock as joints. Small crystal of sericite (altered orthoclase or plagioclase feldspars) are found in the side of the thin section as well. Feldspars had undergone mineral replacements and formed sericite (as shown in figure 18). Phenocryst of quartz are found in the thin section, especially in the micro crack of the rock.

4.1.4 Carbonaceous Limestone

Carbonaceous limestone is found in Locality 8, beside the calcareous shale. In fact, these two lithology are in contact with each other (Figure 19). Compared to the calcareous shale, the limestone does not have the parallel arrangement of clay minerals.

Figure 19: The contact between calcareous shale and carbonaceous limestone (marked with red line)

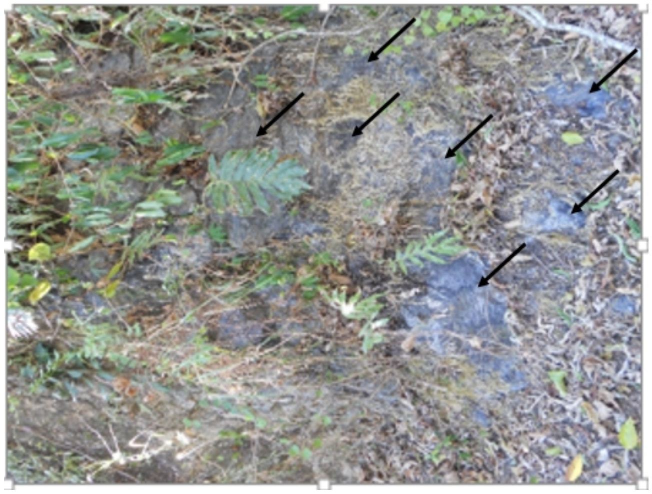


Figure 20: Carbonaceous Limestone in Locality 8 (indicated by arrow)

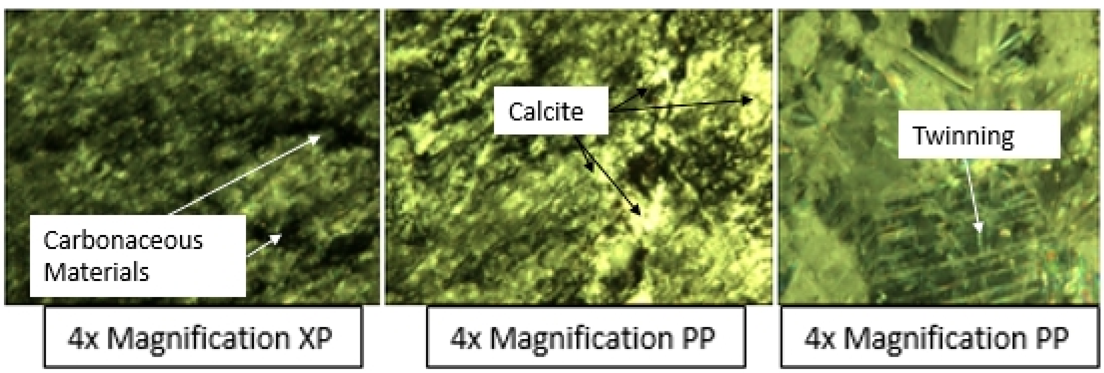


Figure 21: Thin section images of S8(C)

Carbonaceous materials are seen as opaque mineral in plane polarised and cross polarised, deposited along the cleavage plane. Small calcite crystals are distributed in most part of the thin section. Calcite phenocrysts are found in parts of the sample indicating that some part of the rock has already metamorphosed into marble. Polysynthetic twinnings are found as well. This is a carbonaceous limestone The XRD results is as below:-

S8C	Amount	Percentage
Smectite	2	8.00
Illite	3	12.00
Orthoclase	3	12.00
Aragonite	2	8.00

Calcite	4	16.00
Muscovite	1	4.00
Plagioclase Feldspar	4	16.00
Dolomite	2	8.00
Kaolinite	3	12.00
Chlorite	1	4.00
TOTAL	**25**	**100**

Table 7: Amount and percentage of each mineral of sample in Locality 8

Calcite and plagioclase feldspar are the dominant minerals in the tested sample. Aragonite and dolomite are mineral replacements of calcite that happen probably due to the regional metamorphism in the area. They made up 16 percent of the sample. Despite the amount of clay minerals is 68 percent, the outcrop did show portrait the significant slatty cleavage or schitosity. The total clay percentage is only 32.

Sample	Whole Rock Minerallogy (%)								Clay Minerallogy (%)				
	Quartz	K-Feldspar	Plagioclase	Calcite	Dolomite	Siderite	Pyrite	Total Clay	Illite	Smectite	Mica	Kaolinite	Chlorite
S2A	12.00	0.00	28.00	4.00	8.00	0.00	12.00	36.00	20.00	12.00	0.00	4.00	0.00
S4L	14.29	7.14	10.71	0.00	10.71	3.57	3.57	50.00	3.57	25.00	0.00	17.86	3.57
S4R	7.14	7.14	28.57	0.00	3.57	0.00	10.71	42.86	3.57	24.98	7.14	7.14	0.00
S5	4.35	0.00	13.04	8.70	8.70	0.00	0.00	65.22	13.04	17.39	4.35	17.39	13.04
S7	0.00	0.00	20.00	26.67	0.00	0.00	0.00	53.33	13.33	33.33	0.00	0.00	6.67
S8A	0.00	10.00	15.00	10.00	15.00	0.00	10.00	40.00	10.00	15.00	0.00	15.00	0.00
S8C	0.00	12.00	16.00	16.00	12.00	4.00	4.00	36.00	12.00	8.00	0.00	12.00	4.00

Table 8-: General XRD table for all 7 samples

Table 8 shows the summary of XRD data of samples from 4 outcrops (XRD plot graphs can be found in Appendices 4). Sample from Locality 5 have the highest clay content followed by sample from Locality 7. Clay is important to the petroleum production as it retains and adsorb water, for base change capacity and lastly, for flocculation and deflocculating. (Baptist & Sweeney; Johnston, n.d.). The productivity of the oil and gas wells are dependent upon the location and amount of clay. Clay content are also associated with the low energy environment. The samples tested contains moderate to high amount of clay suggesting the depositional environment to be low energy, such as deep marine.

Quartz on the other hand, indicates the maturity of the outcrops. The higher the content of quartz, the rock is more mature. Sample from Locality 4 has the highest content of quartz (14.3 %) and the outcrop from Locality 7 and 8 have no quartz at all. This means Locality 4 is more mature as compared to other outcrops while Locality 7 and 8 is the least mature. As the maturity increases, the hydrocarbon potential of the rocks decreases. When the rocks is over-matured, it is no longer considered as having good reservoir potential.

4.2 Mapping

Mapping is an important aspect for this project. Several maps had been produced to further understand the study area.

4.2.1 Traverse Map

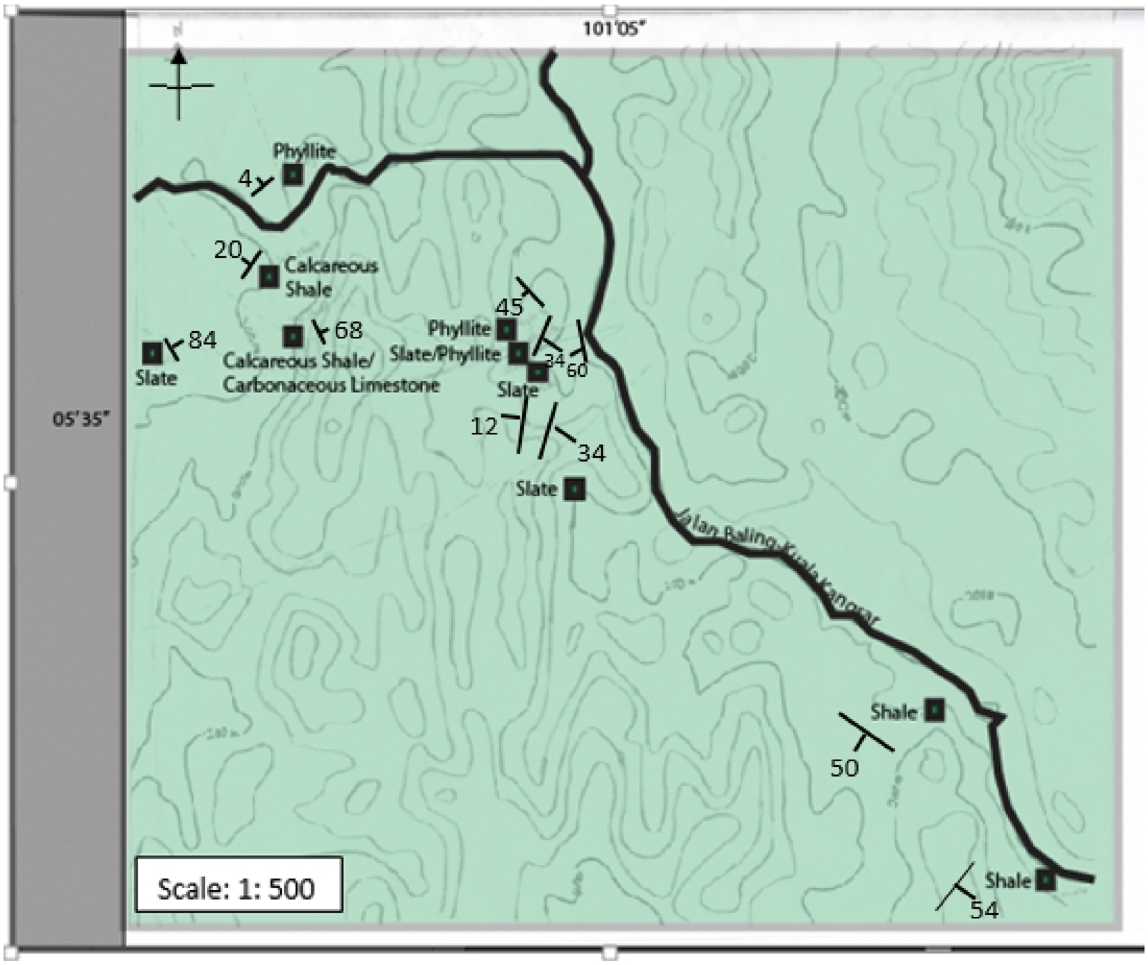


Figure 22: Traversing map with lithology for each Locality

The distance from Locality 1 to Locality 9 is estimated to be 12 kilometres. These outcrops were mainly seen along the side of the road from Gerik town to Kampung Pahit. The rocks observed are mostly metamorphic rocks, such as shale and phyllite (Refer Appendices 2).

4.2.2 Geological Map

Geological map is constructed based on the lithology, strike and dip. The outcome is as follows:

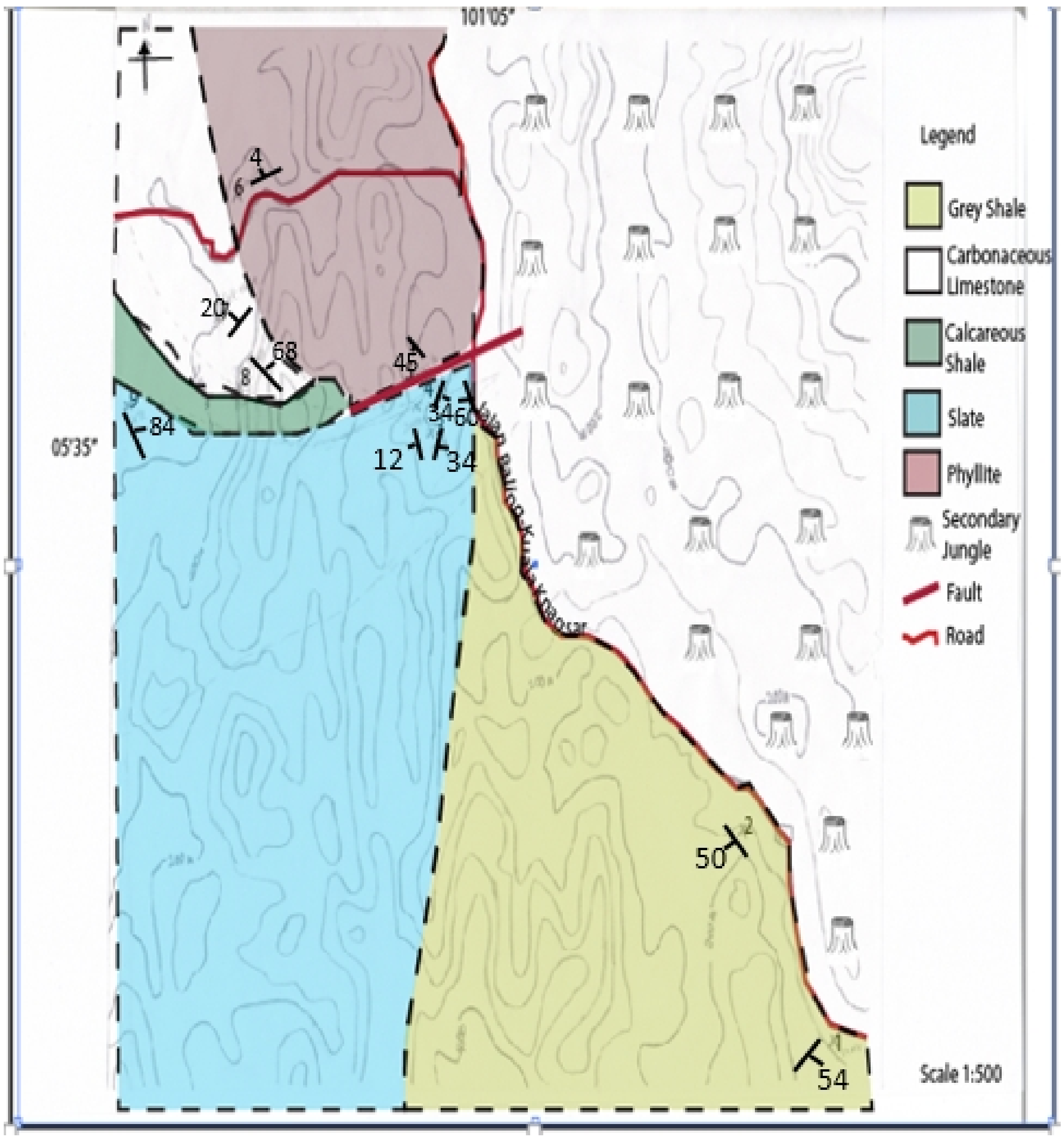


Figure 23: Proposed geological map

Grey shale and slate are the dominant lithology in this area. As phyllite tends to have a small amount of carbon (they appear dark), it is believed that some of the carbon leaked into the limestone nearby, forming carbonaceous limestone. There is a fault along the Locality 4-Locality 5 road, which separates the slate from the phyllite. As the other side of the highway is filled with vegetation, there are difficulties to search for the nearby lithology. Thus it is labelled as secondary jungle.

4.2.3 Topographic Profile/Map

Topographic profile or map is basically the cross section across a certain surface. For this project, a cross section is created from the geological map (refer 4.3.2). Refer to the map below, point A and B is marked across the geological section, passing through grey shale, slate, and phyllite.

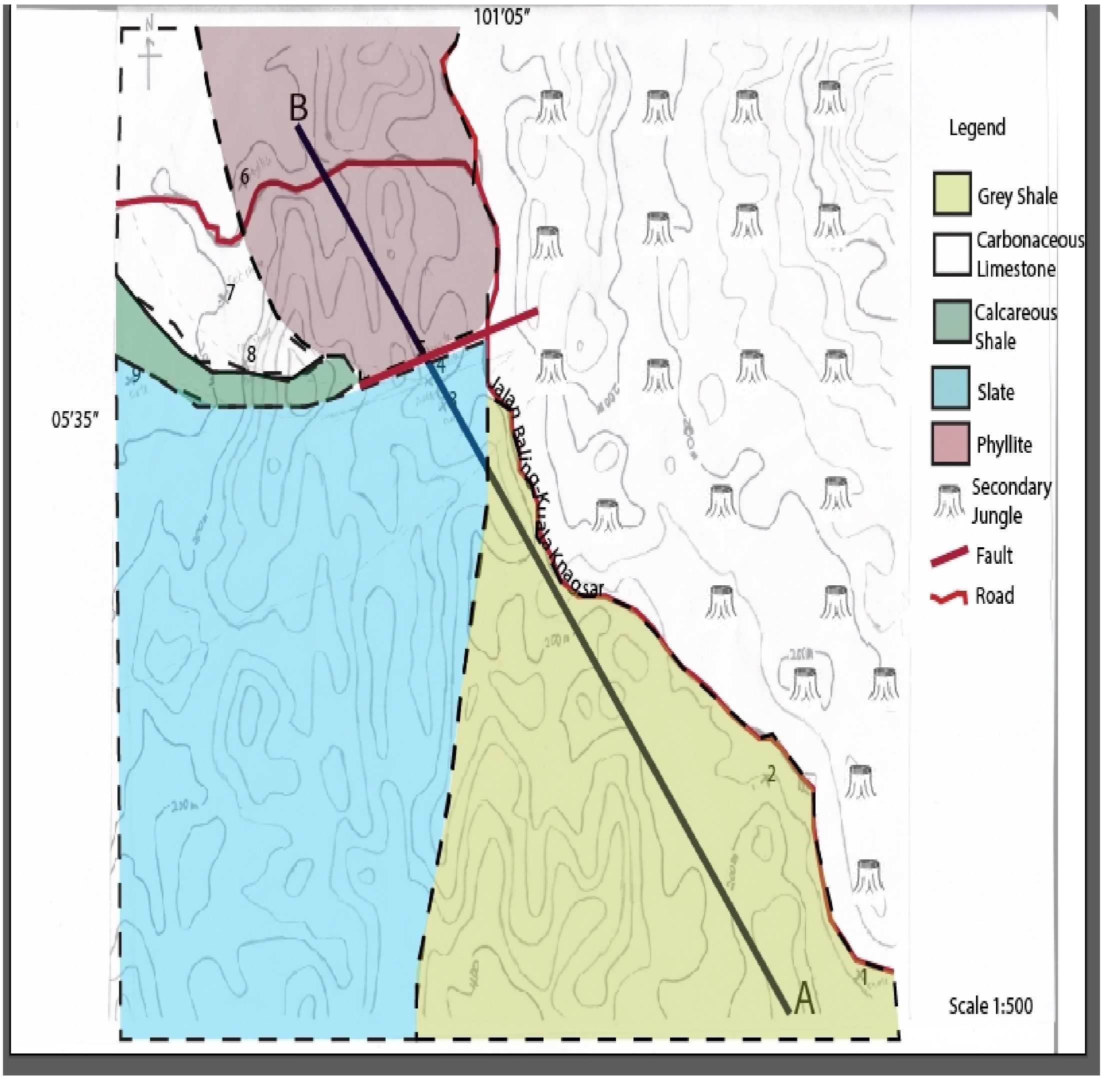


Figure 24: Cross section point A and Point B

The outcome from the analysis of the cross section from point A to Point B is as follows:-

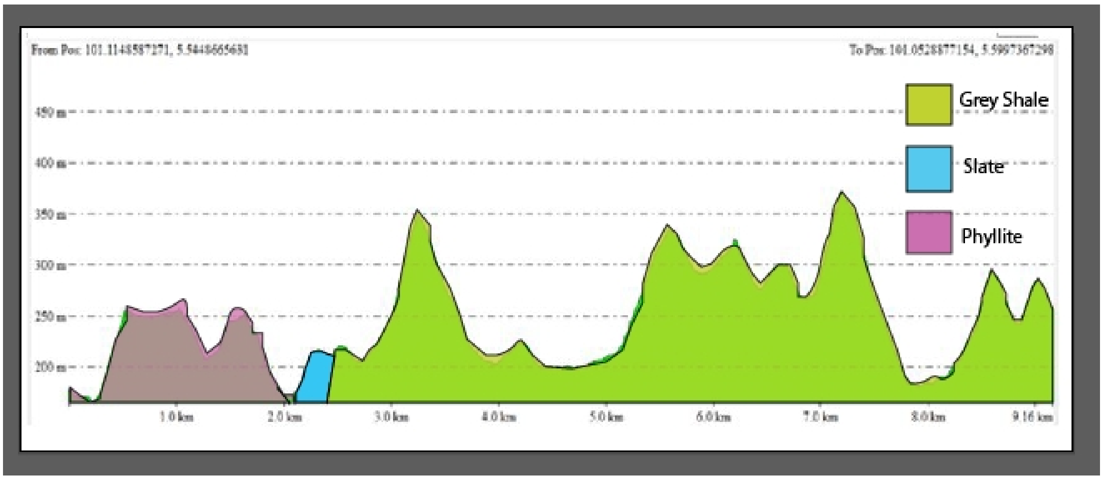


Figure 25: Topographic profile for Kampung Pahit

The highest elevation is 354m above sea level, which is nearby Locality 3, 4, and 5. As the outcrops in the study area are exposed since Lower Palaeozoic, some of the outcrops had undergone weathering that causes the top part to be eroded, creating different elevation profile along the road. The construction of the highway also played a role is causing the hills to be cut shorter.

4.3 Organic Carbon Content

Carbonaceous rocks collected from Locality #4, #5, #6, and Locality #8 were sent for Total Organic Carbon analysis in Block 16 to determine the organic carbon content present in the rocks.

There are two types of carbon in rocks, namely inorganic carbon and organic carbon. (Goodarzi, F. & Norford, B.S.,1987). Inorganic carbons are usually derived from mineral matter; combined with calcium and magnesium commonly found in carbonate rocks. If the parent rock is limestone or other carbonate rocks, the inorganic carbon content in the rock is higher. Organic carbon is distinguished from inorganic by its derivation from the source. Organic carbon is usually originated from biogenic matter. (Jarvie, 1991)

Sample preparations were standard, 90mg of grinded rock powder is weighted and place into the equipment. For the carbonaceous limestone found in Locality #8, the sample was first treated with 20ml of 10% concentration hydrochloric acid to remove inorganic carbon, illustrated by the formula below

$$\mathbf{CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O}$$

Hydrochloric acid will remove all the inorganic carbon (escaped as CO_2) and retain the organic carbon, $CaCl_2$. The limestone sample is then dried in over for 3 hours at 105 degree Celsius to remove access water and acid.

In sediments and rocks,

Total Carbon (TC) =Total Inorganic Carbon (TIC) + Total Organic Carbon (TOC)

TOC content can be measured by the difference if TC and TIC contents are measured. The equation above is true for all carbonate rocks. However for metamorphic rocks such as slate and phyllite, the amount of TIC is minimal and negligible, thus the equation becomes:

Total Carbon= Total Organic Carbon

The result of TOC is shown in table 7 below:

Sample	Weight(mg)	Total Carbon(%)	Total Organic Carbon (%)	Total Inorganic Carbon (%)	Source Rock Potential
S4R	90.100	3.380	3.380	-	Good
S4L	90.300	1.780	1.780	-	Good
S5	90.100	2.580	2.580	-	Good
S6	90.200	0.699	0.699	-	Good
S6I	90.000	0.861	0.861	-	Good
S8	90.100	16.000	3.510	12.490	Good

Table 9: TOC Results for 6 samples

Rock samples with TOC content more than 0.5% are considered a good source rock. The higher the TOC content, the better the hydrocarbon generating capability. The results, as shown in Table 7 above, suggests that all the rock analysed have the potential from the table above, all the samples have the potential to become a source rock. Of all the 6 samples, samples from Locality 4, Locality 5 and Locality 8 recorded higher percentage of organic carbon, further analysis is needed for a better evaluation of the source rock potential. Vitrinite Reflectance can be used to determine whether if the carbon deposited is residual carbon. Rock eval pyrolysis can be used together with vitrinite reflectance to further verify the source rock potential.

The organic carbon content in the rock can also help in interpreting the environment of deposition as carbon is mostly form in anoxic condition. Carbon is formed in anoxic and deep marine environment. Rocks in Locality 4, 5 and 8 are interpreted to be deep marine, as their TOC content is high.

CHAPTER 5
STRUCTURAL GEOLOGY

5.1 Structural Geology

Kampung Pahit has a strong isoclinals folding and faulting. These folding and faulting induced the metamorphism of the sedimentary rocks and mudstones in the area.

5.2 Types of Fracture

There are 3 types of fractures found in the study area, namely faults, joints and folds.

5.2.1 Faults

A fault is a planar fracture or discontinuity in a rock, across which there had been displacement along the fracture as a result of the earth crust movement. Large faults are associated with the action of plate tectonic forces. Faults are seen in Locality 4 and along the area of Locality 5.

The fault in Locality 4 is a small fault measuring about 5m in length. The folding might have cause the materials in the fault to be mylonitic. Large fault are seen along the area of Locality 5 where the fault are regional. The large fault actually initiated the metamorphism process, causing part of the outcrop to metamorphose into slate.

Figure 25a: Fault along Locality 4 to Locality 5

5.2.2 Joints

Joints are planes of separation which no shear displacement had taken place. Joints may formed from the regional tectonics, folding, faulting or internal stress release during uplift or cooling. Perpendicular and conjugate joints is a prominent feature in Kampung Pahit area.

A B

Figure 26: (A) Quartz joints in Locality 6 (B) Calcite Joints in Locality 7

In Locality 6, perpendicular joints are abundant. The joints had been filled with quartz. Calcite joints are common in Locality 7 and Locality 8 as well, on the surface of the calcareous shale.

5.2.3 Fold

Fold occurs when one or a stack of flat planar surfaces are bent or curved as a results of deformation, caused from the application of stress towards the rock. Incline folding are quite distinct in this study area.

Figure 27: Fold in Locality 4

Figure 21 shows the massive folding (in black circle) in Locality 4. This folding is considered as of regional scale. The joints found in the study area probably are initiated from this folding.

5.2.4 Slump

Slump happens when the sediments layer failed and collapse as it is not able to retain it shape due to heavy sediment loading from above. It can be initiated from the folding and faulting of the rock layer. Slope failure is found in Locality 5. The slump is mostly of phyllite-graphite content.

Figure 28: Slope Failure in Locality 5 (as circled)

5.3 Fracture Analysis

These fracture data (Refer Appendices 3) are analysed using Rose Diagram to identify principal stresses. The rose diagram was plotted from all the strike data of the joints and fractures of the outcrop in the incursion. The rose diagram might be a little rendered from the actual fracture system of the study area. Sigma 1 is the maximum stress that is 30 degrees from most prominent strike while sigma 3 is the minimum stress which is 90 degrees from sigma 1. In between these two sigmas are the shears S1 and S2.

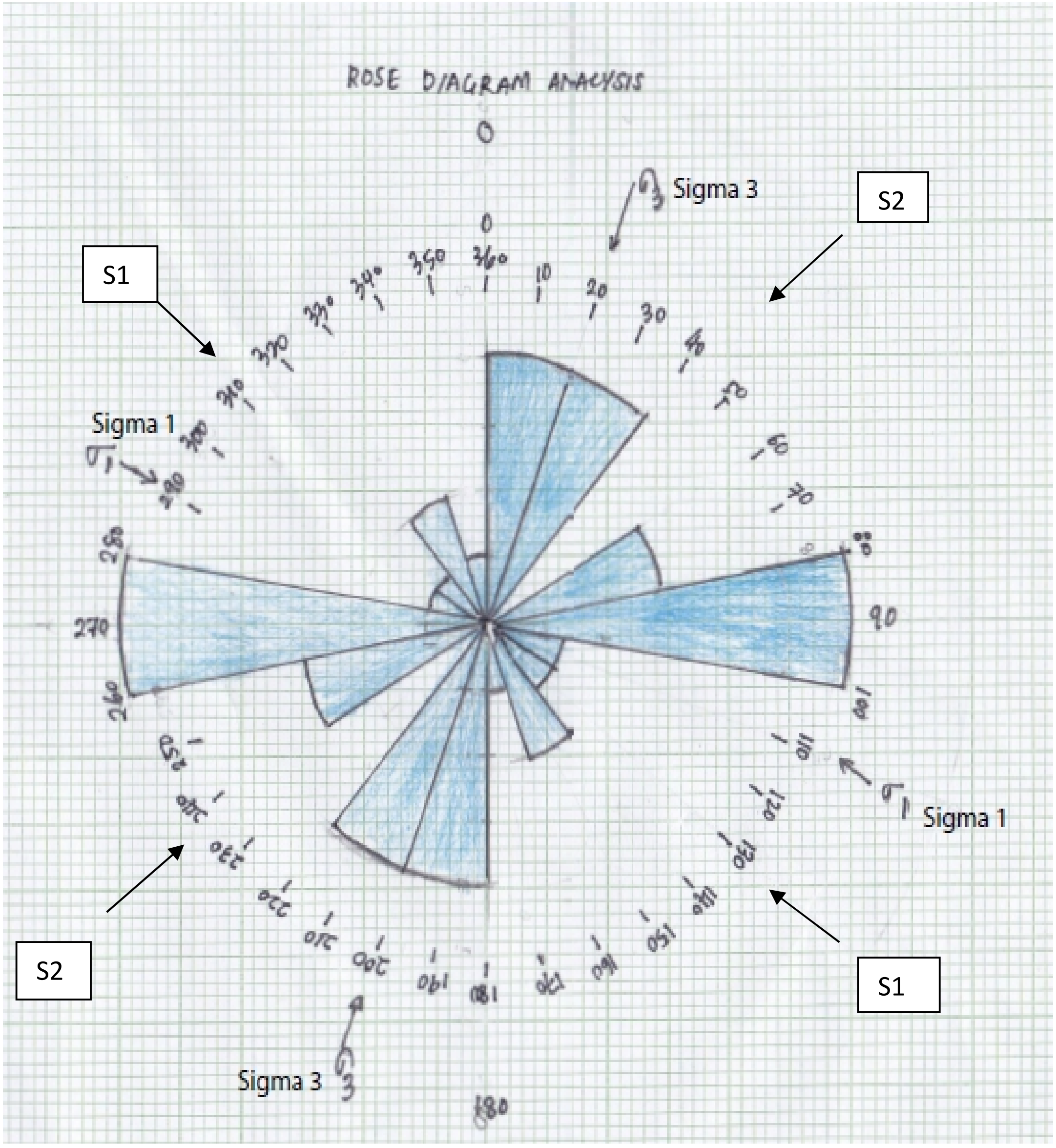


Figure 29: Rose Diagram for Stress and Shear Analysis

The principal stress Sigma 1 is at 110 degrees, and Sigma 3 is at 20 degrees. Majority of the fractures has the strike reading in the range of 80 to 100 degrees, which is approximately comfort to the S1 and S2 shear.

CHAPTER 6
FOSSILS AND AGE OF THE STUDY AREA

6.1 Fossils

According to Jones (1968, 1970), several species of graptolites and other fossils had been found in Kampung Pahit. The Thai-Malaysia Working Group (2009) found Monograptus sp. and Spirogratus sp. in the argillite near Kampung Pahit. Similarly, Jones (1973a,b, as cited in Lee, 2009) found graptolites belonging to Linnaei, Minor, Crispus, Griestoniensis, Spiralis and Grandis zone between Gerik and Pengkalan Hulu. The Thai-Malaysia Working Group (2009) mentioned that there is a fossilifereous mudstone/shale formation where fossils had been found.

There is only 1 (one) graptolite found in the study area, near the phyllite block of Locality 6. The species of graptolite found is *Spirograptus* sp. The fossil found is only fragment instead of a complete fossil. Rootmarks are found as well in Locality 6.

Figure 29a: Graptolite (arrow) and root-marks found in study area.

The analysis of the *Spirograptus* sp are as follow:

Kingdom	Animalia
Phylum	Hemichordata
Class	Graptolithina
Order	Graptoloidea
Family	Monograptidae
Genus	Spirograptus

Table 10: Details of *Spirograptus* sp.

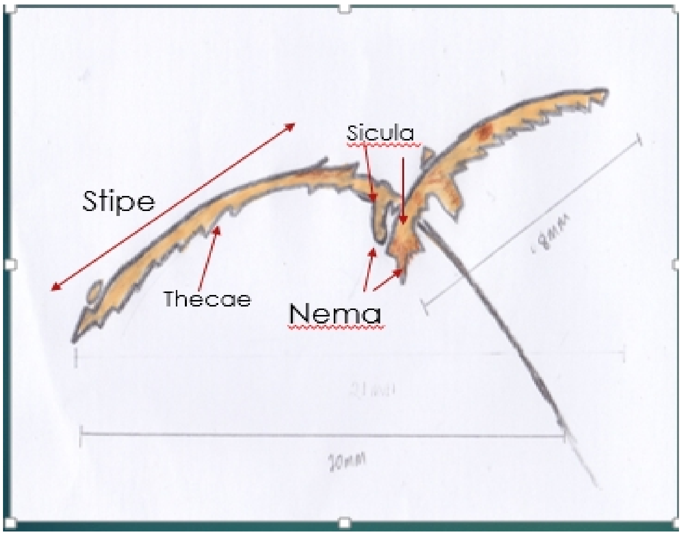


Figure 29b: Detailed Drawings of *Spirograptus,* sp.

Figure 29b shows the detailed drawing of the graptolite found on the rock. Overall, it is about 21 millimetres in total length, and the parts such as stipe, thecae, nema and sicula are clearly seen. It is a fossil from early Silurian and it extinct in the Devonian. Spirograptus sp is commonly found in pelagic zone.

6.2 Age of the Study Area

Based on the fossil found by the previous writer, the age of the rocks in the study area is Lower Palaeozoic, specifically Late Ordovician to Early Silurian. The present study failed to find any fossils in the Kampung Pahit area. In the year 1993, Mohd Badzran et al discovered *Monograptus* sp. and *Spirograptus* sp.in the argillite near Kampung Pahit. Besides graptolites, brachiopods, trilobites and bryzoan are found in the study area. Styliolina sp. discovered at southeast of Kampung Pahit to be Lower Palaeozoic.

Referring to the graptolite found near Locality 6, the age of the study area is estimated to be Early Silurian. This coincides with the discoveries of graptolites made by Jones (1970) in between Gerik and Pengkalan Hulu which also confirms the age of the study area to be Early Silurian.

It is recommended that more fossil searching around the area to be done around the area where the graptolite is found to further verify the age of the whole study area.

CHAPTER 7

DEPOSITIONAL ENVIRONMENT

Based on the field data, low grade metamorphic rocks common in the study area. The presence of shale, slate and phyllite with muddy to silt grain size indicates the calm depositional environment where all the sediments are allowed to deposit without interruptions. The fine-grained limestone in Locality 8 also support the idea. This supports the literature prepared by The Thai-Malaysia Working Group (2009). The muddy and fine-grained materials also supports the idea that the deposition took place in a quiet and undisturbed environment. The materials are fine-grained, and fine-grained materials indicate long distance transportation.

Along the outcrop from Locality 3 to Locality 5, the grain size shows a coarsening upwards pattern. The coarse sediments might be transported from the erosion of sediments from the continental shelf. This observation suggests that the depositional setting to be deep marine environment and the depositional environment to be slope apron. In the energy sector, slope apron commonly form stratigraphic traps and they form deep-marine reservoirs. Slope apron occur near the base of the slope. The depositional environment along Locality 3 to Locality 5 is interpreted to be continental slope. The presence of slump near Locality 5 also support this interpretation. The coarse grains are transported from the continental crust to the slope, going down to deep marine.

The Thai-Malaysia Working Group (2009) depicts that with the considerable amount of carbonaceous content in the widely spread argillaceous facies, the depositional environment is estimated to be euxinic marine environment. The TOC content in the samples tested coincides with the literature and the deposition setting is set to be in deep marine.

The calcareous materials in Locality 7 and 8 indicate that the depositional environment around the continental shelf area, perhaps the slope apron. This finding also coincides with the studies done by The Thai-Malaysia Working Group (2009). Besides the lithology and grain size, the fossil evidence can provide a hint on the depositional environment as well. The discovery of Spirograptus sp. shows that the depositional environment to be deep marine.

The overall depositional environment suggested are base of continental slope to deep marine area (as shown in figure 31, circle in red). Locality 7 and 8 (calcareous shale) will be at the shallower part, at the shelf area and the metamorphic rocks are located at the deep marine region. The fine sediments are transported from the shelf to the deep marine, thus some fine sediments can be found near Locality 4 and 5.

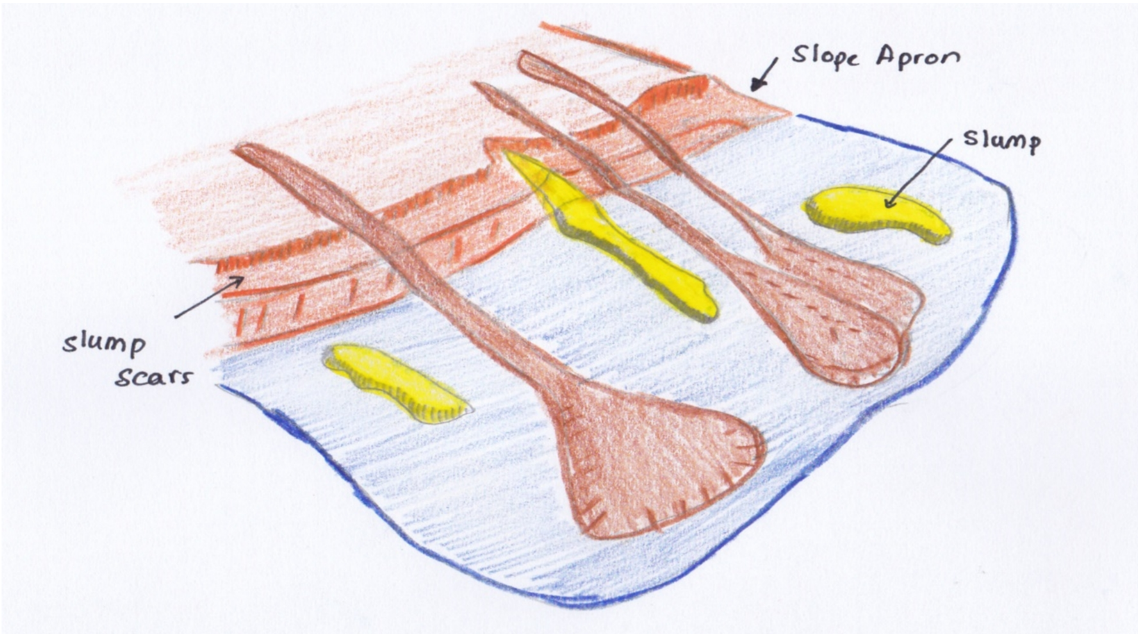


Figure 30: Proposed EOD model

CHAPTER 8
CONCLUSION AND RECOMMENDATION

8.1 Conclusion

The presence of inclinal folding and small joints in the rocks suggest that the study area had underwent regional metamorphism. Low grade metamorphic rocks such as shale, slate and phyllite is common in this area. Limestone is found as well. The lithology found in Kampung Pahit indicated the depositional environment to be continental shelf to deep marine setting.

The organic carbon content supports the interpretation of depositional environment. Besides this, the study area has good hydrocarbon reservoir potential as all the samples recorded significant amount of organic carbon content.

The discovery of *Spirograptu*s sp suggest that the age of the study area to be Early Silurian and support the estimation that the depositional environment to be deep marine setting.

8.2 Recommendation

- Further studies on the structural geology of the study area is recommended as the area is highly foliated and folded
- Further analysis on the age of the study area using more fossil evidences

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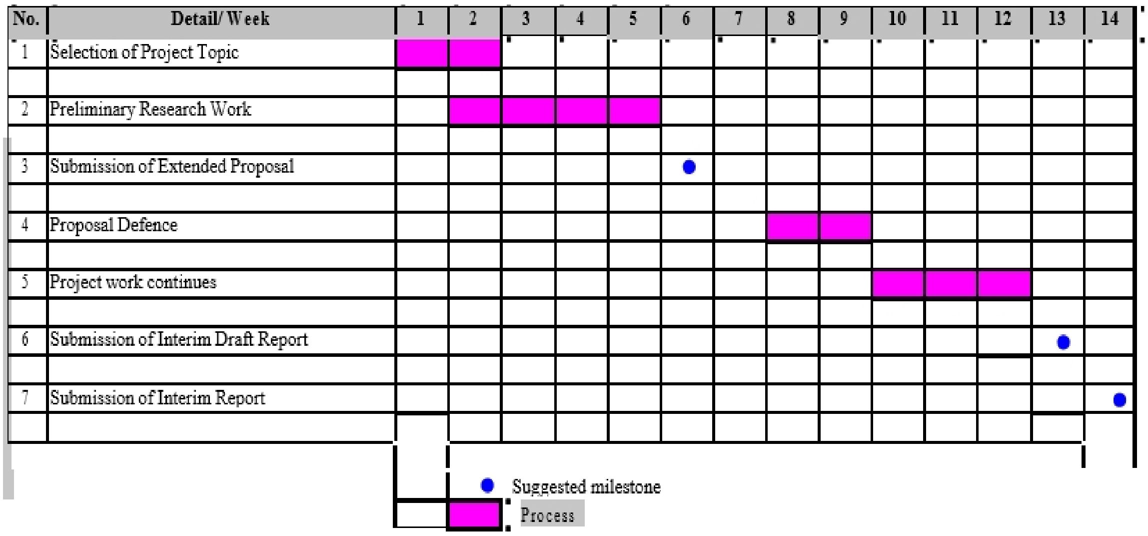
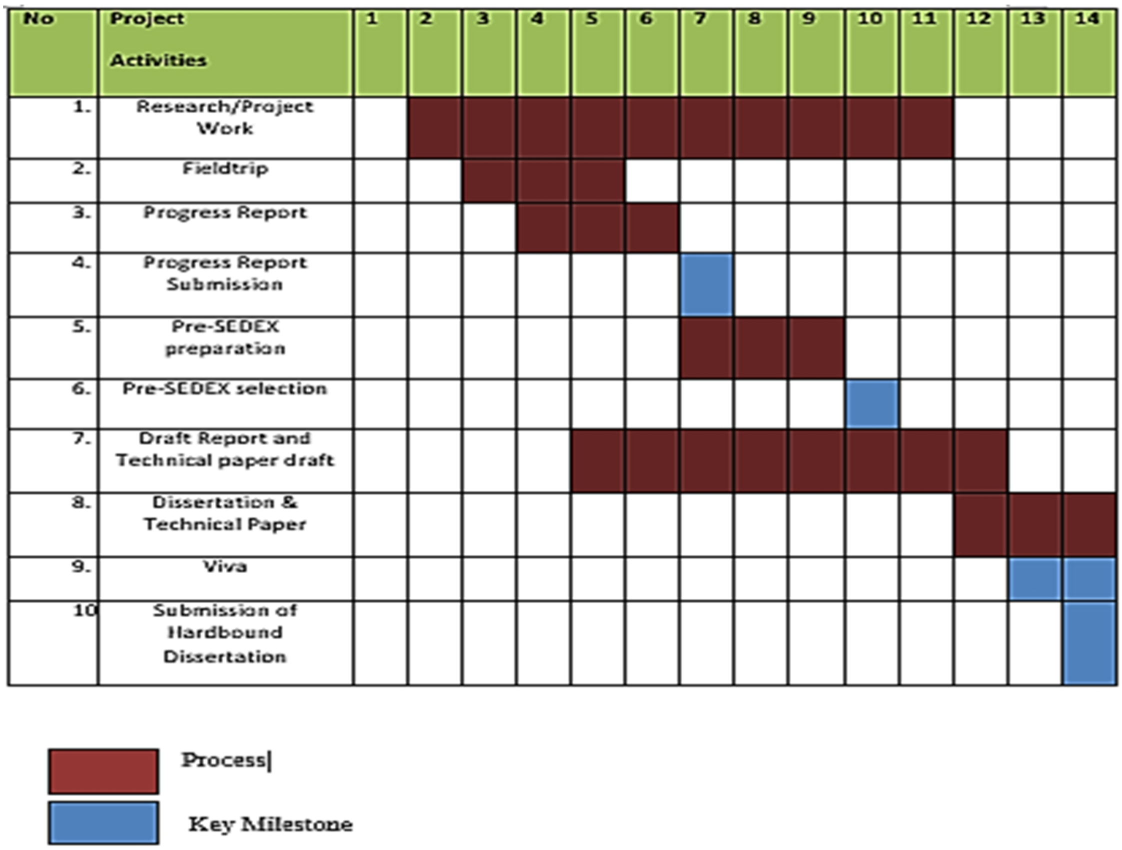
Appendices 1: Gantt chart

For FYP 1



For FYP 2



Appendices 2: Field Record

Fieldtrip to Kampung Pahit area had been conducted on 6th to 9th March, 2014 to collect relevant rock samples and field measurements. The following table summarized the field observations:-

#	GPS Coordinate	Observations
1	347000 614863	Left side weathered, Right side partially weathered Weathered shale/ slate becoming pre-phyllite white/grey/red conjugate, perpendicular joints Deep Marine Fine Grained
2	346062 616159	Heavily weathered sandstone/slaty sandstone black/brown conjugate joints transitional area- upper part partially oxidised possible shale/sandstone contact
3	343445 618468	slate grey/orange angular uncomformity conjugate joints
4	343350 618624	phyllite/slate/graphite/mylonite black/brown/black inclinal folding/slope failure/slump Dynamic metamorphism faults
5	343246 618700	Black/Carbonacroues Phyllite/Graphite Slump/Inclinal Folding/slope failure Dymanic correlation Part of formation connected from Locality#4
6	341544 619962	Phyllite/Slate perpendicular joints grey/black/brown/red quartz joint root mark poorly carbonaceous
7	341539 619650	Impure Limestone/Clayish Limestone greyish calcite infill
8	341405 619155	argillaceous limestone/carbonaceous limestone calcite infill in joints

		greyish/redish/black contact between grey and black limestone Limestone becoming marble
9	341241 618541	joints Slate/pre-slate greyish/yellowish colour brittle/slatty

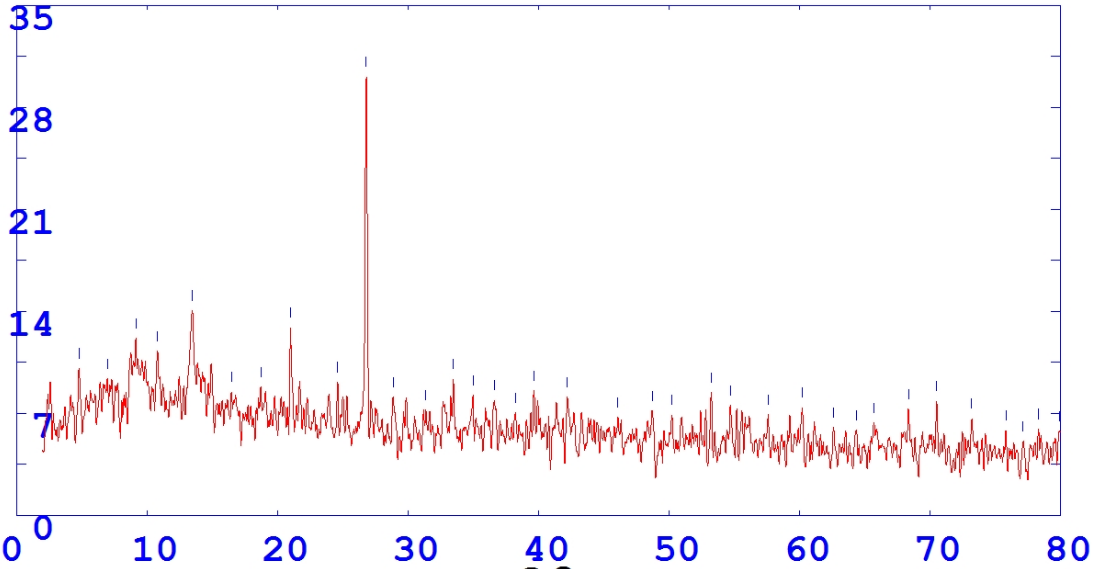
Appendices 3: Fracture Raw Data

The table below summarize the raw data for bedding and fracture measurements from the field:

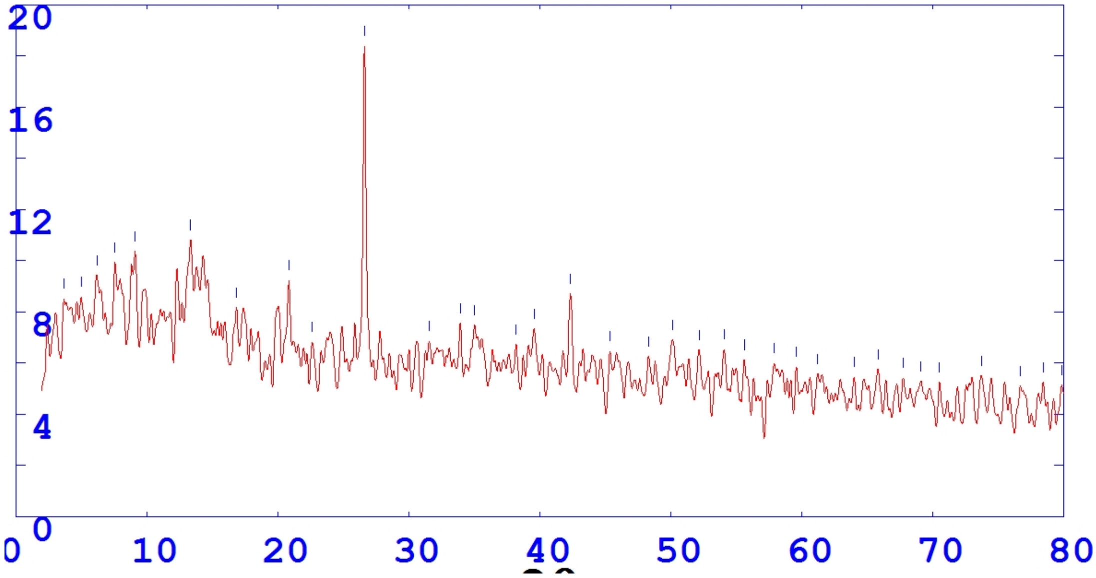
#	Bedding	Fracture Reading
1	B1: 072/54 B2: 058/50 B3: 085/27 B4: 266/86	CJ1: 282/84 CJ2: 338/64 PJ1: 014/14 PJ2: 078/78
2	B5: 140/050	CJ3:030/038 CJ4: 032/24
3	B6: 016/12 B7: 024/34	CJ5:020/20 CJ6: 034/33
4	B8:005/034 B9: 330/60	Fault1: 010/10 Fault2: 009/9
5	B10: 125/45	-
6	B11: 004/4	PJ3: 092/2 PJ4: 254/78 PJ5: 265/70 PJ6: 180/075 PJ7: 275/063
7	B12: 010/20	J1: 330/60
8	B13: 344/068	J2: 264/082 J3: 023/20 J4: 070/54
9	B14: 352/084	J5: 268/006 J6: 290/024

Note:
B : Bedding
J : Joints
PJ: Perpendicular joints
CJ: Conjugate Joints

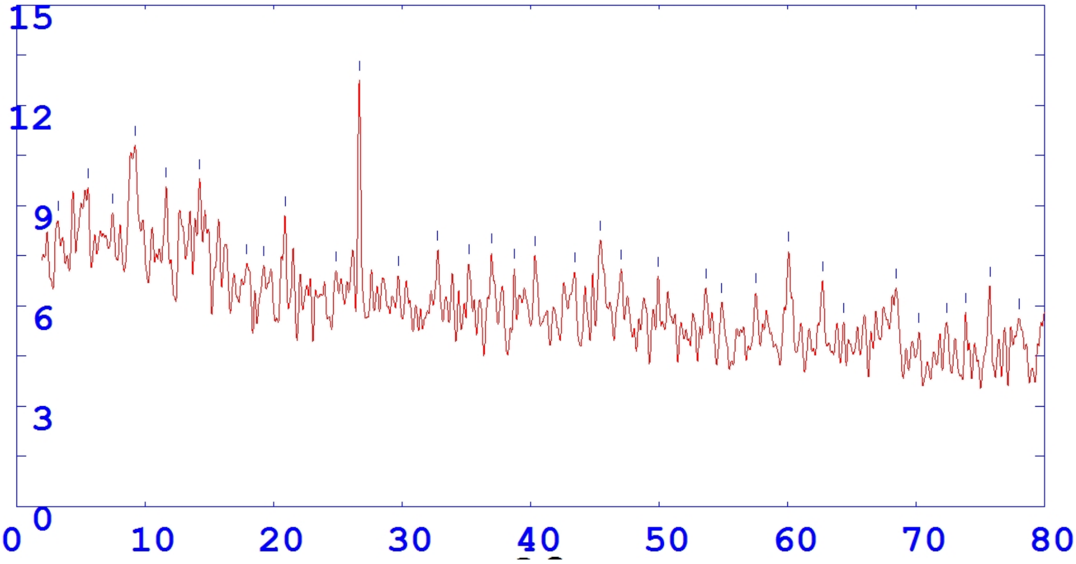
Appendices 4: XRD data



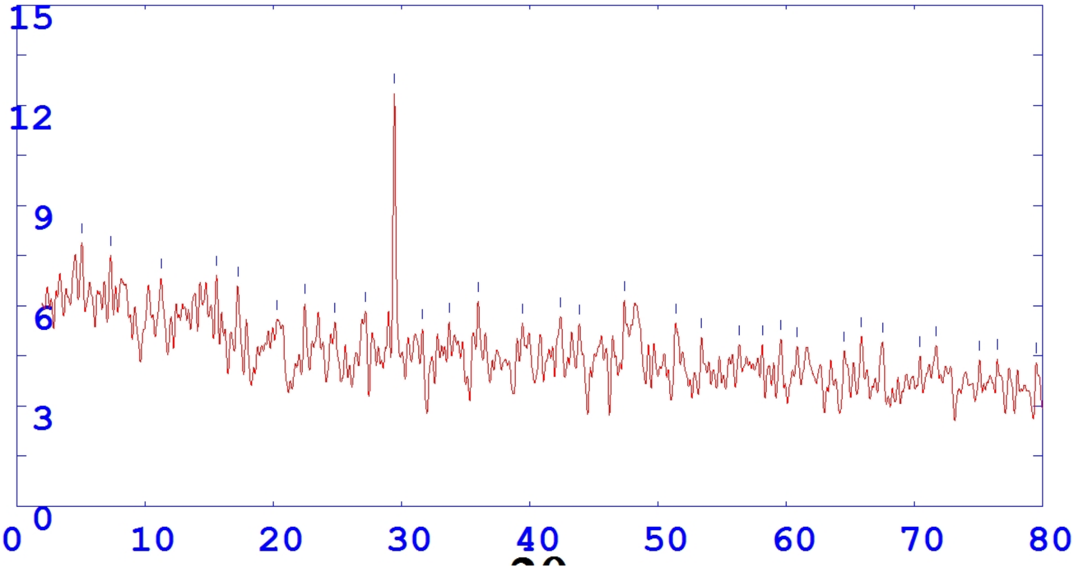
XRD graph for S4L



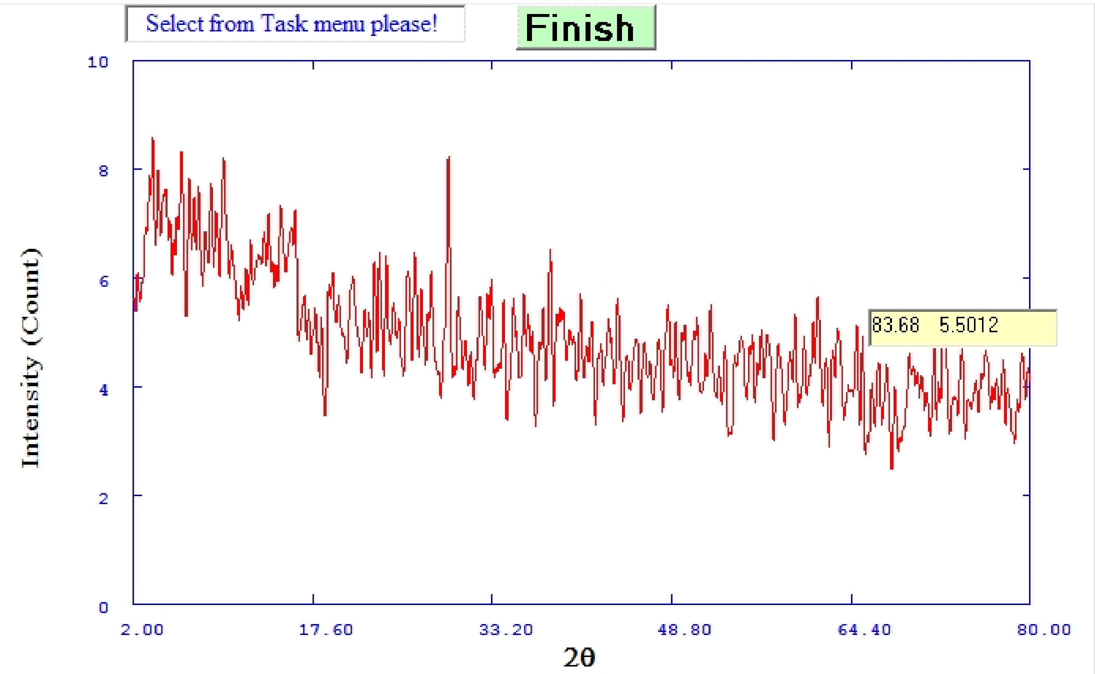
XRD data for S4R



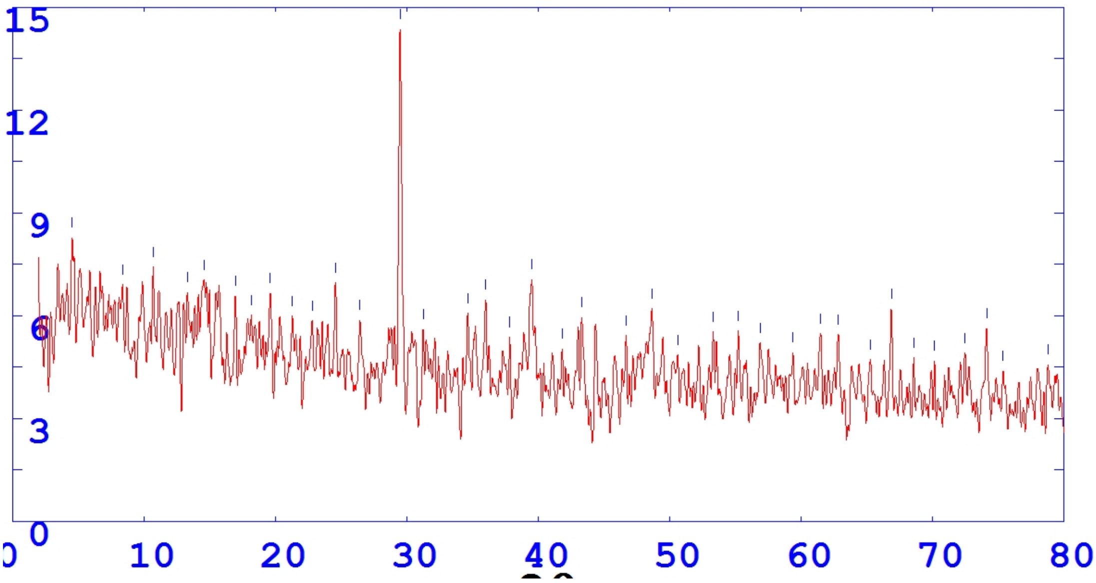
XRD data for S5



XRD data for S7

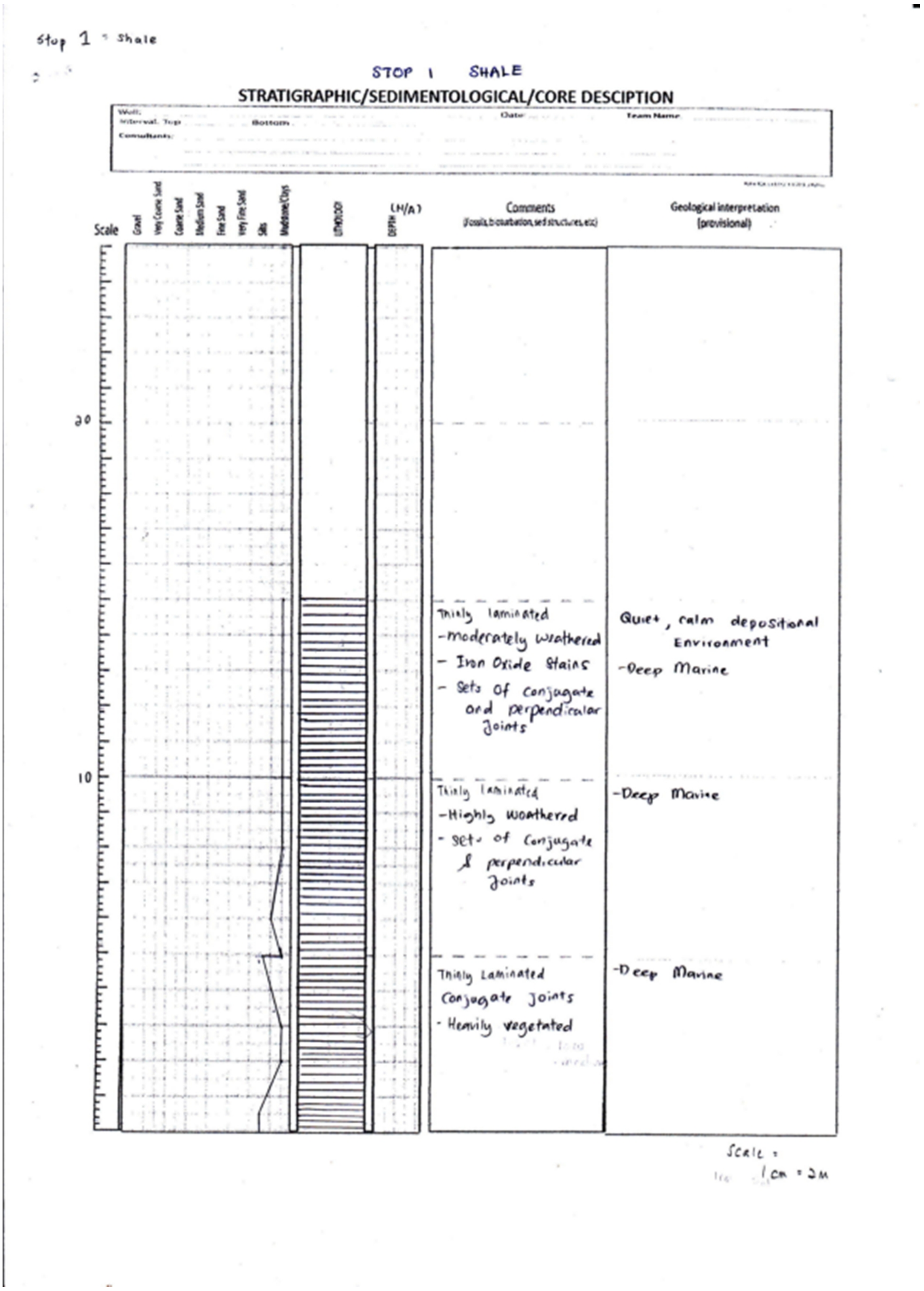


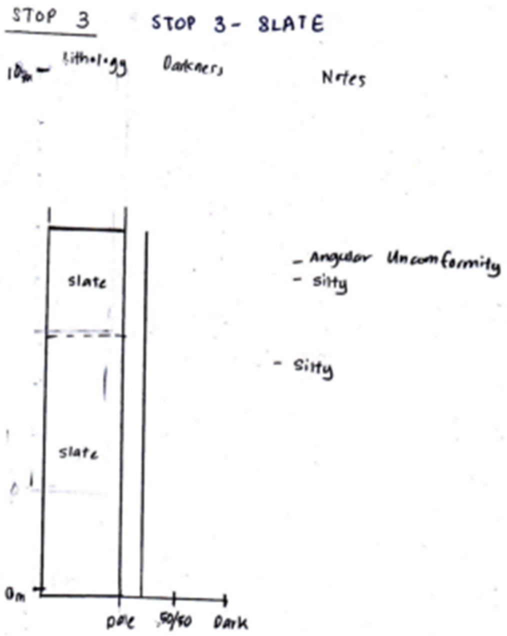
XRD data for S8A

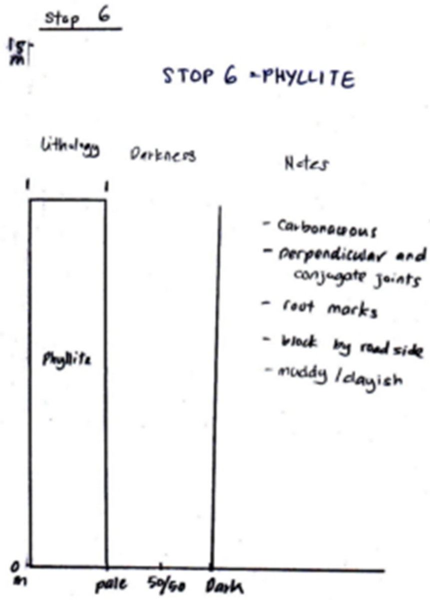


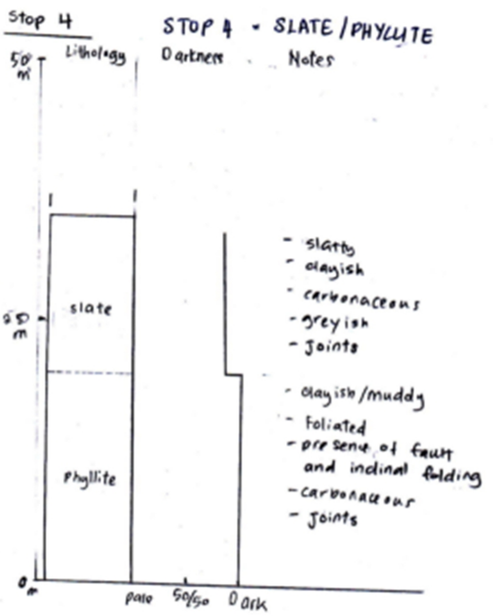
XRD data for S8C

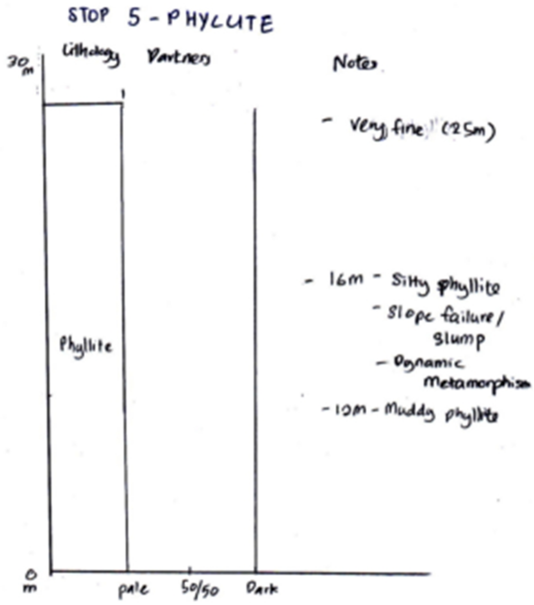
Appendices 5: Sedimentary Logs




STOP 3
STOP 3 - SLATE
10m
Lithology
Darkness
Notes
slate
slate
- Angular Unconformity
- silty
- Silty
0m
pale
50/50
Dark


Stop 6
15m
STOP 6 - PHYLLITE
Lithology
Darkness
Notes
Phyllite
- Carbonaceous
- perpendicular and conjugate joints
- root marks
- block by road side
- muddy / clayish
0m
pale
50/50
Dark


Stop 4
STOP 4 - SLATE / PHYLLITE
50m
Lithology
Darkness
Notes
slate
phyllite
- slatty
- clayish
- carbonaceous
- greyish
- Joints
- clayish / muddy
- Foliated
- presence of fault and inclinal folding
- carbonaceous
- Joints
0m
pale
50/50
Dark

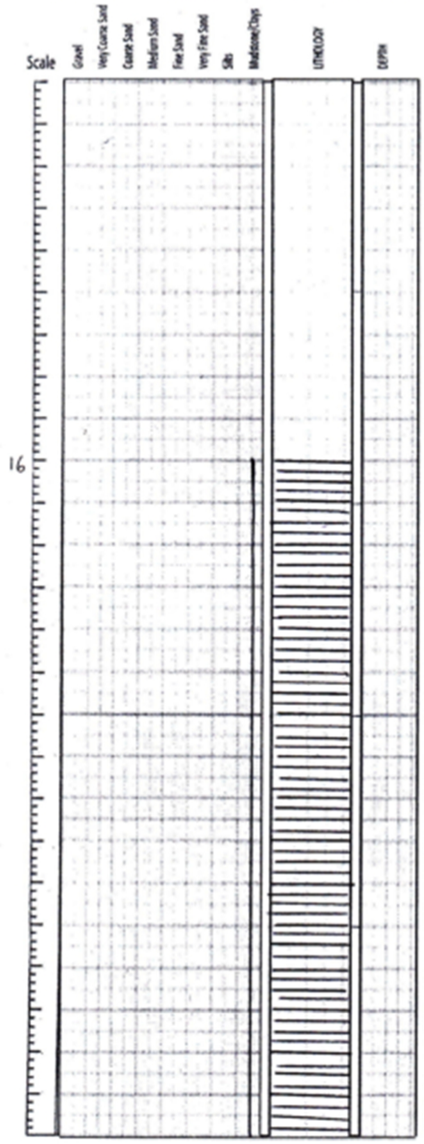

STOP 5 - PHYLLITE
30m
Lithology
Darkness
Notes
Phyllite
- very fine (25m)
- 16m - Silty phyllite
- Slope failure / slump
- Dynamic Metamorphism
- 10m - Muddy phyllite
0m
pale
50/50
Dark

Stop 7

STOP 7 : CALCAREOUS SHALE

STRATIGRAPHIC/SEDIMENTOLOGICAL/CORE DESCIPTION

Well: Date: Team Name:
Interval: Top Bottom
Consultants:



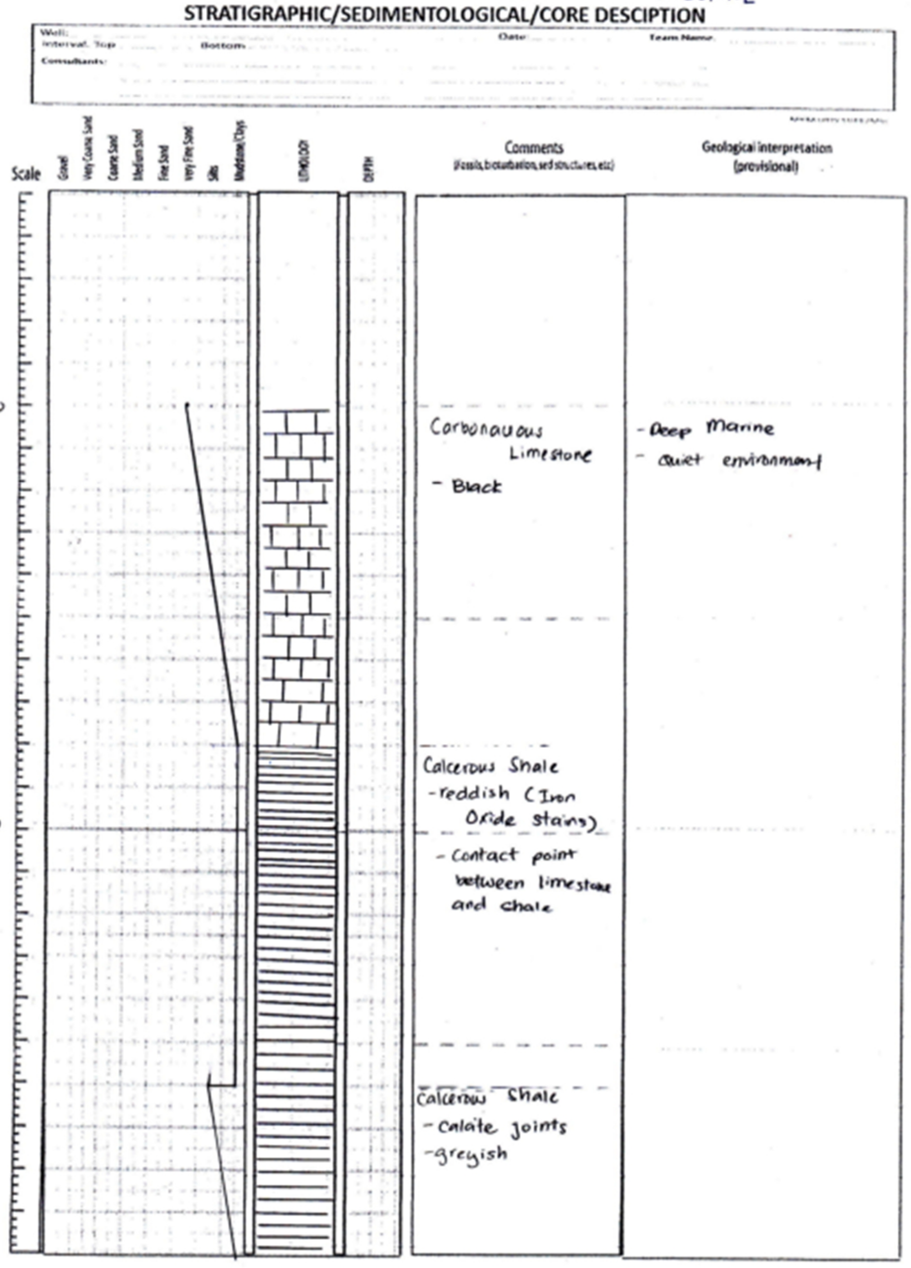
Comments (Fossils, bioturbation, sed structures, etc)	Geological interpretation (provisional)
Calcarous shale	- Deep Marine
- slatty cleavage - Grey in colour - reacts to acid - Joints (Calcite filled) - Calcareous Shale	- Deep Marine - Quiet, Calm environment
- Slatty cleavage - Grey in Colour - reacts to acid - Calcite joints - Calcareous Shale	- Deep marine - Quiet, calm environment
- Slatty cleavage - Grey in Colour - reacts to acid - Calcite Joints - Calcareous Shale	- Deep Marine - Quiet, calm environment.

1cm = 1m

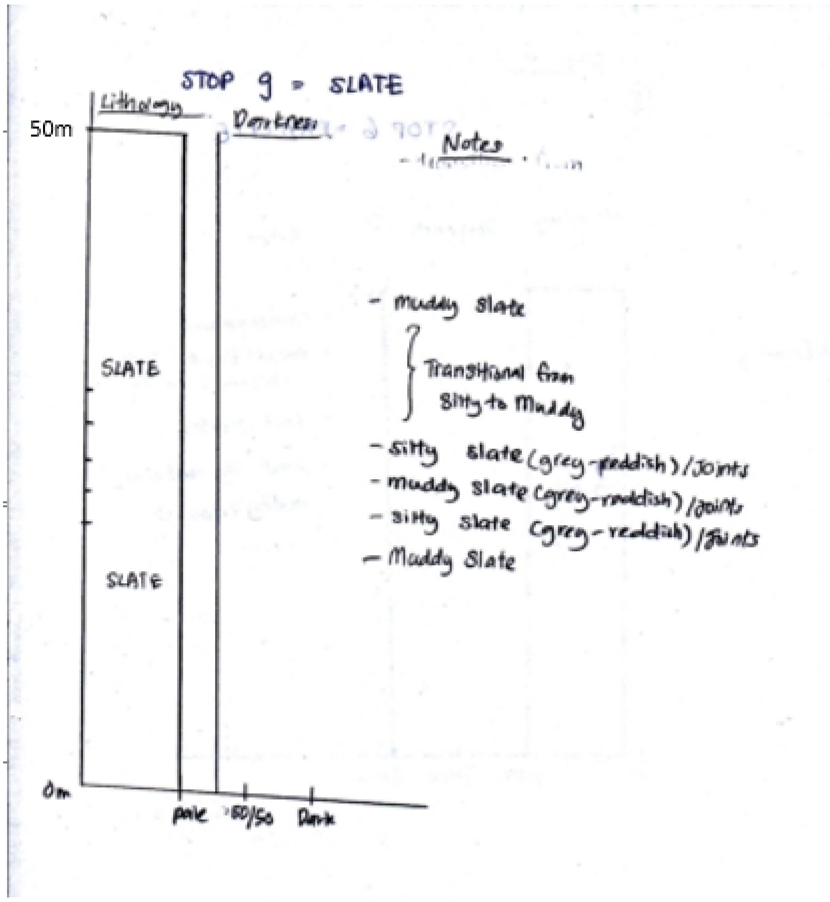
Stop 8

Stop 8 : CALCAREOUS SHALE / CARBONACEOUS LIMESTONE

STRATIGRAPHIC/SEDIMENTOLOGICAL/CORE DESCIPTION



1cm = 1m



STOP 9 = SLATE
Lithology
Darkness
Notes
50m
SLATE
SLATE
0m
pale
50/50
Dark
- Muddy slate
Transitional from Silty to Muddy
- silty slate (grey-reddish)/Joints
- muddy slate (grey-reddish)/joints
- silty slate (grey-reddish)/Joints
- Muddy Slate