



**GEOLOGY & LITHOSTRATIGRAPHY OF THE
PANAU BEDS, BUKIT PANAU, TANAH MERAH
KELANTAN**

by

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A report presented in accomplishment of the essential for the degree of Bachelor of
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2023

DECLARATION

I declare that this thesis entitled “**GEOLOGY & LITHOSTRATIGRAPHY OF THE PANAU BEDS, BUKIT PANAU, TANAH MERAH KELANTAN**” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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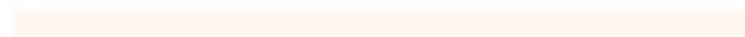
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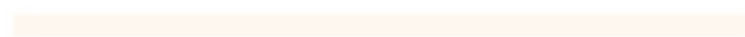
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GEOLOGY & LITHOSTRATIGRAPHY OF THE PANAU BEDS, BUKIT PANAU, TANAH MERAH KELANTAN

ABSTRACT

Geologists from local and overseas have studied Panau Hill, Tanah Merah in Malaysia due to unique geological phenomena, such as the isolated formation of Bukit Panau. This research focuses on conducting detail geological studies on Panau Bed exposed at Bukit Panau, Tanah Merah, Kelantan. The study area is located at the latitudes of 05°49'21.25" N to 05°54'11.25" N and longitudes from 102°8'48.75" E to 102°11'11.25" E. The primary goal of this research is to update a geological map of the Bukit Panau area, to determine the stratigraphic correlation between the Panau Beds and Granite in the Bukit Panau and to conduct lithofacies analysis the Panau Beds. The methodology used in this research included extensive geological mapping such as traversing, structural geology, geomorphology, rock sampling and laboratory analyses. As a result, that have been taken, Bukit Panau area is geomorphologically consists of 234 m high single hill that surrounded by a large plain area. The Erosion and weathering are the main exogenous geomorphological processes in the region while minor endogenous process such as intrusion and faulting. The lithological consisting of Granite, sandstone beds, and alluvium which is belong to Panau Bed that geologically from the Jurassic, Cretaceous and Quaternary period. The nonconformity has been observed between the granite and overlying sandstone at an abandoned Bukit Panau quarry at the slope of hill. Its shows that Bukit Panau bed is younger than Granite. The rock sampling has been taken which is total of 6 rock sample, 4 of rock is sandstone and 2 of rock is granite at the study area. These rocks go through the lab analysis which is petrography analysis that have been conducted and the results is all of sandstone rock is lithic-sub lithic sandstone rock and all igneous rock is granite. Lithofacies analysis shows that the outcrop at foothill that have been observed is interbedded sandstone and mudstone that have horizontal planar lamination that have been flood stage deposited and meandering channel sequence association. Based on observation, almost 70% of the study area is alluvium. The structural geological analysis conducted through stereo net analysis of joints, bedding, and lineament analysis. Joint analysis has been performed, and the results show that the study region has deformed in a direction of northwest to southeast with a force of 142°. Bedding analysis found that the directions of force are North East North and South West South. Lineament analysis have been conducted through ArcGIS and found that, the direction of the maximum force is N 305°W and minimum is 90° perpendicular to the maximum force which is the direction of the minimum is N 15 E. Overall of this research, The study also suggests that Bukit Panau's rock series was deposited in a meandering river and that its sandstones came from recycled orogens, where massive plates collided and increased source regions. It is recommended to investigate the connection between geological mapping and the capability to recognize the impact of weathering and erosion on the environment.

Keywords: Bukit Panau, Panau bed, nonconformity

GEOLOGI & LITOSTRATIGRAFI KATIL PANAU, BUKIT PANAU, TANAH MERAH KELANTAN

ABSTRAK

Ahli geologi dari dalam dan luar negara telah mengkaji Bukit Panau, Tanah Merah di Malaysia kerana fenomena geologi yang unik, seperti pembentukan terpencil Bukit Panau. Penyelidikan ini tertumpu kepada menjalankan kajian geologi terperinci mengenai Katil Panau yang terdedah di Bukit Panau, Tanah Merah, Kelantan. Kawasan kajian terletak pada latitud $05^{\circ}49'21.25''$ N hingga $05^{\circ}54'11.25''$ N dan longitud dari $102^{\circ}8'48.75''$ E hingga $102^{\circ}11'11.25''$ E. Matlamat utama penyelidikan ini adalah untuk mengemaskini peta geologi kawasan Bukit Panau, untuk menentukan korelasi stratigrafi antara Katil Panau dan Granit di Bukit Panau dan untuk menjalankan analisis lithofacies Katil Panau. Metodologi yang digunakan dalam penyelidikan ini termasuk pemetaan geologi yang meluas seperti traversing, geologi struktur, geomorfologi, persampelan batuan dan analisis makmal. Hasilnya, yang telah diambil, kawasan Bukit Panau secara geomorfologi terdiri daripada bukit tunggal setinggi 234 m yang dikelilingi oleh kawasan dataran yang luas. Hakisan dan luluhawa merupakan proses geomorfologi eksogen utama di rantau ini manakala proses endogen kecil seperti pencerobohan dan sesar. Litologi yang terdiri daripada Granit, batu pasir, dan aluvium yang tergolong dalam Katil Panau secara geologi dari zaman Jurassic, Cretaceous dan Quaternary. Ketidakkuratan telah diperhatikan antara granit dan batu pasir atas di kuari Bukit Panau terbiar di lereng bukit. Ia menunjukkan katil Bukit Panau lebih muda daripada Granit. Persampelan batuan telah diambil iaitu sebanyak 6 sampel batuan, 4 batuan adalah batu pasir dan 2 batuan adalah granit di kawasan kajian. Batuan ini melalui analisis makmal iaitu analisis petrografi yang telah dijalankan dan hasilnya kesemua batuan batu pasir adalah batuan batu pasir litik-sub litik dan semua batuan igneus adalah granit. Analisis lithofacies menunjukkan singkapan di kaki bukit yang telah diperhatikan ialah batu pasir berselang dan batu lumpur yang mempunyai laminasi satah mendatar yang telah dimendapkan peringkat banjir dan perkaitan jujukan saluran berliku. Berdasarkan pemerhatian, hampir 70% daripada kawasan kajian adalah aluvium. Analisis geologi struktur dijalankan melalui analisis rangkaian stereo bagi sambungan, tempat tidur, dan analisis lineamen. Analisis bersama telah dilakukan, dan keputusan menunjukkan bahawa kawasan kajian telah berubah bentuk ke arah barat laut ke tenggara dengan daya 142° . Analisis tempat tidur mendapati bahawa arah daya adalah Timur Laut Utara dan Barat Daya Selatan. Analisis lineament telah dijalankan melalui ArcGIS dan mendapati bahawa, arah daya maksimum ialah $N 305^{\circ}W$ dan minimum ialah 90° berserenjang dengan daya maksimum iaitu arah minimum ialah $N 15^{\circ}E$. Secara keseluruhan kajian ini, The kajian juga mencadangkan bahawa siri batuan Bukit Panau telah dimendapkan dalam sungai yang berliku-liku dan batu pasirnya berasal daripada orogen kitar semula, di mana plat besar berlanggar dan meningkatkan kawasan sumber. Adalah disyorkan untuk menyiasat hubungan antara pemetaan geologi dan keupayaan untuk mengenali kesan luluhawa dan hakisan terhadap alam sekitar.

Kata kunci: Bukit Panau, katil Panau, ketidakkuratan

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Panau Hill, Tanah Merah has been a focal point for geologists from overseas and local, when scientists from both countries undertook a geological study of the two countries' borders because of unique and remarkable geological phenomena such as only the isolated formation on Bukit Panau and named from it. The latest previous researcher has been taken by Adilla Syakirah (2017) that updating the geological information on Bukit Panau area such as lithological rocks and sedimentary structure of that area. But all these of previously studies does not emphasize the lithostratigraphy research eventhough there have research about it but the information is little or nonexistent. There have been an example of lithostratigraphy study have been made in Malaysia such as The stratigraphy of northern Labuan, NW Sabah Basin, East Malaysia (Mazlan Madon,1994).

1.2 Study area

This research is focusing on Panau Hill and its surrounding, which is located near the boundaries between Tanah Merah and Pasir Mas districts. The study area is located at the latitudes of 05°49'21.25" N to 05°54'11.25" N and longitudes from 102°8'48.75" E to 102°11'11.25" E. The research area covered an area of 5 x 5 km with a total area of 25km². Panau Hill is part of the Tanah Merah district..

Basemap of Bukit Panau, Tanah Merah Kelantan

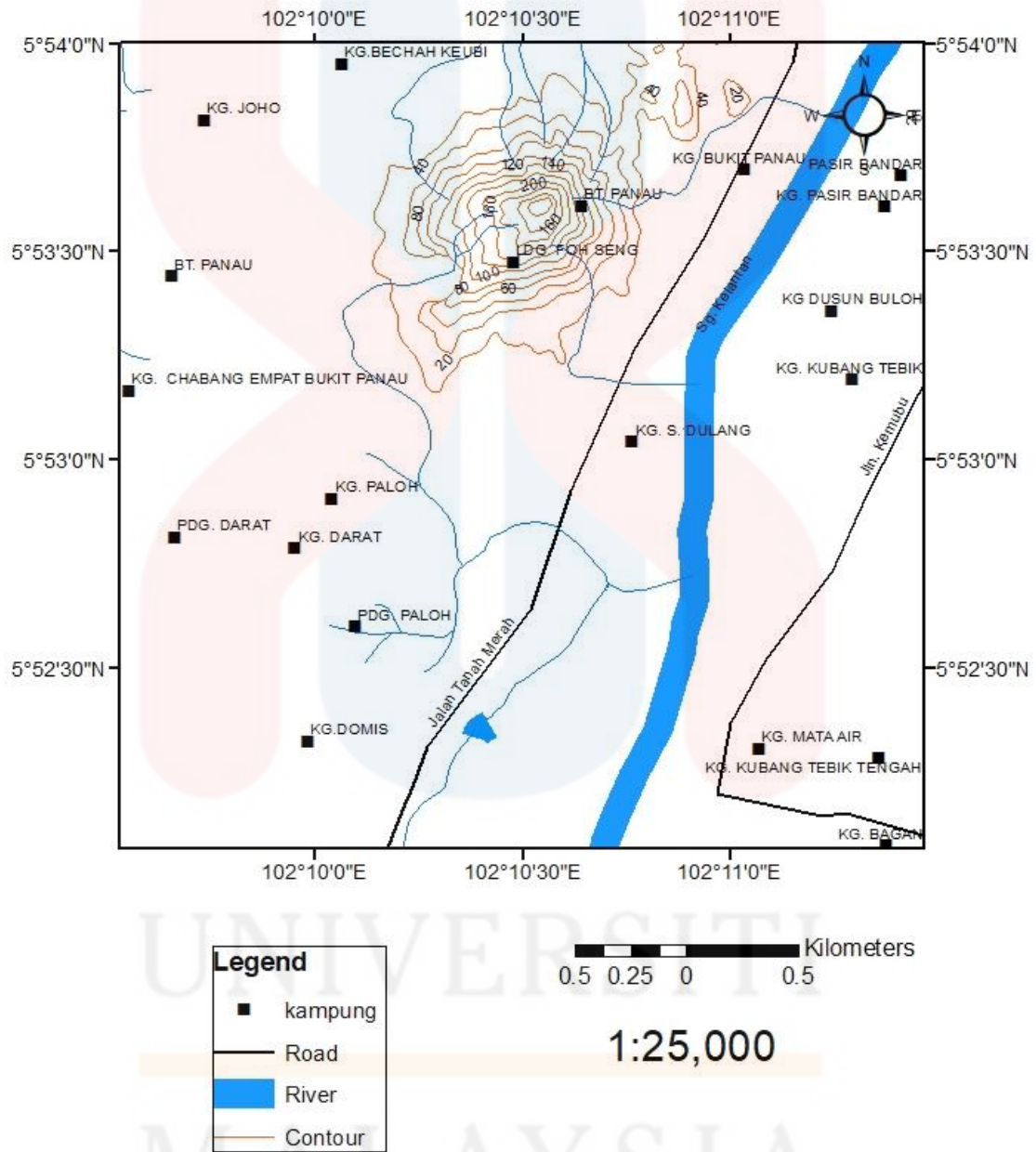


Fig 1.4 Map of Bukit Panau, Tanah Merah Kelantan

1.2.1 Demography

In 2020, there were approximately 66,324 people living there, the vast majority of whom were Malay in Bukit Panau area. There was also a small population of Chinese (4,439) and Indian (54) people. A portion of the population is made up of immigrants, the majority of whom came from the neighbouring country of Thailand.

The majority of the population lives in the surrounding suburbs and villages (known as "kampung" in Malay), while the town itself is home to only a small percentage of the total population. It used to be a small town, but Tanah Merah has undergone significant transformations over the past decade as a result of the younger generation's migration to larger cities along the west coast of Malaysia in search of employment with higher pay. The growth, expansion, and development of the town were all fueled by the money that residents sent back to their families.

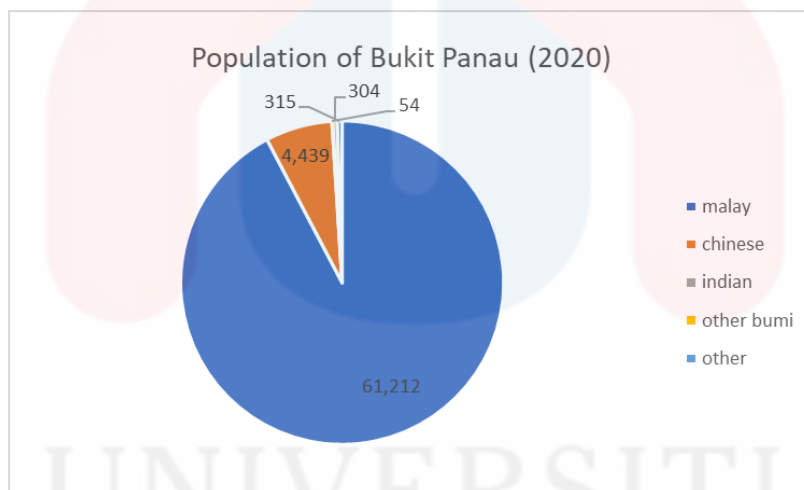


Fig 1.1: This piechart show Population of racial in Tanah Merah Kelantan (Population and housing census Malaysia, 2020)

1.2.2 Road

Proper road infrastructure is particularly important for connecting different locations and facilitating the movement of local populations from one location to another. The main road to access Bukit Panau is the Tanah Merah – Pasir Mas road. . The area relates to pavement road and mostly road have been tarred road. This is because this road is used by the villagers daily that using that road for daily life. The traverse can be done by riding a vehicle such as car and motorcycle and easily to do it because the road mostly tars and not have any trouble to drive it.

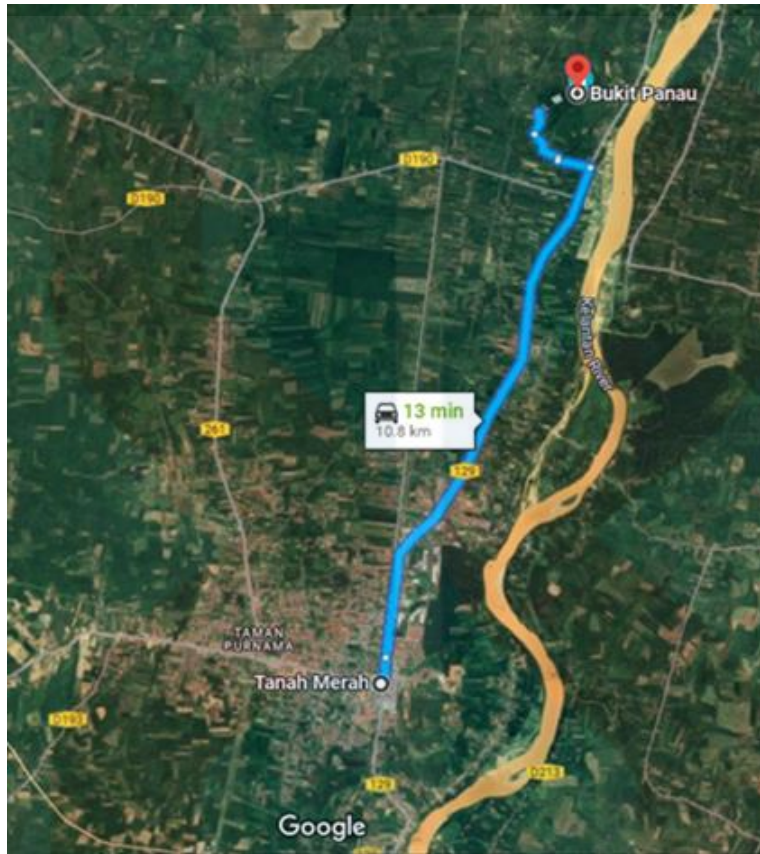


Fig 1.2: Route from Tanah Merah to the study area via driving (Copernicus imagery, 2022)

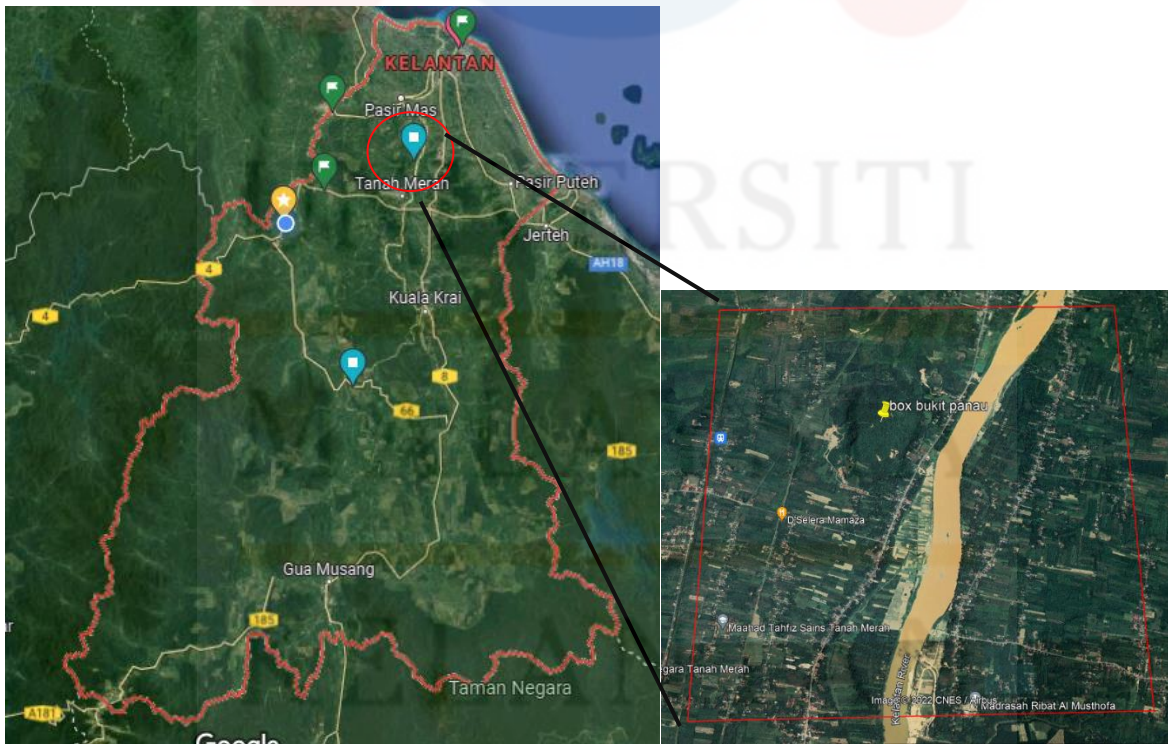


Fig 1.3: The map show of Kelantan map and the zoom in at area of Bukit Panau (Copernicus imagery, 2022)

1.3 Problem Statement

According to previously researchers that have been conducted in the last few years, Panau Hill is an isolated hill surrounded by level terrain, this hill has been subjected for many researchers for many differences field of geology such as geoheritage, sedimentology (depositional environment) and paleontology. Prior research in Panau Hill provide there have no studies have been conducted on lithofacies & lithostratigraphy of the study area so far. Besides that there is not updates on geological information between the last previous researcher compared to my study since the latest one is 2019 that gaps of time is around 3 years. The highlight of the gaps as needed of updating geological mapping in this study will be emphasized in the north east in Bukit Panau because there is no study and research done in that area. This is believe there are more of its unusual succession and geological age in term of stratigraphy on that area. There is a difference of opinion regarding the stratigraphic sequence in Bukit Panau whether the rock lithology like granite and or Panau Beds sandstone is younger. Panau Hill is thought to have angular unconformity and non-conformity that claimed by Nur Farrina & Askury (2019). The sandstone rock that finds at Bukit Panau since its to general and need to been naming by the classification of sandstone rock since no previous researcher ever done this. Maybe in this research can fill the gaps of this question whether is the answer or in this new findings that creating deeper and more detailed questions on this study area.

1.4 Objectives

The primary goal of this research is: -

- To updating a geological map of the Bukit Panau area with scale 1:25000.
- To Determine the stratigraphic correlation between the Panau Beds and Granite in the Bukit Panau
- To analyse the lithofacies of Panau Beds.

1.5 Scope of Study

The study location at Bukit Panau, Tanah Merah Kelantan, focuses more on lithostratigraphy over a 5 x 5 km region. The study area more specifically on the surrounding of Bukit Panau area that more focusing more taking the litholog data and taking the sedimentary rock sample at Panau Beds such as sandstones to determine the classification naming of sandstone rock using plotting the petrology triangle diagram that previously not studies by previous researcher.

1.6 Significance of Study

This study is a continuation of previous studies and to complete the results of incomplete studies by previous researchers which can provide an overview of the Panau Hill formation area, especially the area that have no conducted of research. The importance of the outcome of this research that lots questions marks on site with doing fieldwork and geological mapping as mentioned on problem statement. The study of lithostratigraphy is significant in understanding the geology of a study area. Lithostratigraphy is the branch of geology that deals with the study of rock units based on their lithology or rock type. This type of stratigraphy is important in the characterization and correlation of rock units in a study area, and it provides a framework for understanding the geological history & evolution of that area and to updated geological map . This research might provide information on topographical spare and lithology for any improvement territory, for example, Land and District Office, Public Works Department, and Town and Regional Planning Department. This study would also be beneficial to the Department of Minerals and Geosciences (JMG) especially researchers since this area was once highlighted as a potential dinosaurs trace habitat. The beneficial is Bukit Panau itself that in future can be potential become the geopark.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussion will focus on the general geology of study area, Geology & lithostratigraphy of Panau Beds, Bukit Panau, Tanah Merah Kelantan. The general geology will cover the regional geology and tectonic setting, stratigraphy, Panau beds geological settings & lithostratigraphy and Nonconformity contact in Bukit Panau of study area.

Under the stratigraphic topic, the discussion will concentrate on the overall of Malaysia peninsular Mesozoic stratigraphy their formation and naming of all of western, central and eastern belts and the second paragraph telling about the Jurassic- Cretaceous of stratigraphy of Malaysia more focused on the eastern belts of Malaysia peninsular stratigraphic.

Under the Panau beds geological settings, its focuses on the lithological of rock and depositional environment that found from previous researcher that will be discussed detailed in chapter 5.

For nonconformity contact in Bukit Panau, the description will highlight the previous research on stratigraphy layer of unconformity contact that found on Bukit Panau through the investigation and observation that can be related from stratigraphy studies that determined the layers of lithology of rocks.

Research Topic	Researchers
Geology of Bukit Panau, Tanah Merah, Kelantan	Nur Farrina and Askury (2019)
lithology and stratigraphy of the Panau Formation	Jamaluddin and Abdul Rahman (2014)
Geology and Potential Geoheritage Features of Bukit Panau	Nur Hidayah (2016)
General Geology, Depositional Environment and Provenance of Bukit Panau	Nur Adila Syakirah (2017)
The Sauropod Dinosaur Trackways from Tanah Merah, Kelantan, Malaysia	Arham Muchtar and Syakir (2020)
Geology of the Batu Melintang-Sungai Kolok Transect area along the Malaysia – Thailand Border	The Malaysian and Thai Working Groups (2006)

Table 2.1: Several geological studies have been conducted in the study area as summarized

2.2 Regional Geology and Tectonic Setting

The Malaysian state of Kelantan is located in the north-eastern part of the country. Its northern neighbour is Thailand. Thailand is located to the north-west of the country. It is surrounded to the west by Perak, to the south by Pahang, and to the east by Terengganu. Kelantan has ten districts with a total area of 17,100 square kilometres. The seven districts of northern Kelantan are Tumpat, Kota Bharu, Pasir Mas, Bachok, Tanah Merah, Machang, and Pasir Puteh. Located in the southern part of the state are the districts of Jeli, Kuala Krai, and Gua Musang.

In Kelantan, there is a core zone of sedimentary and metasedimentary rocks, which is bordered by granites from the Main Range and the Boundary Range, respectively, on both the west and the east. Three prominent granitic intrusions include the Ulu Lalat (Senting) batholith, the Stong Igneous Complex, and the Kemahang pluton. North Pahang's regional geology extends to the north, with a north-south trend in these granite and country rock bands. A coastal alluvial flat covers much of Sungai Kelantan's shore in the east, while areas of Boundary Range granite may be seen in western and central Kelantan that extend north into southern Thailand.

Rocks dating back to the Lower Paleozoic may be found in a band that has a northerly trending direction and extends throughout the state from the foothills of the Main Range to Sungai Nenggiri. The bulk of them are composed of metapelites, which are characterised by the presence of minute volcanic fragments as well as arenaceous and calcareous intercalations. Rare minerals such as amphibolite and serpentinite include: (MacDonald, 1967).

Predominantly In southwest Kelantan, Permian volcanic-sedimentary rocks abound on the eastern side of and unconformably underpin the Lower Paleozoic sequence. The Taku Schist, whose age is unknown but certainly pre-Triassic, dominates central north Kelantan.

The majority of Kelantan's Triassic rocks may be found in the state's central and southern areas. The bulk of these rocks are composed of argillo-arenaceous sediments with volcanics and limestone being intercalated between them. It is possible to make out a number of Permian inliers as they make their way through the Triassic sedimentary layers (MacDonald, 1967).

The youngest rocks are the Jurassic-Cretaceous continental rocks that lie beneath the Border Range Granite and the Triassic sediments in the Gunung Gagau region at the common state border between Kelantan, Terengganu, and Pahang. Additionally, the Jurassic-Cretaceous

continental rocks can be found to the west in the Gunung Perlis and Gunung Pemumpu sectors. These rocks are located in the westernmost parts of the Gunung Perlis and Gunung Pemumpu sectors, respectively. The conglomerate has been covered by sandstone at this point; the sandstone has intermittent intercalations of volcanic debris (Rishworth, 1974).

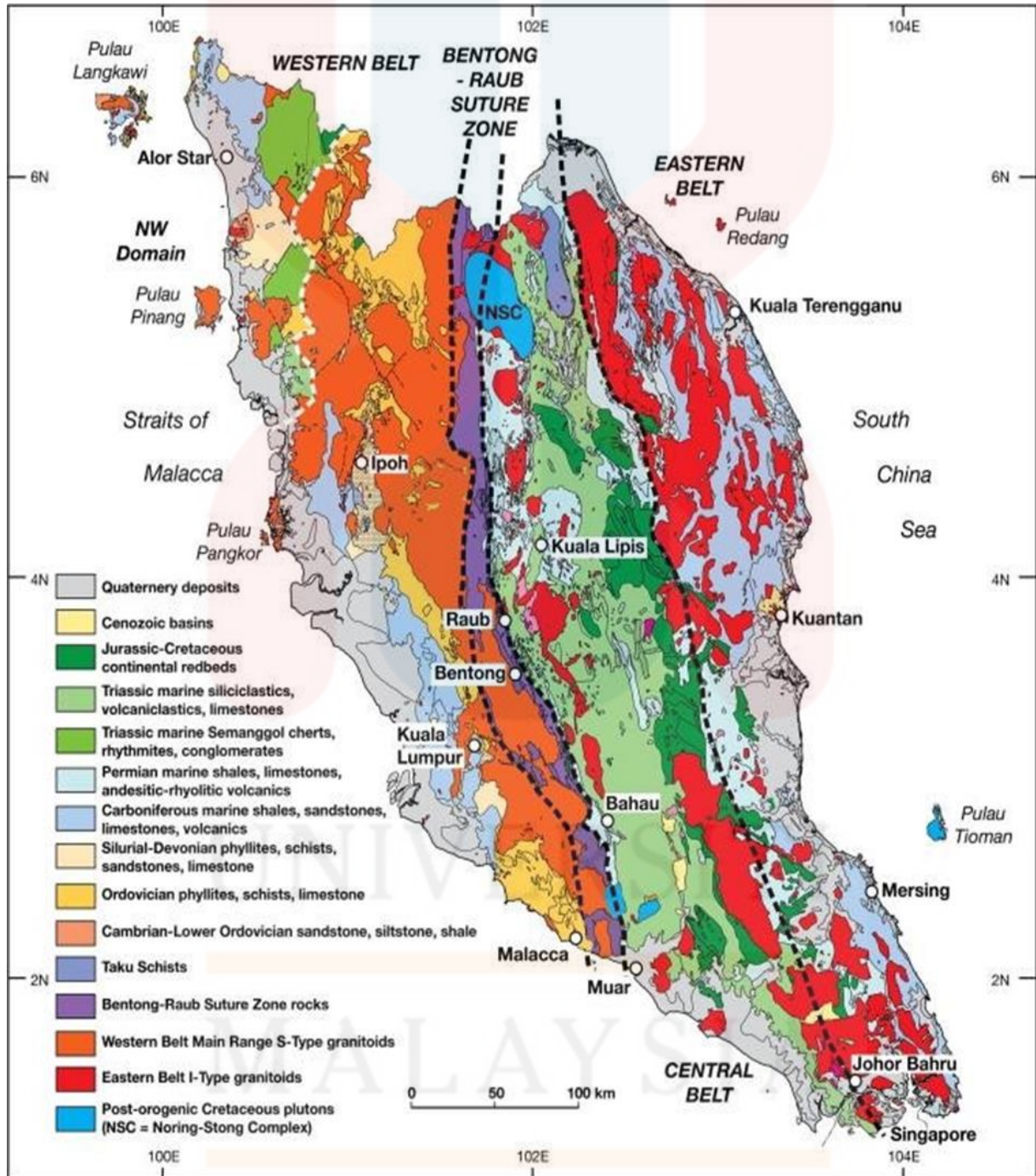


Fig 2.1: Simplified geological map of the Malay Peninsula. After Tate et al. (2009).

2.3 Stratigraphy

2.3.1 Malaysian Peninsula Mesozoic stratigraphy

Malaysia's Northwest and Central Belts have Mesozoic rock formations, according to the stratigraphic lexicon of Malaysia (2004). Peninsular Malaysia's Mesozoic sedimentary rocks are split into three belts: Western, Central, and Eastern Belts (Khoo & Tan, 1983). The Chuping limestone (see Paleozoic section), Kodiang limestone, and Semanggol formation are all part of the Central Belt. The Central Strip of Peninsular Malaysia is dominated by Mesozoic rocks, which form a continuous north-south trending belt that reaches to Thailand and Singapore. Only two late Mesozoic rock units, the Saiong Bed in northeast Kedah and the Nenering Bed in north Perak, are known from two tiny isolated basins.

In most areas, the marine ecosystem existed only until the Middle Triassic or early Late Triassic. Jurassic-Cretaceous deposits may be found in several isolated basins on the onshore Eastern Belt. The Late Triassic - Jurassic Koh Formation and Tembeling Paloh Formation overlie the Triassic sediments on the eastern end of the Central Belt, while the Ma'Okil Formation overlies them on the western end (Malaysia lexicon, 2004).

2.3.2 Jurassic-Cretaceous Stratigraphy of Malaysia

The Jurassic-Cretaceous periods in Peninsular Malaysia are represented by continental deposits deposited in various separate basins across the nation. The fining upward sequences of reddish-brown to crimson siltstone, sandstone, and conglomerate, which are generally interpreted as molasse sequences, characterise the sequences in general (Niza,2019).

Saiong Formation, Kayu Hitam Formation, Berapit Formation, Tan Hain Formation, Panau Formation, Koh Formation, Tembeling Group, Gagau Group, Gerek Sandstone, Bertangga Sandstone, Ma'okil Formation, Paloh Formation, Lesong Sandstone, Ulu Endau Beds, Tebak Formation, and Panti Formation are the Jurassic-Cretaceous continental sequences found in Peninsular Malaysia. The sequences are found in Peninsular Malaysia's Western, Central, and Eastern Belts. Except for the Saiong Formation, which extends northward into southern Thailand, the rest of the sequences are visible in the Central Belt.

The Jurassic-Cretaceous sequences are located in the Eastern Belts, in the southeastern part of the Peninsular. Palynomorphs, gastropods, bivalves, and plants were discovered in certain rock units. Dinosaur teeth and footprints have been discovered in the Lotong Sandstone of the Gagau Group in Hulu Terengganu. Dinosaur teeth have also been found in the Cretaceous rocks of Pahang (Niza,2019).

Age	Central Belt – Eastern Belt		
	Kelantan	Pahang-Terengganu	Johor
Jurassic – Cretaceous	Panau Formation Koh Formation	Gagau Group Tembeling Group Gerek Sandstone Bertangga Sandstone	Ma’Okil Formation Paloh Formation Lesong Sandstone Ulu Endau Beds Panti Formation

Table 2.2: List of the Jurassic-Cretaceous sequences within the Central-Eastern Belts in Peninsular Malaysia (Niza,2019).

2.4 Historical Geology

Based on the previous researches the Mesozoic Era is considered to be the beginning of the formation of Bukit Panau. This was a direct consequence of the rocks that were located in this area. The sedimentary rocks make up the vast majority of the rocky terrain in the Bukit Panau region. At a defunct quarry in Bukit Panau, one can observe the nonconformity structure that exists between the granite and the unit that lies above it. This structure shows that the Bukit Panau bed is significantly younger than the granite. Cretaceous age is apparently indicated by the presence of plant fossils, most likely fragments of *Frenelopsis* sp., *Otozamites* sp., *Calamites* sp., and *Pecopteris* sp. (The Malaysian and Thai Working Groups, 2006)

2.5 Panau beds Geological Setting & Lithostratigraphy

Panau Hill is a tiny hill about 10 kilometres northern of Tanah Merah Town in Kelantan, surrounded by the Panau Formation. Except for a somewhat hilliest part in the north, There is a sharp incline on this hill, while the surrounding landscape is flat plain. The hill is approximately 240 m high and 1.50 kilometres broad. Based on previously researched according to Malaysia and Thai working groups (2004) and Mohamad & Mat Niza (2014), Interbedded thin argillite layers, laminated fine-grained sandstone, poorly sorted pebbly sandstone, and paraconglomerate make up the Panau beds. The colour of the argillite rocks is maroon. Some argillite rocks are channel lenses embedded in sandstone strata. This suggests that the rocks were formed in a channel lag, in oxygenated, continental conditions. The argillite rock is made up of maroon, sandy shale, pebbly sandstone, and light greyish to light brownish siliceous shale. The bed thickness ranges from 1 cm to 1.5 m. The majority of the sandy shale has a coarsening upward sequence, with sand-sized quartz grains visible at the top of the bed. Plant fossils have been found in several of the argillite strata. Light grey poorly sorted sandstone, predominantly pebbly and laminated fine-grained sandstone, makes up the arenaceous rock.

The laminated fine-grained sandstone near Panau Hill foothill and summit exhibits cross-bedding. Pebbly sandstone stones can grow to be 3 cm in diameter. In certain sandstone beds, the bedding is graded. Clasts can be angular or subrounded. Sandstones are arkosic mineralogically due to the significant amount of feldspar, which is predominantly converted to kaolinite. This demonstrates that this rock unit was generated from the Boundary Range Granite that is located in the vicinity. Both arenaceous and argillaceous lithofacies may be found within the Panau Formation because to the stratigraphic division that exists between the two. The arenaceous facies is distinguished by the presence of fine- to coarse-grained, poorly sorted graded sandstone with subordinate graded grit, maroon paraconglomerate, and very thin- to thin-bedded maroon shale, mudstone, and siltstone. The argillaceous facies is characterised by plant pieces that range in colour from light grey to dark grey and comprise shale, siliceous shale, mudstone, and a thin layer of fine-grained sandstone and siltstone (Malaysia and Thai working groups, 2004)

The Panau Formation was named after a sedimentary sequence discovered by the Malaysian – Thailand Border Joint Geological Survey Committee as Panau bed although the bed was given the formal name by the Malaysia Stratigraphic Nomenclature Committee (1977) as Panau Formation that was discovered in the area of the abandoned quarry of Panau Hill foothills and the summit of that hill. Only the Panau Formation is carved out at that place, and the ground surrounding the hill is flat, making Panau Hill a one-of-a-kind hill since only the Panau Formation is cut out in that location, and the terrain around the hill is flat. A nonconformity between Triassic granite and the overlaying Panau Formation sandstone is revealed at the abandoned rock quarry at Bukit Panau foothill, based on the presence of plant pieces in the fine-grained sandstone layers at the Bukit Panau foothill, both studies conclude the Panau Formation is younger than the Triassic granite and has a Jurassic-Cretaceous date. Plant fossils classified as *Frenelopsis* sp., *Otozamites* sp., *Calamites* sp., and *Pecopteris* sp. are thought to be Cretaceous in age (Farrina & Askury, 2019).

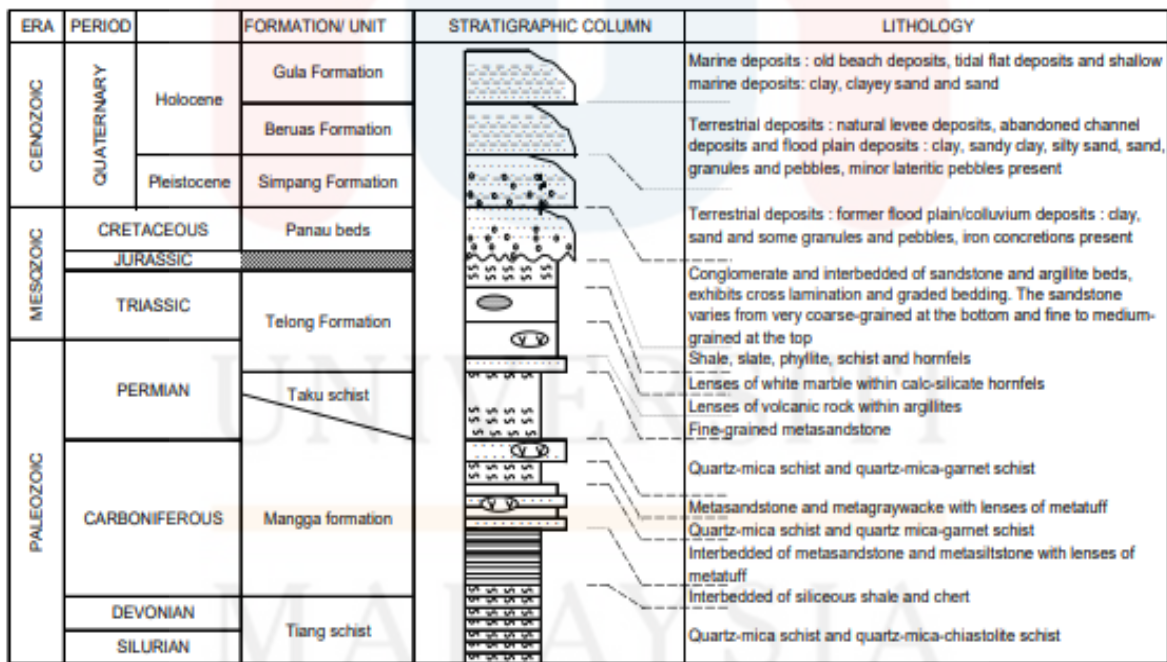


Fig 2.2: Schematic stratigraphic column of the Batu Melintang-Sungai Kolok Transect area in Malaysia. (Malaysia and Thai working groups,2004)

2.6 Nonconformity Contact in Bukit Panau

Concerns concerning the nature of contact between the Panau Formation and granite, according to Farrina & Askury (2019), can be addressed by gathering more specific information through field surveys. If the granite body contains rock fragments from the Panau Formation sedimentary rocks, and the sedimentary layers have been in contact and metamorphosed when they are adjacent to the granite body, this indicates that the granite has intruded the older sedimentary layers, making the granite body younger than the layers. The inclusion principle refers to the occurrence of sedimentary rock fragments in a host rock that is older than the host rock. The presence of rounded granite stones in sedimentary layers suggests that the granite body was raised and the surface eroded before the deposition of fresh sediments, indicating that the granite is older than the underlying rocks.

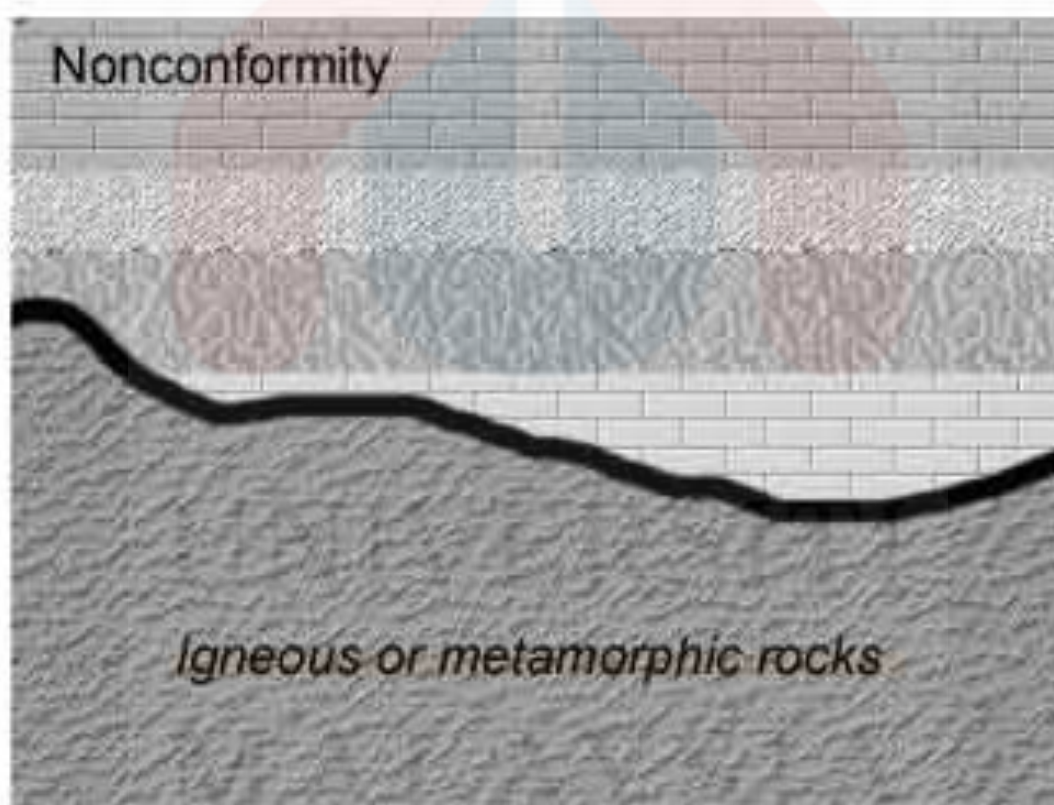


Fig 2.3: this picture shows the simplest form to shows the Nonconformity of geological unconformity ()

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CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

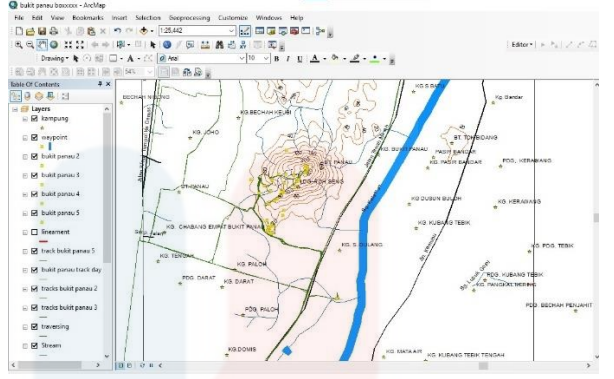
This chapter will focus on the materials and the methodology of the study conducted. It will cover the discussion on the materials, lab apparatus as well as the software used. The methodology is covered from the preliminary studies, data collection, data preparation, analysis, result and discussion until the submission of this research's report.

3.2 Materials

3.2.1 Fieldwork Equipment

<p>Geological Hammer</p>	
<p>Brunton Compass</p>	

Topographic Base Map



Hand lenses



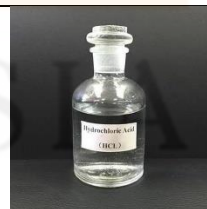
Global Positioning System (GPS) – Garmin
GPSmap 62s


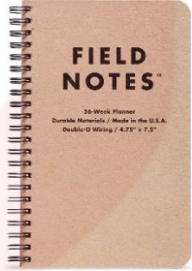



Measuring tapes



Hydrochloric Acid (HCl)



<p>Sample bags</p>	
<p>Field notebook</p>	
<p>Digital Camera</p>	

3.2.2 Lab Apparatus

<p>Thin section</p>	
<p>Microscope</p>	

3.2.3 Software and Mobile Application

Arcgis	 ArcGIS
Qgis	 QGIS
Google earth	 Google Earth
Google map	 Google Maps

3.3 Methodology

3.3.1 Preliminary studies

A preliminary study is pre-research undertaken before doing research. A preliminary study's goal is to comprehend this topic more thoroughly of the research field and the scope of inquiry. Preliminary research was carried out by checking current studies on the subject or study area. This research is essential before traveling to the location to do fieldwork.

3.3.2 Data Collection

3.3.2.1 Fieldwork

Traversing

When mapping rock types, it is to have a strategy in place to ensure that traverses cover the whole region. A careful examination of aerial pictures and topographical maps can assist in avoiding locations that are problematic to cross or impossible to climb owing to steepness. It may be the only efficient option if rock exposures are confined to stream sections or roads, or where access is limited to streams, roads, ridges, and so on.

Geological Mapping

It will be completed. the traverse technique. Various information on geomorphology, structural geology, and lithology can be retrieved immediately from field observation by accompanying geological mapping. The most significant aspect of outcrop field investigation is a careful examination of its lithology, which includes colour, texture, grain size, structure, and any other apparent aspects.

Structural Geology

For measure, the strike, dip, and dip direction for planar features such as bedding, cleavage, fault, and fold axial surface, while the plunge and plunge direction are measured for linear features. These data can be related to significant events in the past that caused rock deformation (e.g., mountain building, rifting) as a result of plate tectonics.

Geomorphology

The landforms and landscape of the Earth's surface are represented by geomorphology. Before doing field research, the geomorphology of the location may be anticipated via map analysis. To create a geological map, we must first identify the landforms in the region, such as mountains, hills, rivers, lakes, and others.

Sampling

It is useful in geological studies where further analysis is required after the fieldwork. Samples will be collected from various outcrops and locations. The materials for sampling will be a hammer and sample bags. Fresh sample collection must be done with care to ensure that the sample is not tampered with. The sample size is determined by its intended function, such as petrographic analysis. However, a sample should not be too large or it would be difficult to transport while in the field.

3.3.2.2 Thin Section Preparation

Thin section preparation is a process in which a small, thin slice of a rock or mineral sample is cut and ground down to a thickness of approximately 30 microns (0.03 millimeters) and mounted onto a glass slide for microscopic analysis. Thin sections are widely used in geology and petrology to identify minerals and study the textures and structures of rocks.

The process of preparing a thin section typically involves the following steps:

1. **Cutting:** The first step is to cut a small piece of the rock or mineral sample using a saw or diamond blade. The piece should be as thin as possible to make the grinding process easier.
2. **Grinding:** The sample is then ground down to a thickness of approximately 1 millimeter using a grinding machine. This rough-grinding process is usually done using a coarse diamond abrasive disk.
3. **Mounting:** The ground-down sample is then mounted onto a glass slide using an epoxy resin or similar adhesive. The sample is carefully placed onto the slide, and the resin is added to hold it in place.
4. **Fine grinding:** The mounted sample is then ground down to a thickness of approximately 30 microns using a series of finer diamond abrasive disks. This process is usually done under a continuous flow of water to prevent overheating and to wash away the debris.
5. **Polishing:** The final step is to polish the thin section using a series of very fine abrasive disks. This creates a smooth and flat surface that is suitable for microscopic analysis.

After the thin section is prepared, it can be examined under a petrographic microscope, which uses polarized light to identify minerals and study the texture and structure of the rock.

3.3.2.3 Updating geological map

Updating geological information is an essential task to ensure that geological maps, databases, and other information resources are accurate and up-to-date. This information is crucial for various applications, including mineral exploration, environmental planning, hazard assessment, and land-use planning.

Here are some steps that can be taken to update geological information:

1. **Field mapping:** Field mapping is a crucial step in updating geological information. Geological mapping involves the collection of geological data, including rock types, structures, and stratigraphy, from the field. This data can be used to update geological maps, databases, and other information resources.
2. **Remote sensing:** Remote sensing techniques such as satellite imagery, LiDAR, and aerial photography can also be used to update geological information. These techniques provide high-resolution images that can be used to identify geological features and structures that are not visible at ground level.

Updating geological information is an ongoing process, and it is important to regularly review and revise the available data to ensure that it remains current and accurate. This ensures that the geological information can be used to make informed decisions about resource management, environmental planning, and hazard mitigation.

3.4 Analysis

3.4.1 Lithofacies analysis

Lithology

It is a studies and represent the physical characteristics of rocks in the study of sedimentary rocks. During mapping, lithology is studied by seeing and recognize the rock type, hue, mineral content, and grain size. A stratigraphic unit's lithology may be referred to as sandstone, shale, limestone, and so on.

Facies association

It is a total of a sedimentary unit's features, which include Dimensions/geometry, sedimentary structures, lithology, grain sizes and types, colour, and biogenic material are all aspects of a sedimentary unit (fossils). In the study of sedimentary sequences, it is frequently

discovered that facies associations are established from a collected collection of facies. These facies relationships were also defined and interpreted in relation to other well-described facies associations. The facies study is based on field observations.

Lithologic correlation

It is a means of extending geological knowledge about geologic sequences over a vast geographic region by leveraging similarities between geologic units. A unit is identified in lithologic correlation by its lithology (rock type) or a succession of lithologies.

3.4.2 Petrography Analysis

The data will be interpreted using a petrographic microscope to examine a thin piece of rock. This covers mineral identification, texture, clast and matrix identification, fossil content, and rock classification. A few spots in a sample will be inspected for each thin slice, and point counting will be performed to determine the proportion of mineral composition.

Texture	The texture research considers mineral particle types, grain size, shape, roundness, sorting, matrix content, maturity, and other factors.
Grains	The grain analysis is concerned with the features of framework grains, such as the presence of quartz, feldspar, and lithic pieces in the rocks.
Cement/matrix	The study is performed to determine the types of cement or matrix, or both, that are used to bind the framework grains together

3.4.3 Geological map comparison analysis.

Geological map comparison analysis is a method of comparing and contrasting geological maps to identify similarities, differences, and changes in the geological features over time. This analysis is important in understanding the geological history of an area and can provide valuable information for mineral exploration, land-use planning, and hazard assessment.

Here are some steps that can be taken for a geological map comparison analysis:

1. Identify the area of interest: The first step is to identify the area of interest and obtain the geological maps of the area. These maps should cover the same area but be from different time periods, typically decades or even centuries apart.
2. Familiarize yourself with the maps: Before starting the comparison analysis, it is important to familiarize yourself with the different symbols, colors, and patterns used on the geological maps to represent various geological features such as rock types, faults, and folds.
3. Compare the rock types: The first step in the comparison analysis is to compare the rock types shown on the maps. This can help identify changes in the rock types over time and provide insights into the geological history of the area.
4. Compare the geological structures: The next step is to compare the geological structures such as faults, folds, and thrusts. Changes in the location, orientation, and magnitude of these structures over time can provide important information about the tectonic processes that have shaped the area.
5. Identify areas of similarity and difference: After comparing the rock types and geological structures, it is important to identify areas of similarity and difference between the maps. This can help identify areas where the geological history has remained stable or areas that have undergone significant changes over time.
6. Interpret the findings: The final step in the analysis is to interpret the findings and draw conclusions about the geological history of the area. This can provide valuable information for mineral exploration, land-use planning, and hazard assessment.

Geological map comparison analysis is a powerful tool for understanding the geological history of an area and can provide insights into the tectonic processes that have shaped the earth's surface. By identifying changes and similarities over time, geologists can better understand the evolution of the earth and make informed decisions about resource management and hazard mitigation.

3.4.4 Data Analysis

Geological Data

To map the region, the GPS data and raw data collected during fieldwork must be imported into ArcGIS software. The strike and dip data is turned into a Rose Diagram for additional analysis. The data will be analysed based on the rock type analysis. The mineral composition and proportion of the mineral in the rock are used to examine the thin slice of the rock. First, the rock will be categorised according to its kind, which is igneous, metamorphic, or sedimentary. Each sort of rock has a unique diagram depending on classification or name.

3.5. Result analysis

3.5.1 Petrography

The detail analysis and result will be discuss in chapter 5

3.5.2 Updating Geological Map

The geological map analysis will be discuss in chapter 5

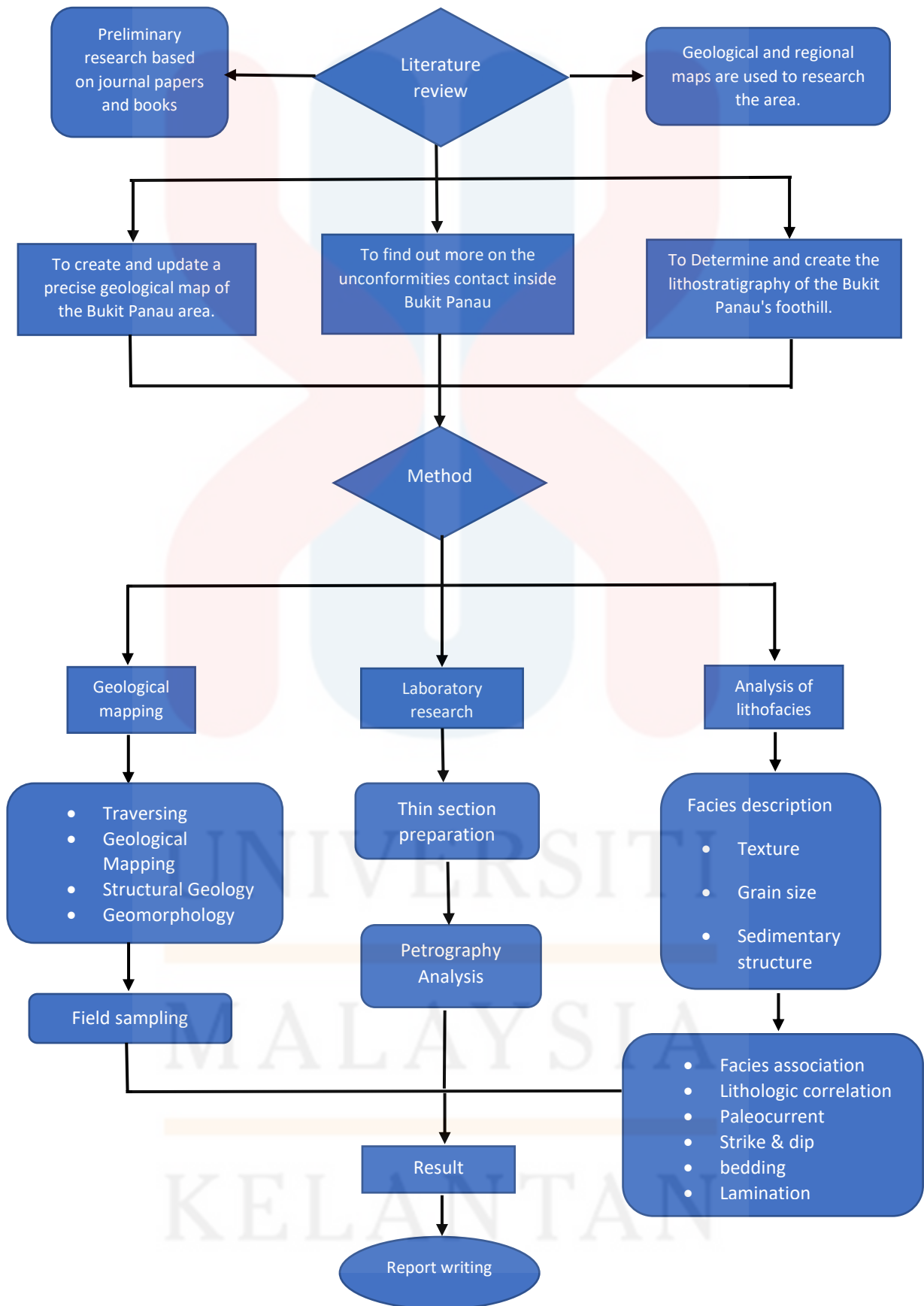
3.5.3 Facies Analysis

The detail results will be discuss in chapter 5

3.6 Report Writing and Submission

Upon completing all the necessary steps in the research process, including data collection, analysis, and interpretation, this final stage represents the culmination of the entire research endeavor. At this point, the researcher is ready to move forward with the next phase of the project, which involves drafting a comprehensive report based on the experiment's findings. It is imperative to prioritize timely completion of this report, ensuring that it is finished well before the deadline and submitted to the supervisor for final evaluation. Ultimately, the quality of this report will play a significant role in determining the researcher's mark for their final year project, making it a critical component of their academic success.

3.7 RESEARCH FLOWCHART



CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter will describe the geology of the study area, which is located in the Bukit Panau region of Tanah Merah, Kelantan. Geology is broken down into four categories: geomorphology, lithostratigraphy, structural geology, and petrology. It will be determined how these various scopes are related to one another. The identification and discussion will corroborate the prior research that was done on this subject. This chapter contains information and statistics gathered from a wide variety of sources; it also contains an analysis of those data.

4.2 Landuse (Forestry and Vegetation)

Land use is the common phrase for the ways in which people put land to work. It's a visual representation of the various economic and cultural pursuits (such farming, living in a house, working in a factory, going on a mining expedition, or going on a camping trip) that take place in a specific area. There can be a wide variety of differences between the public and private uses of land. While private land is rarely set aside for wilderness purposes, public lands (such parks and wilderness areas) are rarely developed.

According to the study area, the region under investigation has a number of different villages, some of which are named Kampung Bukit Panau, Kampung Paloh, Kampung Darat, and Kampung Sungai Dulang. Many of these villages have a relatively low population, which results in very short distances between each of the homes and one another. Another aspect of this is that around sixty percent of the region under investigation was covered by agricultural operations carried out by the villagers, such as farming, orcharding, and rubber planting. From what I can see, this is the primary contributor to the village's economic well-being.

In the region of Bukit Panau, there is an area that is considered to have been a mining area and mining operations that have been dormant for a significant amount of time. This region also has an abandoned quarry. There is also a river called the sungai kelantan that is located next to the bukit panau. This river is one of the primary sources of irrigation for the surrounding agricultural region. Activities, one of which is a sand shovel area for use in construction, are available in the region along the riverside.



Fig 4.1 : There are agricultural activities such as corn plantation that found on Bukit Panau area

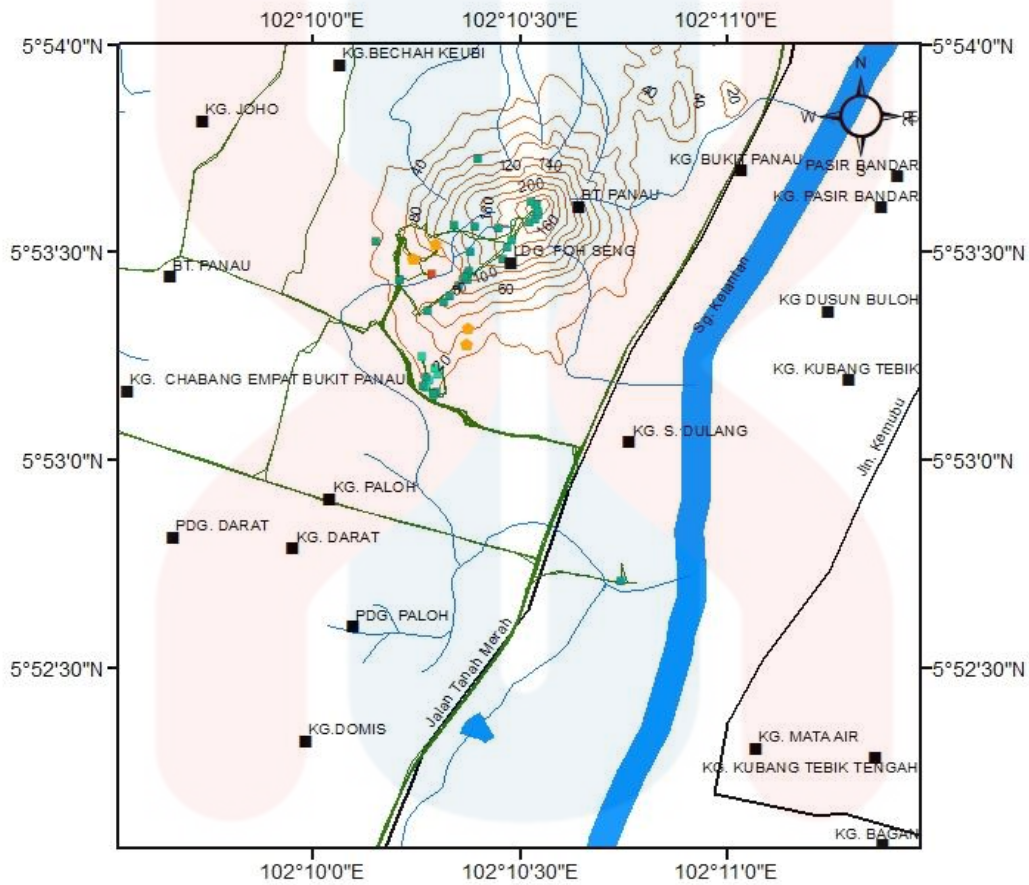
4.3 Traverse and Observation

Geological mapping has been carried out, and when mapping was carried out at Bukit Panau ara, it was effective in traversing seventy percent of the research area, which measures twenty-five km squared. Another thirty percent of the research region was inaccessible due to its steep terrain, high elevation, lack of road access, and proximity to the Jeli reserve forest. Because it is simpler to locate new outcrops on the slope of the hill, the majority of the traverse was conducted by following the route that goes to the hill. The hikers took use of the several routes that were available to them in order to complete the traverse in a variety of different ways. It was helpful to conclude the circuit of the region via the major road that was located in the Bukit Panau area. During the course of the mapping and traversing, the geological data was gathered. The data from the traverse were processed into a map, which may be seen below. This map displays, in a nutshell, all of the tracks that were mapped from day one through day five, together with all of the waypoints of sampling and observation locations. The purpose of sampling is to collect evidence and to make further analysis possible.



Fig 4.2: There are signboard which is for hikers to do activities at Bukit Panau

Traverse map of Bukit Panau, Tanah Merah Kelantan



Legend

- kampung
- sampling point
- Location rock outcrop finding
- location of geological structure
- location of geological structure findings
- location of general geological processes
- traversing
- Road
- River
- Contour



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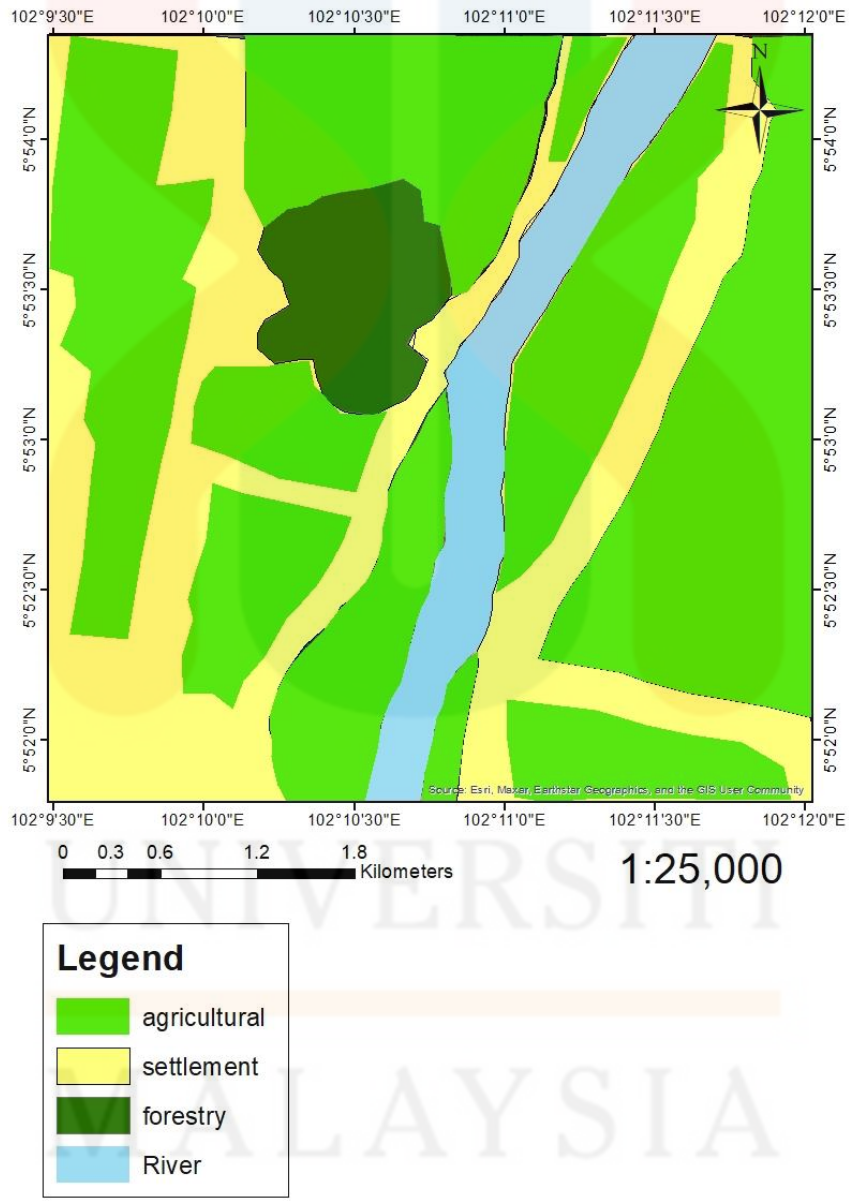
4.4 Geomorphology

The landform that found is hill area, plain area, main river, and riverbank area. There is only hill that surrounded by the large plain area that located beside the main river. At the riverbank area that found the floodplain area the used for the agricultural and sand shovel activities. In the hill area there have a forestry. Almost 80% of that study area is flatland that consist of settlement of villager and agricultural such as rubber plant, vegetation crop, and farming.



Fig 4.3: This picture shows the Bukit Panau and its surrounding of agricultural area such as corn plantation (coordinate : 5°52'42.8"N 102°10'41.4"E)

Landform map of bukit Panau, Tanah Merah Kelantan



4.5 Topography

There are both steep hill and Plain area in the Bukit Panau region, with elevations ranging from around 20 to 220 metres above sea level. Northwest of the investigated area, gradient steepness was found to increase. This map below displays the contour lines and elevation profiles for the research region. As a result, the tallest peak of Bukit Panau is roughly 220 metres above sea level, and the research area's high topography is concentrated in the northwest half of the study area. This area's underlying geology is primarily sandstone and alluvium. Around the hill of Bukit Panau, where sandstone and granite predominate, you'll find a wide spread of lowland territory depicted as alluvial plain at an average elevation of 20 metres above sea level. The study region's lowlands, which make up roughly 70% of the area, have become the centre of daily life for those living in and around Bukit Panau.

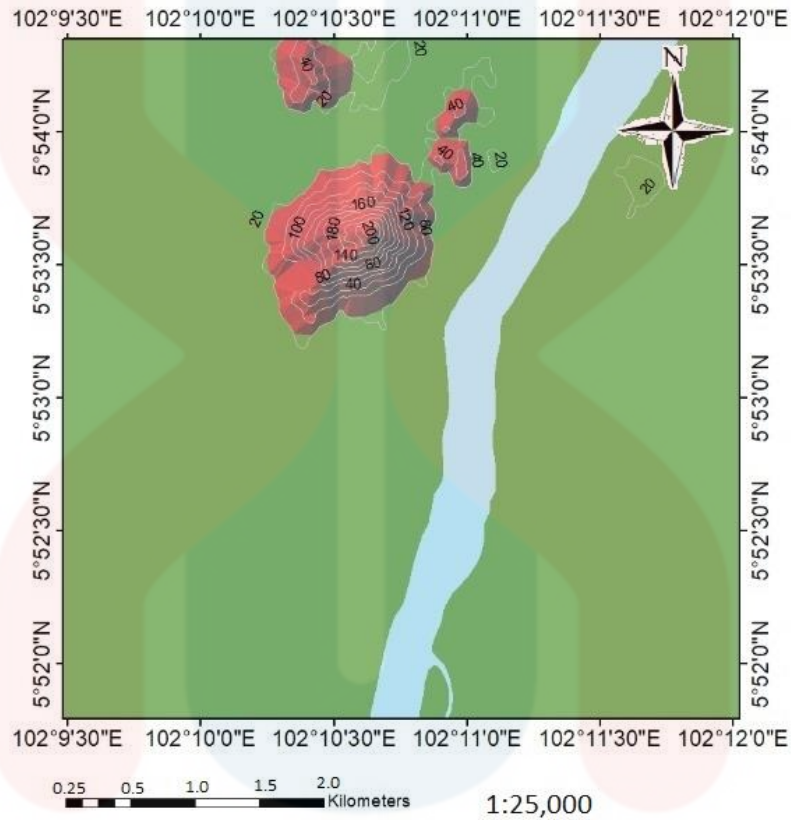


Fig 4.4: On the top of bukit panau, the scenery vast of Plain area of the study are

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ELEVATION MAP OF BUKIT PANAU, TANAH MERAH, KELANTAN



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4.6 Drainage Pattern

In this study area, which is Bukit Panau found that a significant river, particularly the Sungai Kelantan. On the basis of the drainage map of Bukit Panau, the drainage pattern in the study region is radial, as shown at the high topography to the northwest of the study area. The radial drainage system is comprised of streams emanating from a central point, such as a volcanic cone, dome, or hill with a steep slope and flowing in all directions down the slope.



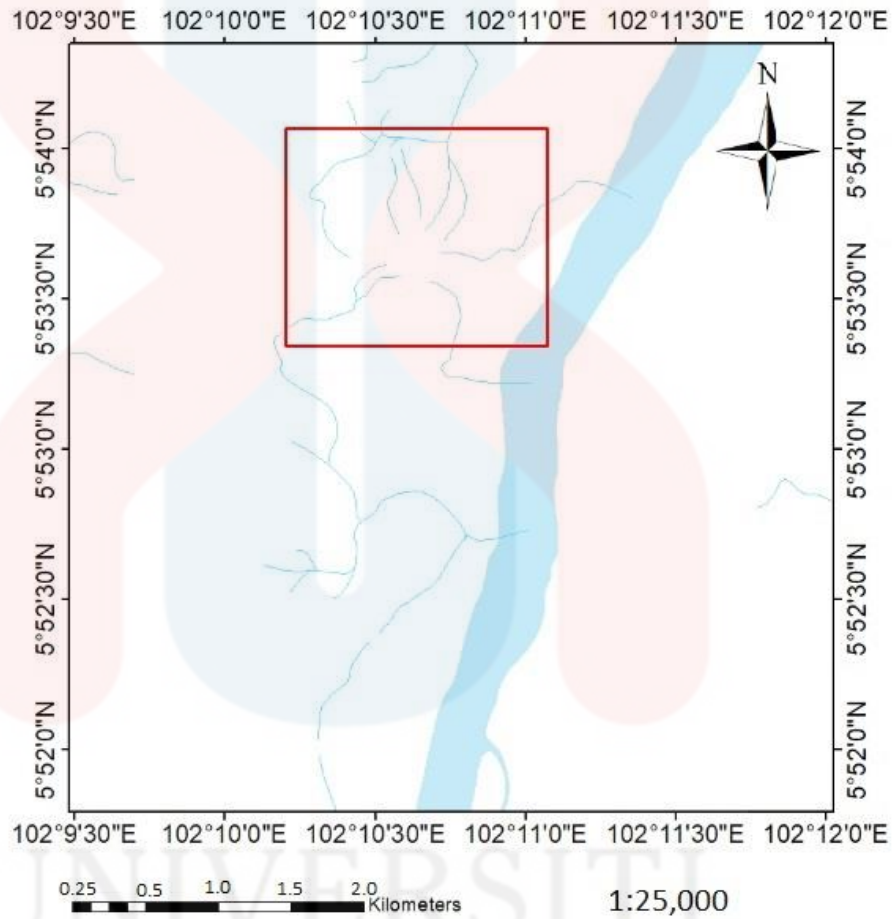
Fig 4.5: From on the top of bukit panau, can see the main river which is Sungai Kelantan




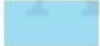
Fig 4.6: There are riverbank at sungai Kelantan, that sand shovel activities occ

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DRAINAGE PATTERN OF BUKIT PANAU, TANAH MERAH KELANTAN



Legend

-  Radial draniage patern
-  River

4.7 Weathering

Based on the field observations on study area suggest that weathering and erosion are the most important external geomorphological processes in the study area, while endogenous processes like faulting and intrusion are more minor. There are 3 types of weathering that found on that area which is Mechanical, Biological, and Chemical.

Mechanical weathering as shown in figure 4.7(c) also known as physical weathering and disaggregation, causes rocks to erode. It eventually widens the cracks and causes the rock to separate. Fissures in a rock may become more visible if the roots of a tree grow into the dirt that has accumulated in the cracks and sprout there. Underground burrowing animals also help to dismantle rock and dirt. When clay and other materials in the proximity of rocks absorb water, they undergo a sort of mechanical weathering.

Mineral solutions, which are chemicals, change rocks' composition. This is chemical weathering as shown in figure 4.7(b). This process involves water reacting with minerals to change rocks. These reactions result from transformation. As the rock's mineralogy adjusts to its surface environment, chemical weathering occurs gradually and continually. Secondary minerals form from rock's basic minerals. In this scenario, oxidation and hydrolysis occur most often. Chemical weathering is accelerated by geological factors like water and oxygen and biological agents like microbial and plant root metabolism acids (Macheyeke 2020).

Biological weathering occurs when plants and animals eat rock. Stress is caused by plant roots growing against rock as show in figure 4.7(a). Biological mechanisms apply pressure, yet the process is physical (i.e., growing roots). Plant roots and bacteria release organic acids that dissolve minerals, causing chemical weathering. Microorganisms destroy rocks' minerals, changing their chemical composition and making them weatherable. Lichen is a symbiotic fungus and algae. Rock-breaking fungus create minerals that algae eat. The rock gets permeable and chemically and physically fragile each day. Burrowing animals transport rock pieces to the surface, where chemical, physical, and biological processes accelerate rock weathering. Multiple types of weathering—physical, chemical, or biological—occur in nature (Passel 2022)



Fig 4.7 a): Plant roots in the research area contribute to biological weathering



Fig 4.7 b): Chemical weathering of granite due to oxidation process



Fig 4.7 c): sandstone outcrop having a highly weathering due to mechanical weathering

Figure 4.7 showing the weathering processes found during field work

4.8 Structural geology

Structural geology is one technique used in the field of geology to learn about the Earth's former geological settings. Specifically, it will detail the steps involved in deforming rock, the results of that process, and the rock's three-dimensional dispersion. An understanding of structural geology features like faults and folds can reveal the force's directional impact on the rocks. Knowing the monetary worth of minerals and conducting targeted studies both require an understanding of structural geology. Historical deformation systems were identified by a lineament analysis performed for this investigation.

4.8.1 Joint

Joints are the most common type of structure in the study area. However, because the production of joints is not related with the interior structure of the rock, joints are not a secondary structure that might explain the history of rock deformation. This is because joints are formed independently of the rock's internal structure. There are joints in every type of rock, and they are neither created by the forces that result in deformation, nor do they entail any movement of the rock's plane or surface. Joints are simply a natural feature of rocks.



Fig 4.10: Nonsystematic joints found in the study area (coordinate : 5.892748 N 102.172369 E)

The findings of the analysis are shown in the form of a rose diagram that also depicts the deformation of the research area. The deformation of the area under examination may be traced back to a joint analysis that was performed, and it was determined that the direction of the deformation is northeast to southwest, with a force angle of 70 degrees.

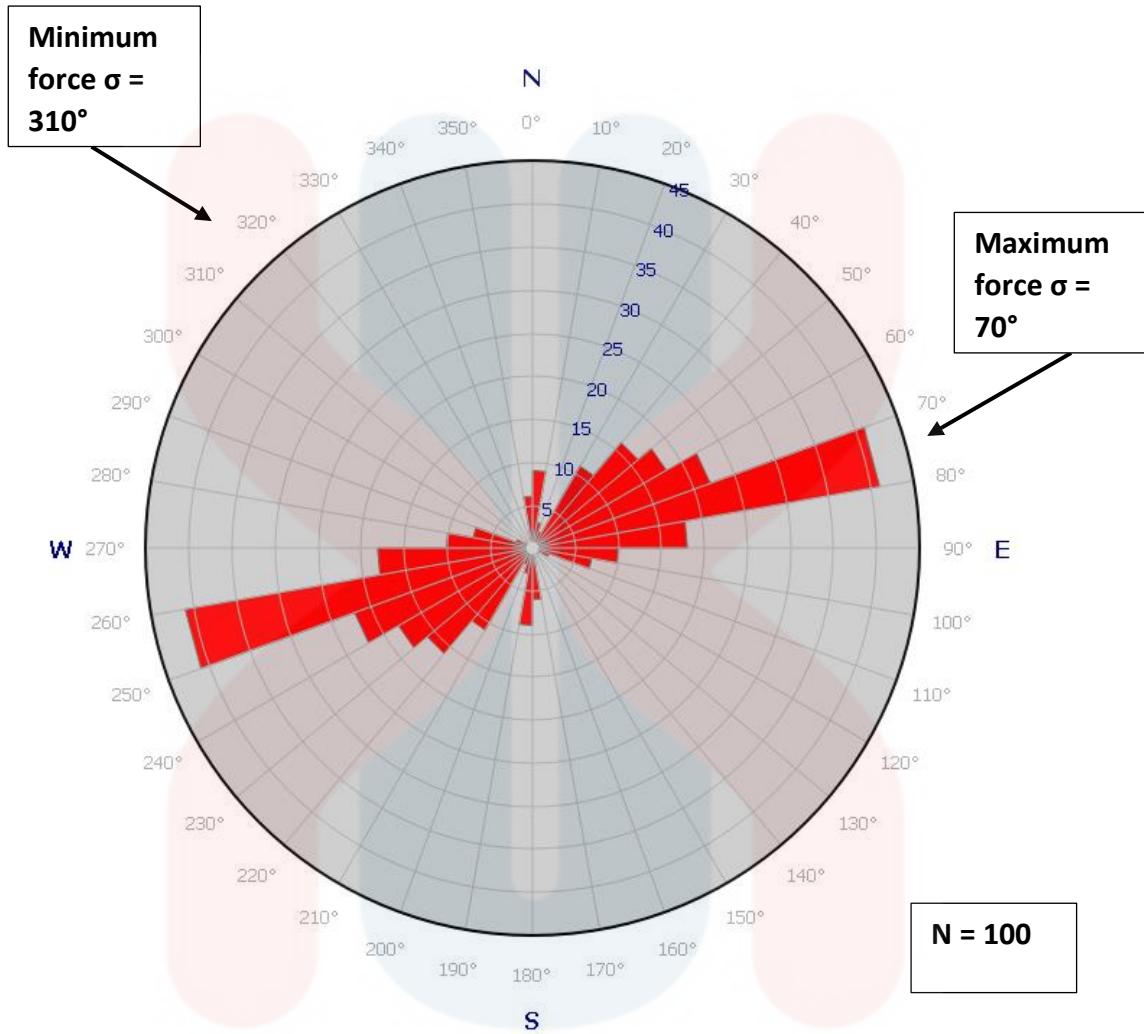


Fig 4.11: Rose Diagram of joint analysis in the study area.

Based on figure the rose diagram of joint has been plotted. The total values of joints are 115 and coordinate of points is **N 05° 89' 27.48"** **E 102° 17' 23 69"**. All of the values inserted to the software to get the rose diagram of joint. From rose diagram, the degree of force and tensional can determine. Based on rose diagram of joints, the degree force is **N 70° E** and tensional **N 310° W**.

No	Strike/dip	No	Strike/dip	No	Strike/dip
1	20/50	39	105/30	77	167/47
2	10/40	40	148/55	78	176/73
3	20/40	41	160/59	79	140/47
4	32/37	42	156/45	80	176/66
5	10/65	43	175/37	81	168/45
6	8/67	44	164/43	82	151/63
7	5/75	45	160/50	83	145/54
8	11/75	46	186/51	84	180/75
9	184/44	47	167/47	85	140/67
10	195/43	48	135/48	86	166/45
11	105/72	49	130/45	87	122/67
12	180/35	50	136/52	88	176/52
13	155/60	51	175/60	89	163/55
14	94/78	52	164/82	90	335/60
15	193/65	53	143/55	91	321/66
16	83/72	54	133/58	92	311/57
17	120/65	55	175/77	93	318/50
18	138/70	56	165/67	94	301/62
19	104/80	57	167/55	95	310/70
20	155/58	58	145/40	96	351/58
21	134/48	59	165/68	97	345/79
22	138/65	60	193/45	98	344/58
23	155/37	61	184/77	99	320/54
24	162/32	62	175/45	100	336/51
25	172/46	63	163/79	101	320/78
26	140/53	64	173/63	102	329/66
27	168/49	65	179/71	103	315/89
28	160/30	66	147/66	104	343/53
29	170/47	67	164/70	105	298/34
30	123/43	68	121/60	106	336/78
31	135/56	69	114/30	107	307/70
32	132/49	70	169/52	108	322/43
33	125/29	71	158/73	109	355/30
34	137/25	72	183/48	110	166/18
35	126/57	73	154/56	111	150/28
36	143/23	74	130/36	112	173/33
37	155/31	75	164/56	113	165/27
38	164/52	76	125/44	114	164/24

Table 4.1: measurement of strike/dip of joints in Bukit Panau

4.8.2 Bedding

Bed analysis included the measurement of strike and dip. The force direction of the study region can be inferred from an examination of the bedding. Bedding force direction patterns in the research area were mapped using stereonet. North East North and South West South are the directions of force.

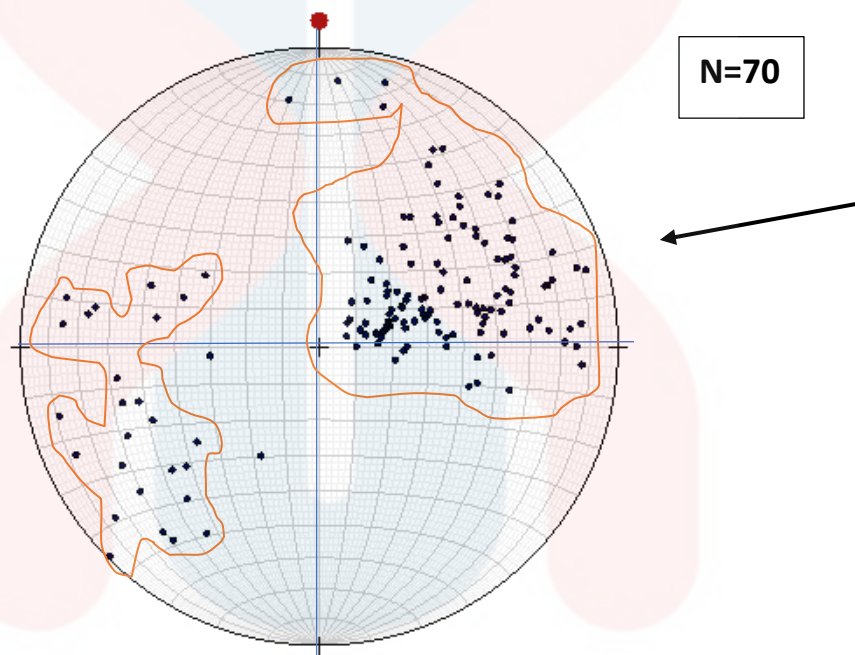


Fig 4.12: Stereonet diagram of bedding analysis



Fig 4.13 : bedding can see clearly through observation on foothill of Bukit Panau

(coordinate: 5.890783 N 102.172881 E).

4.8.3 Veins

Veins are large cracks that are filled with either oriented crystal fibres or mineral deposits that are not aligned (typically quartz, calcite or carbonates). Veins can be found in all kinds of rocks and metamorphic grades. They can be as thin as a millimetre or as thick as several metres. Based on the research there have found of veins on the surface of the highly weathered outcrop at the foothill of Bukit Panau

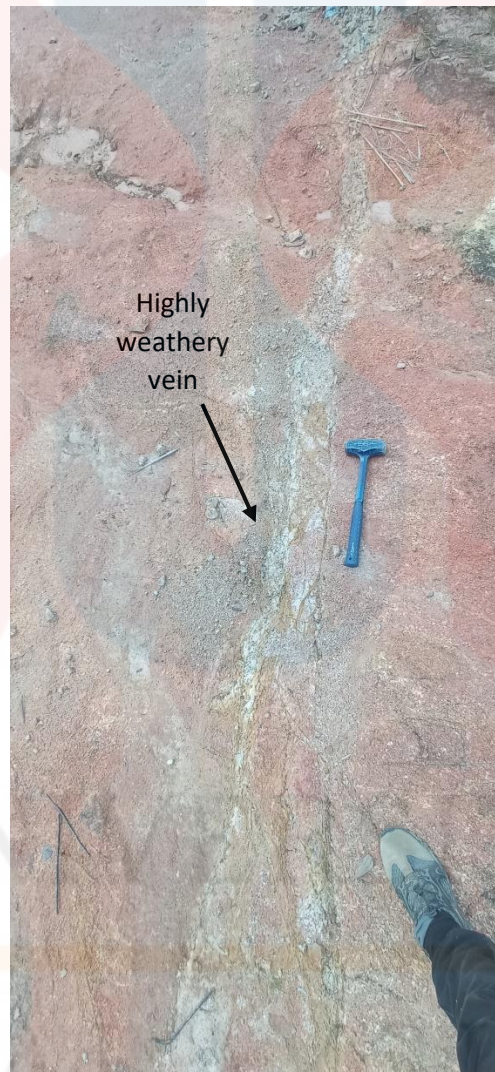


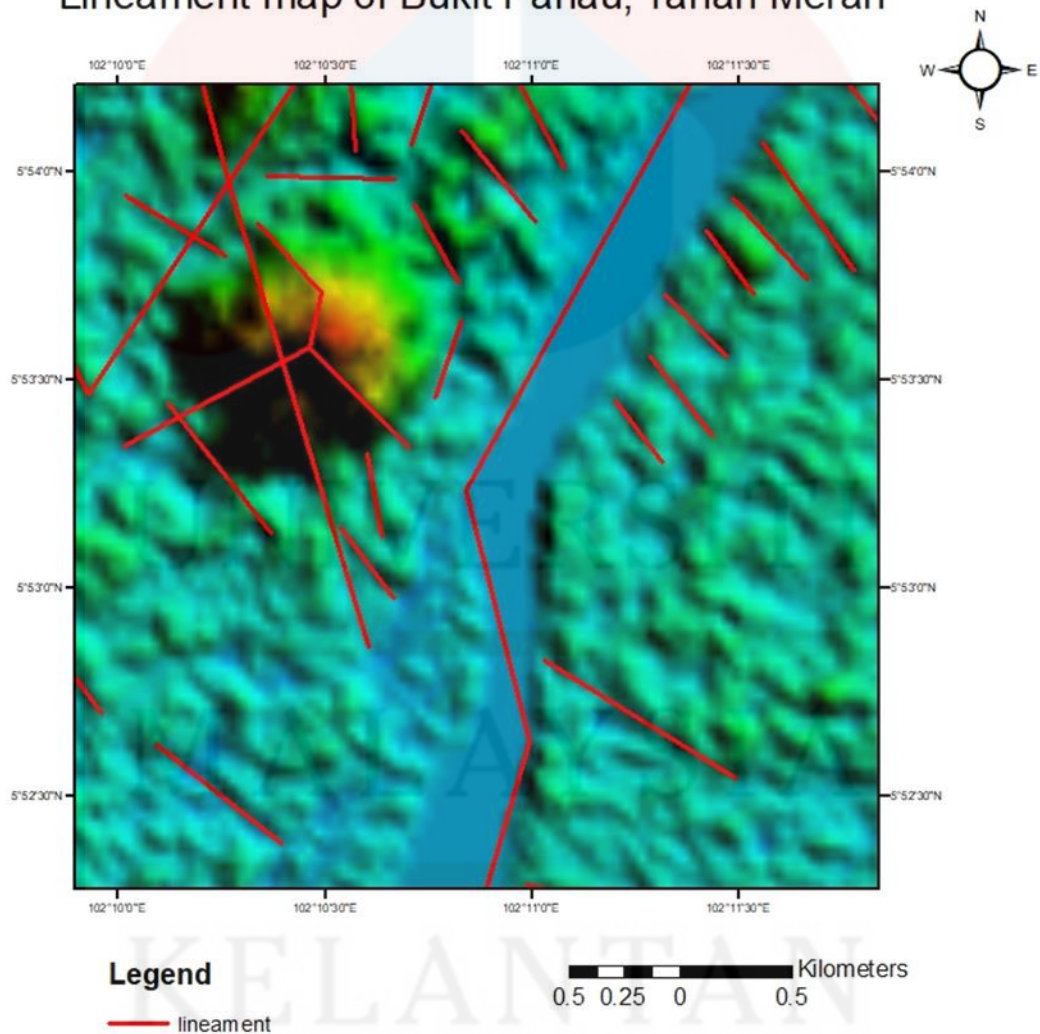
Fig 4.13: The thick vein that found on the highly weathered outcrop (coordinate : 5.892706 N 102.173217 E)

4.8.4 Lineament analysis

. Lineament analysis is a geological method used to study and map linear features on the Earth's surface, such as faults, fractures, joints, and other linear structures. These features can be identified through various techniques, including remote sensing, field mapping, and geophysical surveys.

The analysis of lineaments can provide important information about the tectonic processes that have affected an area, including the direction and magnitude of stresses, the orientation and nature of faults and fractures, and the potential for natural hazards such as earthquakes or landslides.

Lineament map of Bukit Panau, Tanah Merah



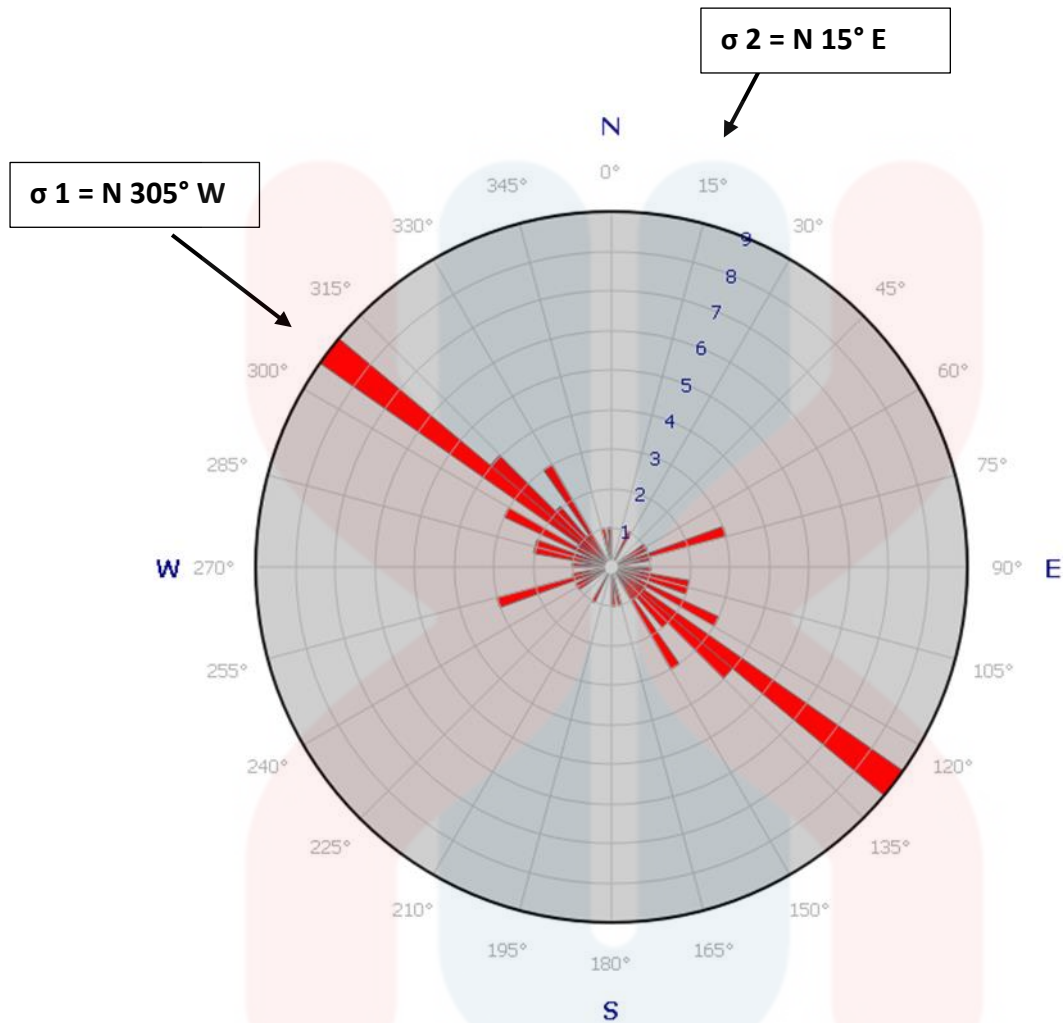


Fig 4.14: Rose diagram of lineament analysis

The rose diagram serves as the basis for the lineament analysis that is described. Aside from that, the studied area possesses a greater quantity of structural geology, such as joints and fractures. Dike and unconformity are two examples of the distinctive characteristics that can be found in these study areas

From the study area, the value of lineament were obtained. Based on the picture of regional area, the rose diagram has been plotted. From the rose diagram, the direction of the maximum force is N 305°W. The minimum of the force are 90° perpendicular to the maximum force which is the direction of the minimum is N 15 E. This data shows the negative lineament analysis since the hill area is lacking the lineament analysis to conduct. overall of the lineament analysis shows the negative lineament at the study area consist of river and low land area.

CHAPTER 5

LITHOSTRATIGRAPHY OF THE PANAU BEDS, BUKIT PANAU, TANAH MERAH KELANTAN

5.1 Introduction

The term "lithostratigraphy" refers to the practise of classifying rocks according to the observable relationships between the lithological features of the strata and their stratigraphic locations. Past glaciers and their environments can be better understood by studying their stratigraphy, which records details such as their genesis, distribution, and palaeoclimate. It's an effort to piece together the timeline of geological occurrences throughout a large region. This lithostratigraphy takes into account a wide range of factors, including sedimentary structure, rock facies, grain size, and colour.

Based on the previous research, the lithostratigraphies of the foothill of Bukit Panau and a quarry in the southern half of the study area, close to the town of Tanah Merah, are two completely distinct things.

The majority of the Bukit Panau is composed of sandstone, however other rocks like as conglomerate, mudstone, and shale can be found in the interstices. It has been determined that the Panau Formation is the lithofacies in question. In addition, granite rock that was formed as a result of intrusion can be found exposed at the nonconformity boundary beneath the rock unit that is a part of the Panau Formation. As a result, it may be demonstrated that the Bukit Panau bed predates the granite.

In addition, extrusive volcanic materials can be found in the region's southern portion of the research area. Extrusive tuffaceous volcanic material. The Carboniferous period is the earliest that any of the volcanic rock has been dated (Nur Adilah., 2017)

5.2 Lithostratigraphy of Bukit Panau

Based on the lithostratigraphy of this study area with 25 km². There are 3 lithology that found in that area and 1 surface deposit which are granite, sandstone and alluvium. The surface of deposit of alluvium also find in this study area. Mostly the study area covered by alluvium which is 70% of the study area. Most of the lithological is the main focus to find the contact between the lithologies.

ERA	PERIOD	FORMATION	LITHOLOGY NAME	LITHOLOGY UNIT	DESCRIPTION
CENOZOIC	QUARTERNARY	-	ALLUVIUM		Composed mainly clay, sand, loam and silt
MESOZOIC	CRETACEOUS	PANAU FORMATION	SANDSTONE		Interbedded of lithic arkose sandstone and mudstone
	JURASSIC ???	-	GRANITE INTRUSION		Granite

Table 5.1: Stratigraphy column of the Bukit Panau.

The alluvium deposit, the granite intrusion, and sandstone are the three rock unit forms that may be distinguished in the research region, and they are listed in ascending order of age from oldest to youngest. Table displays a stratigraphic column for the rock units along with the ages that are associated with each one. The granite intrusion are the oldest formation in the region that was investigated.

There is just one lithofacies that can be differentiated from the Panau Formation, and that is the interbedded sandstone and mudstone. This is the only lithofacies that can be found in the Panau Formation.

The Panau Formation is estimated to have existed during the Cretaceous period. In conclusion, the Quaternary alluvium deposit that was deposited on top of it is the most recent geologic formation in the area that was investigated.

The Panau Formation's sandstone unit is the sequence that has received the greatest attention from researchers. A previous study investigated the plant fossils that were found in the shale layers that were part of the Panau Formation series. As a result of this, many fossils of plants were found and recognised. *Frenelopsis* sp., *Otozamites* sp., *Calamites* sp., and *Pecopteris* sp. are the names of the fossilised plant species. According to The Malaysian and Thai Working Groups (2006), the fossil assemblages of plants place their date during the Cretaceous period.

However, none of the shale rock or fossils were discovered in the Bukit Panau region during the most current investigation that was carried out. The lowest parts of this sequence that make up the Panau Formation have been pushed upwards as a result of a nonconformity feature or an intrusive contact of granite. In accordance with the findings of the investigation, the nonconformity can be found in the research region beneath the overlying units of the Panau Formation. This suggests that the granite was formed more early than the sandstone formation.

At the southern part of the Bukit Panau, there are found of contact of sandstone and mudstone that can be distinguish of characteristics such as texture, grain size and mineral.



Fig 5.1: A huge scale of contact of sandstone and granite intrusion

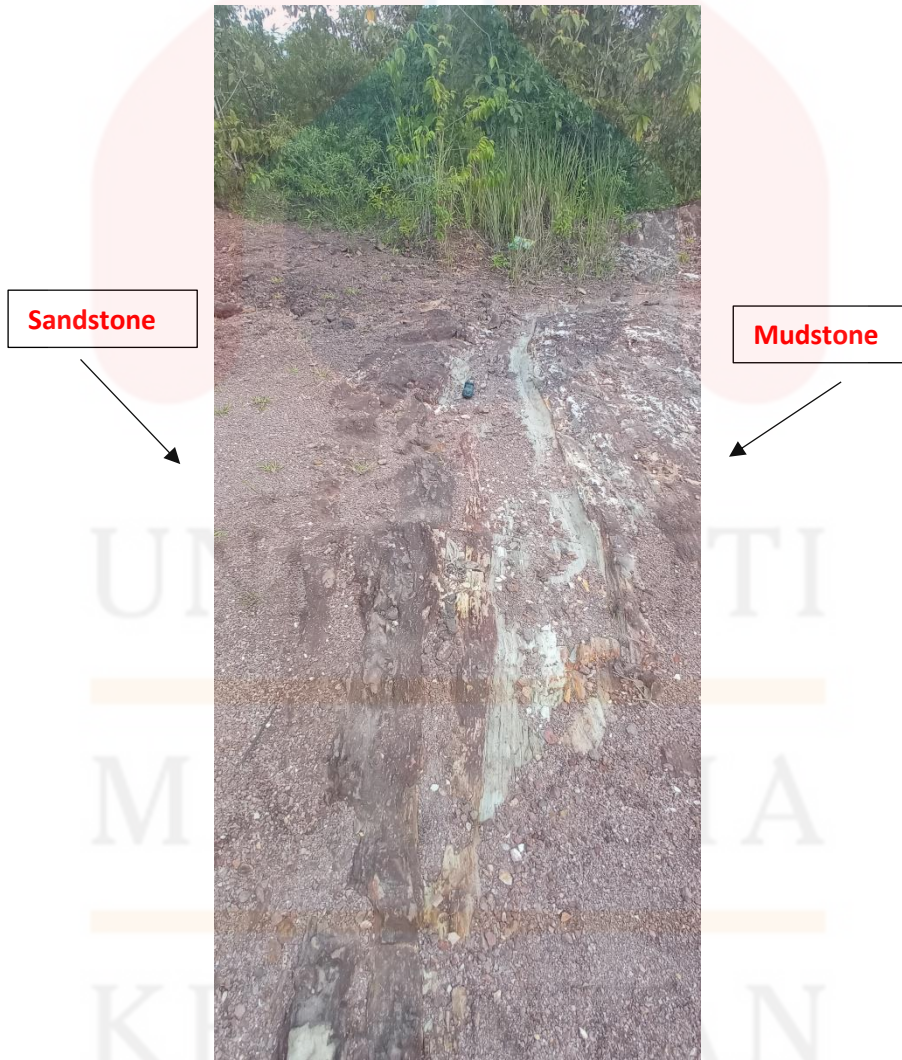


Fig 5.2: The contact between of sandstone and mudstone

Geological map of Bukit Panau, Tanah Merah Kelantan

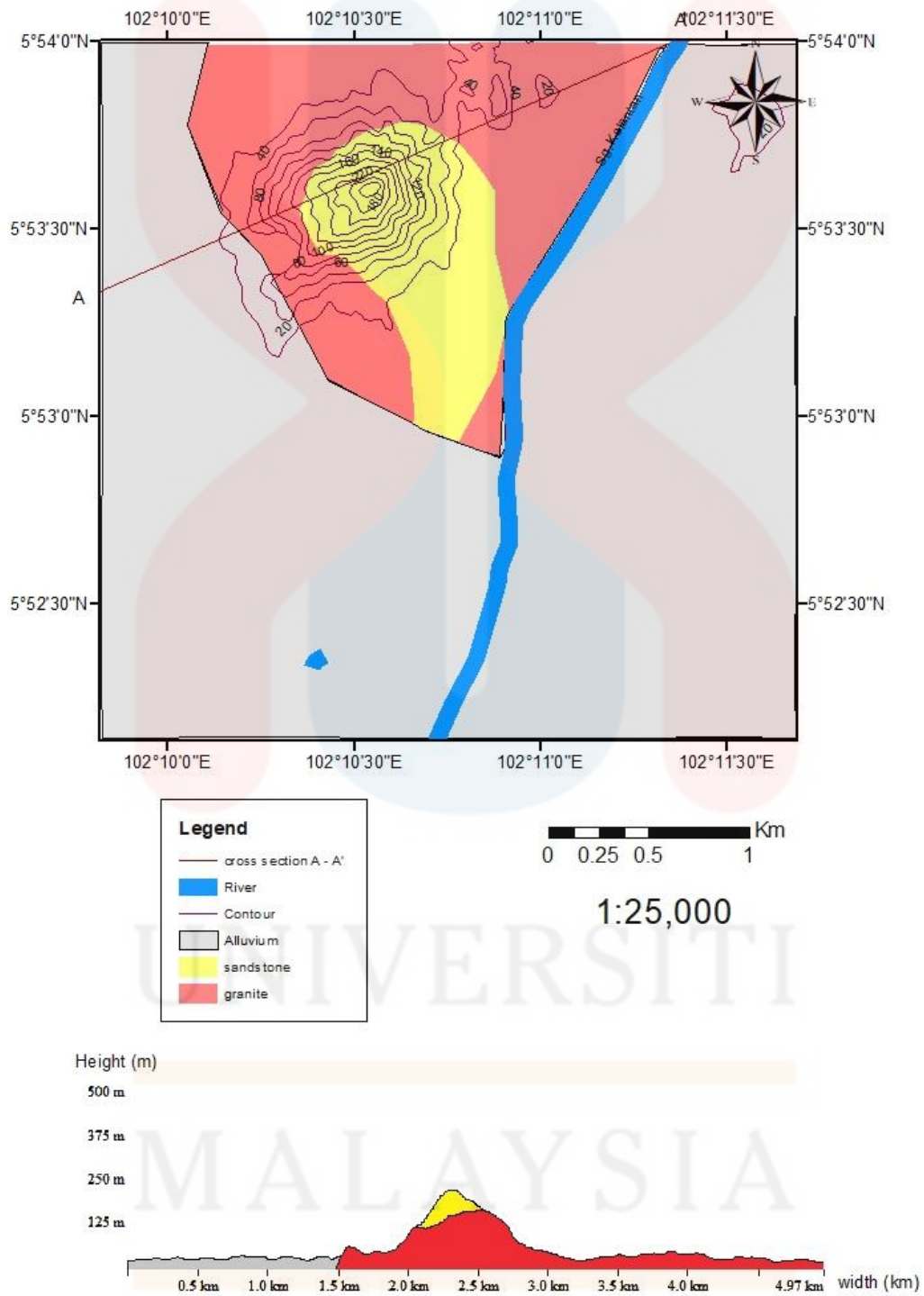


Fig 5.3: Geological map & Geological cross section Map of the Bukit Panau area.

5.2.1 Cretaceous sandstone unit (Interbedded with mudstone)

In general, characteristic of sedimentary rock made of sand sheets, mineral particles, and a binding matrix stacked in aquatic and arid environments. Due to its porosity, water can easily penetrate it. Brownstone sandstones are brown, red, purple, or pink. Surface textures and earth-toned colours are available. When end grain is exposed, weathers best (naturally bedded). Stone deteriorates faster when face-bedded. Face-bedded stone spalls or flakes off due to water. Water enters the stone and freezes and expands, separating the top layer.

This unit is located in the study area, and it is exposed at the foothill and peak of Bukit Panau, which is located locally in the northern section of the Tanah Merah district. About 50 percent of the area under study is composed of sandstone. The majority of the sandstone that is exposed in the region of Bukit Panau is planar laminated fine-grained sandstone. This type of sandstone can be found at the pinnacle of the hill. While on the other hand, the fine-grained sandstone that is interbedded with mudstone may be found on the foothill of Bukit Panau. The thickness of the beds ranges from 2 centimetres to 20 centimetres.



Fig 5.4: This picture shows the outcrop that sandstone interbedding with each other

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Fig 5.5: Hand specimen of sample 4 of sandstone

This sample was collected at the highest point on the Bukit Panau. The sandstone has a fine grain and a reddish-brown in colour.



Fig 5.6: Hand specimen of sample 3 of sandstone

5.2.2 Interbedded sandstone and mudstone

Based on findings in study area, its located in Mudstone interbedded with sandstone is a type of sedimentary rock that consists of alternating layers of mudstone and sandstone. In this type of rock, the sandstone layers are interbedded, or sandwiched, between the mudstone layers.

Mudstone and sandstone are both sedimentary rocks that form through the consolidation of sediment, but they have different characteristics due to the different types of sediment that they are composed of. Mudstones are made up of fine-grained sediment, such as clay minerals, and have a smooth, slippery texture. Sandstones, on the other hand, are made up of coarse-grained sediment, such as sand, and have a rough, grainy texture.

Mudstone interbedded with sandstone can form in a variety of environments, including rivers, lakes, and oceans. In these environments, alternating layers of mud and sand can be deposited as the sediment is transported by water. Over time, the sediment in these layers becomes compacted and cemented together to form rock.

Overall these bedding measures between 2 – 3 metres. Most of the layers mudstone and sandstone measure around 20 -50 cm.



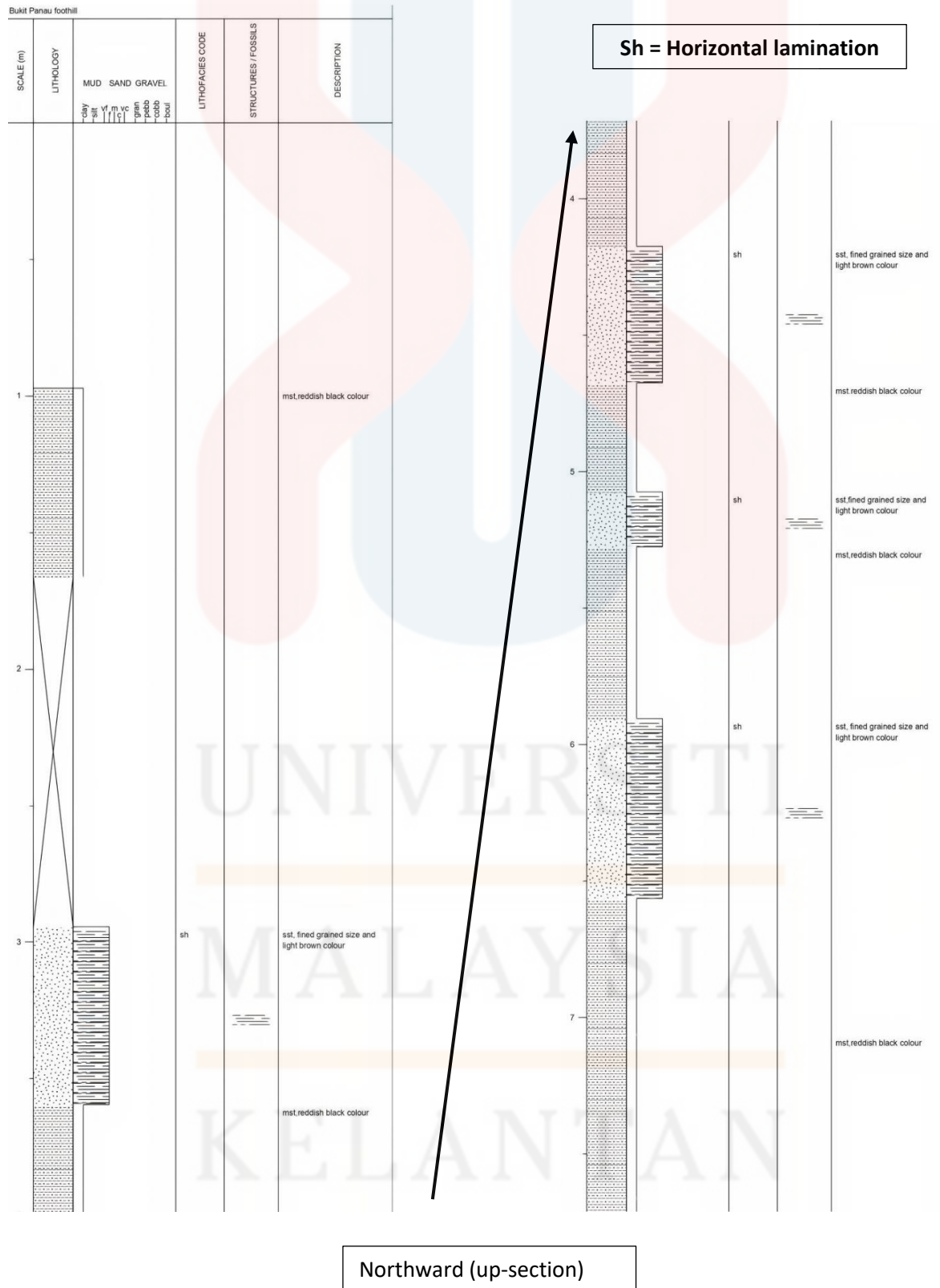
Fig 5.7: This picture shows the interbedded sandstone and mudstone clearly

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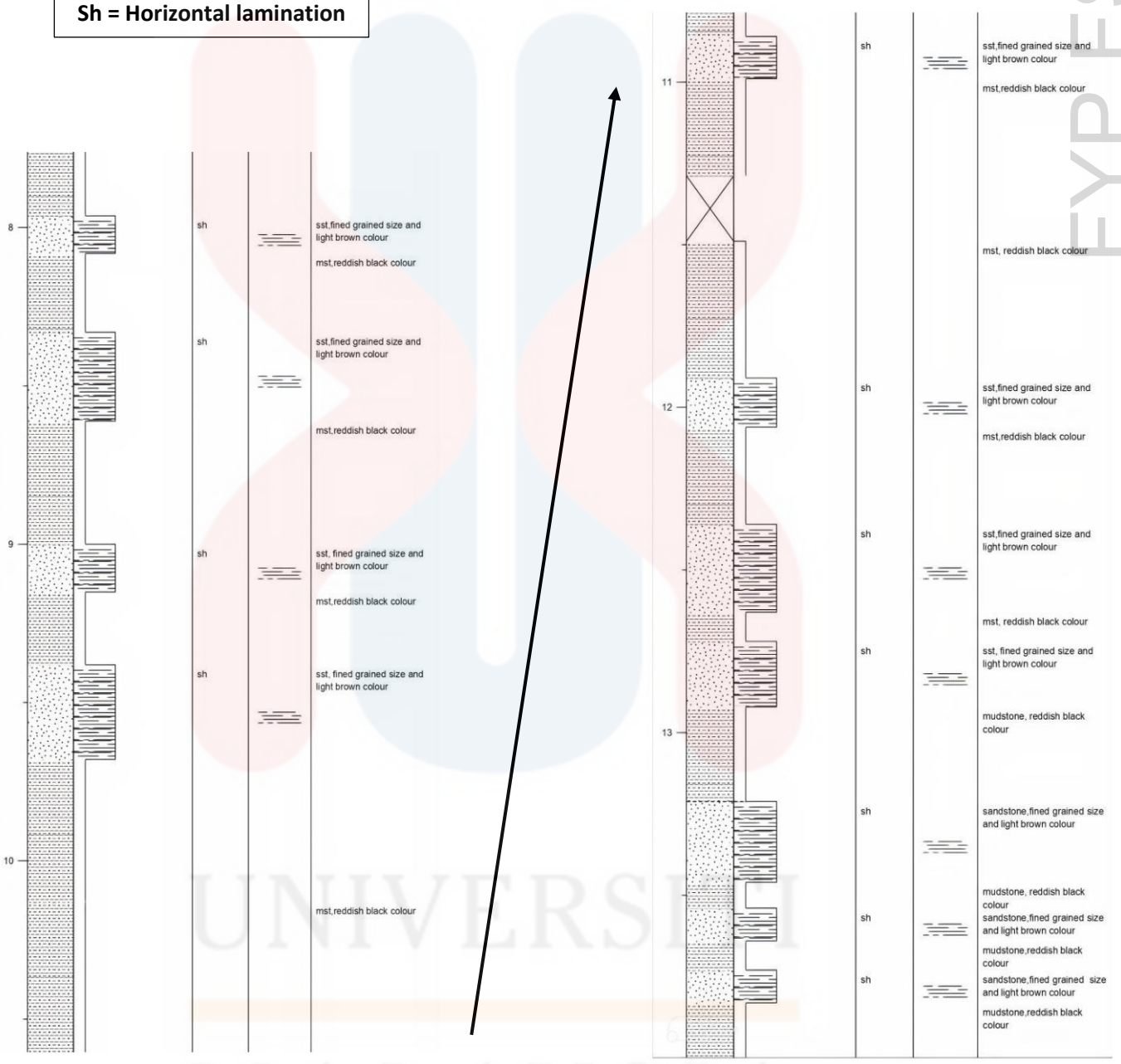
5.3 Field Observation

5.3.1 Litholog

Fig 5.14: The lithology interbedded sandstone and mudstone from Bottom to Upward at foothill of Bukit Panau



Sh = Horizontal lamination



Northward (up-section)





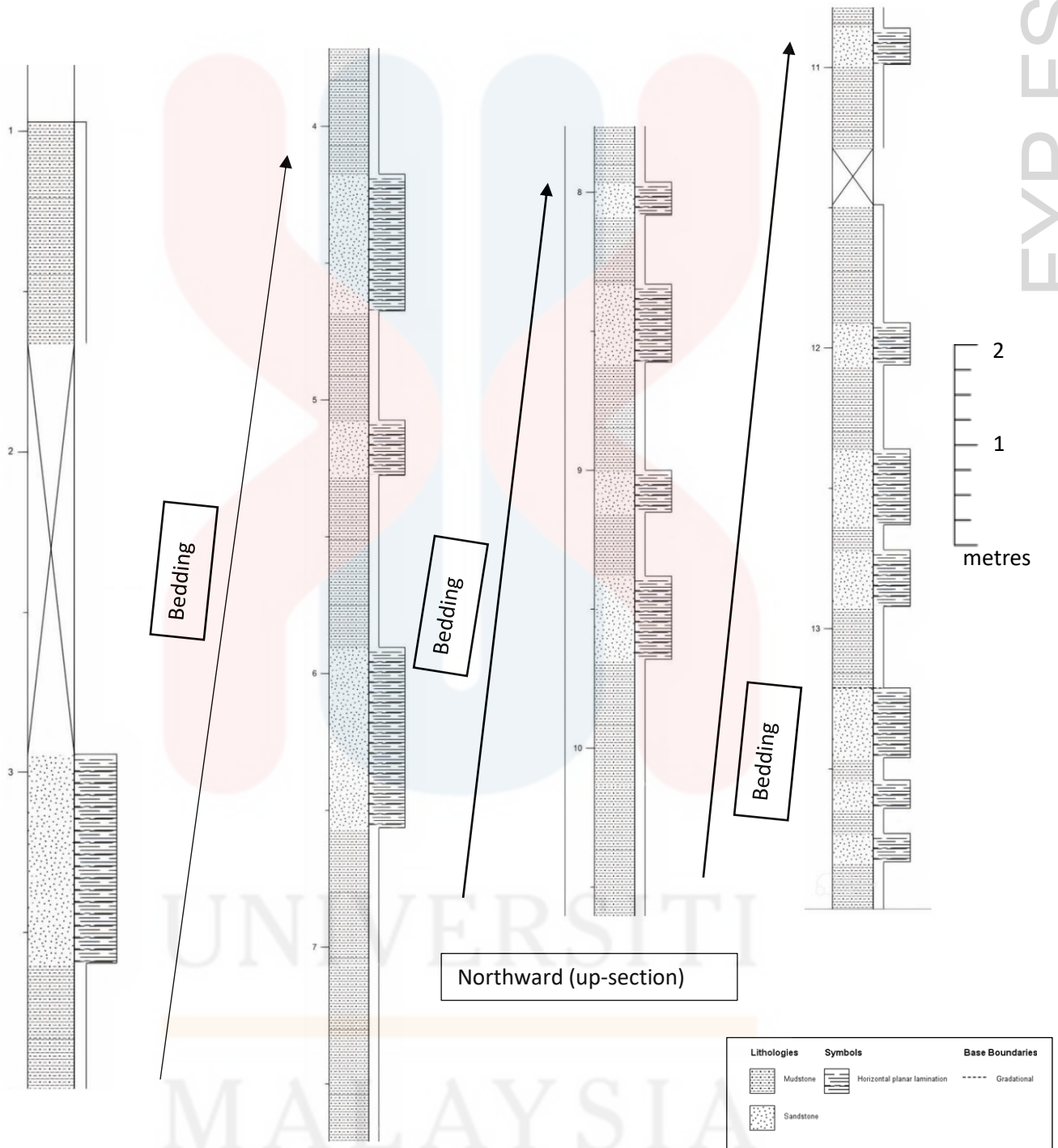
Lithologies	Symbols	Base Boundaries
 Mudstone	 Horizontal planar lamination	 Gradational
 Sandstone		

Fig 5.15: The overall lithofacies interbedded sandstone and mudstone from Bottom to Upward at foothill of Bukit Panau



Sandstone interbedded with mudstone with soft-sediment deformation features and slump

Horizontal planar lamination

Depositional environment is flood plain depositional environment

5.4 Jurassic Granite unit

Granitic rocks make up the subsurface of approximately 20% of the research area, which is located in the northern section of the vicinity of Bukit Panau. Feldspar and quartz make up the majority of granite's composition; a small amount of biotite and the accessory minerals chlorites, muscovite, and pyroxene are also present. Granite is an intrusive rock. The formation of granite involves magma travelling along a plane of weakness, like bedding in sedimentary rocks, and generating a layer as it moves through grey to greyish shale, sandstone, mudstone, and shale. This intrusion has cut through the Panau Formation rocks in the study region, which are formed of interbedded layers of sandstone and mudstone. It is possible that it simply pushed the surface of the Panau Formation upward. The samples show that all of the grains are coarse grained, which indicates that slow crystallisation of magma below the surface of the Earth took place. These findings are based on hand specimens that were collected from exposed granite in the study location



Fig 5.16: Hand specimen of sample 1 of granite



Fig 5.17: Hand specimen of sample 2 of granite

5.5 Alluvium

The research region near Bukit Panau indicates that alluvium is extensively dispersed, accounting for roughly 70% of the whole study area. Commonly found in low plain locations, alluvium deposit is created at river valleys and foot ridges, between 10 and 20 metres above sea level. Smaller streams like the Sungai Kelantan today show alluvium deposits ranging in size from fine particles of silt and clay to massive particles of sand, pebble, and granule. These sediments were found on top of the granite and Panau Formation rocks, which were not conformable. In addition, plantations make up a significant portion of these alluvium deposits.

The majority of alluvium is of Quaternary or younger geologic age. The quaternary epoch is distinguished on the geological time scale by the creation of river valleys and the shifting of river courses, both of which are the results of cultural progress. Due to geomorphological changes, alluvium deposits have been exposed to weathering on Earth's surface.



Fig 5.20: Quaternary deposit of agricultural area

MALAYSIA

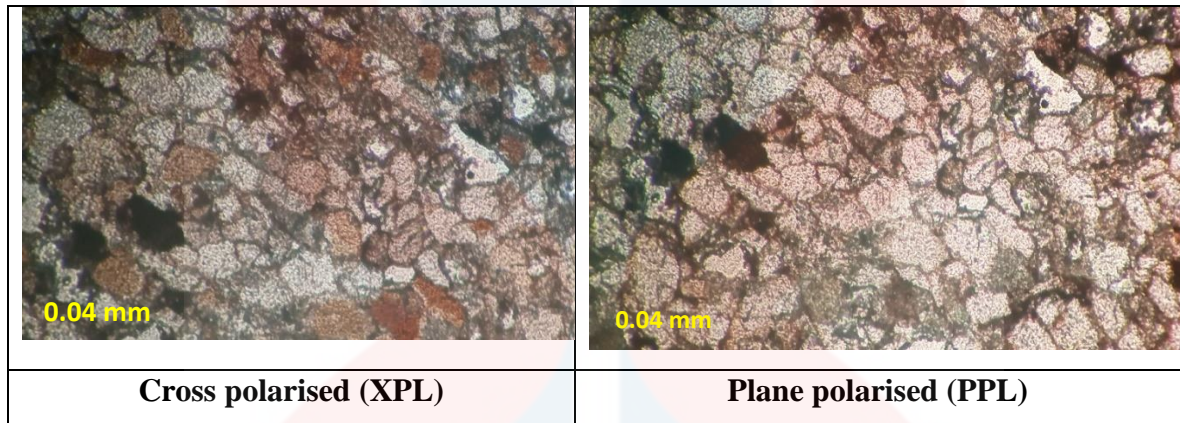
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5.6 Analysis

5.6.1 Petrography

5.6.1.1 Sandstone

Sample 1



Microscopic view on sample 1 (sandstone)

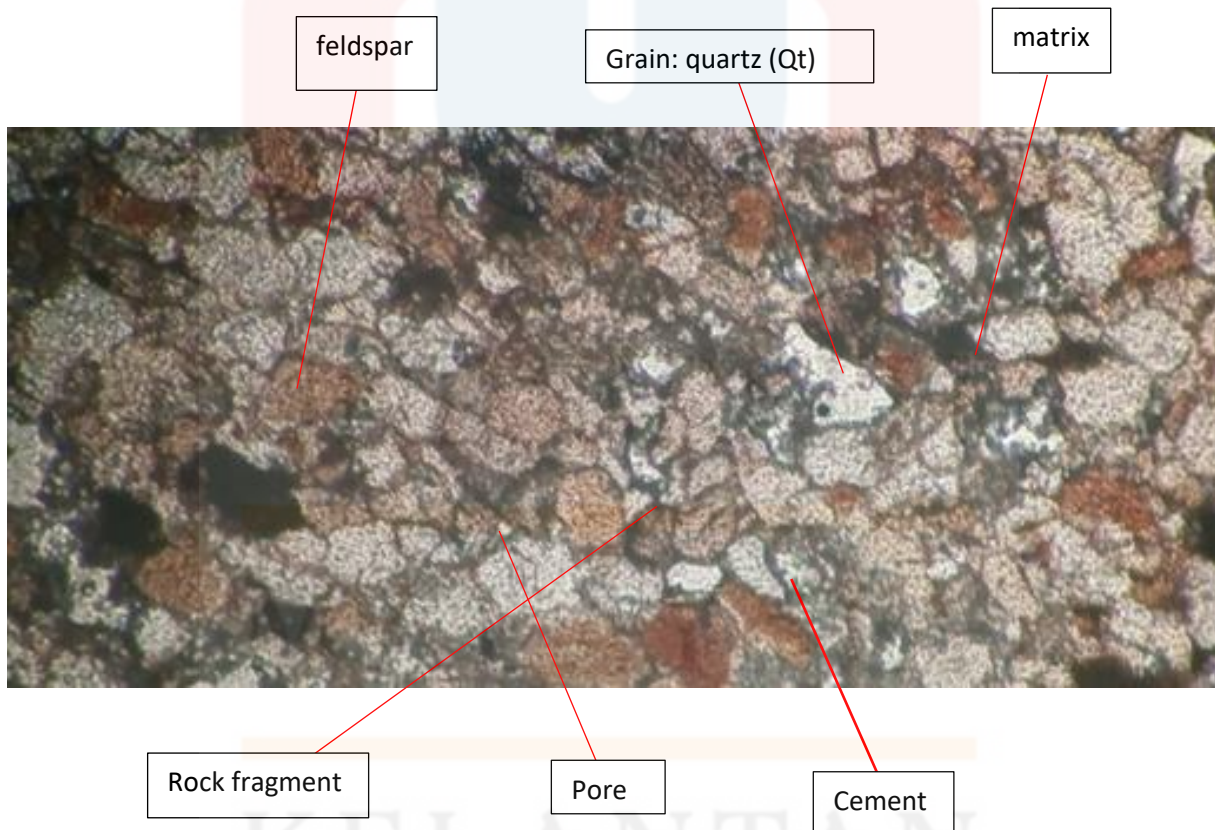
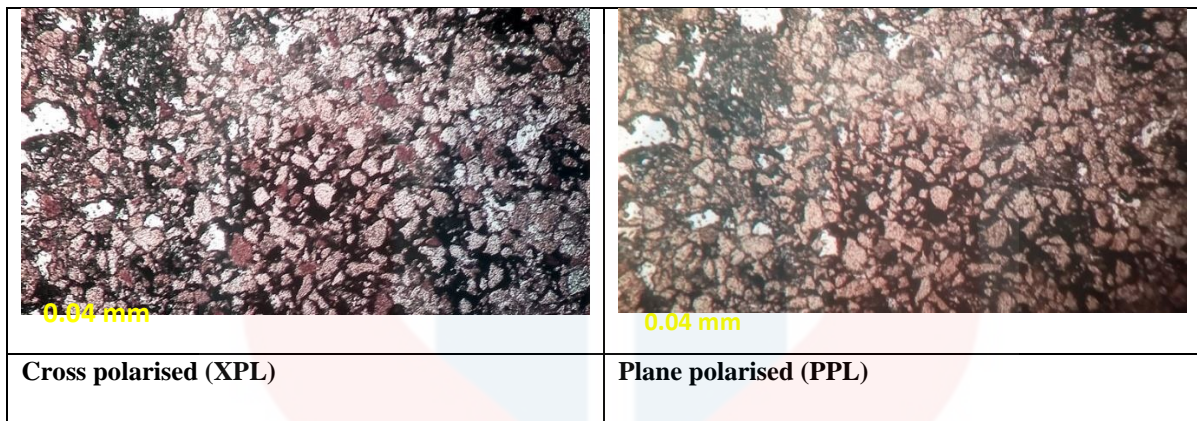


Fig 5.8: shows the rock sample with cross polarised with lable

Sample 2



Microscopic view on sample 2 (sandstone)

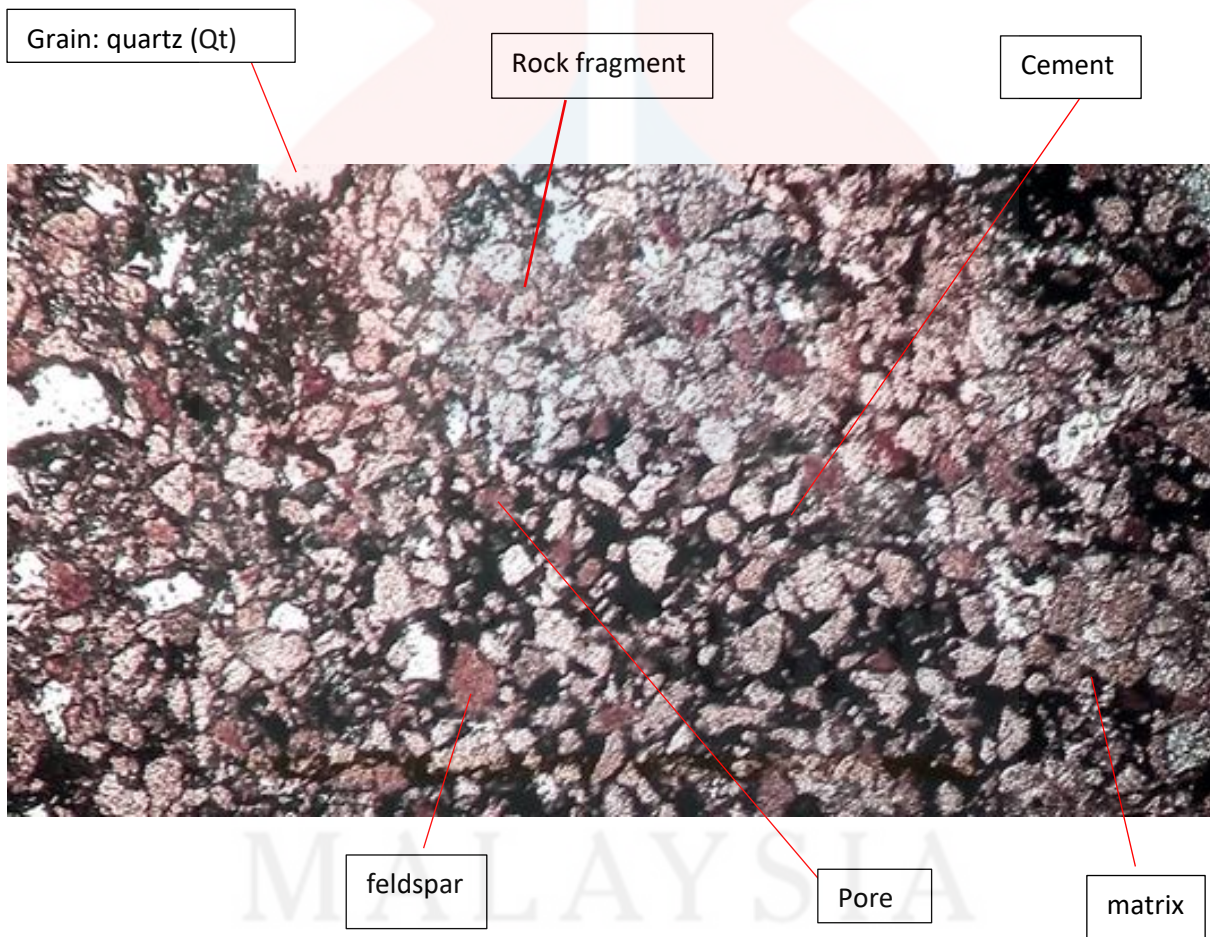
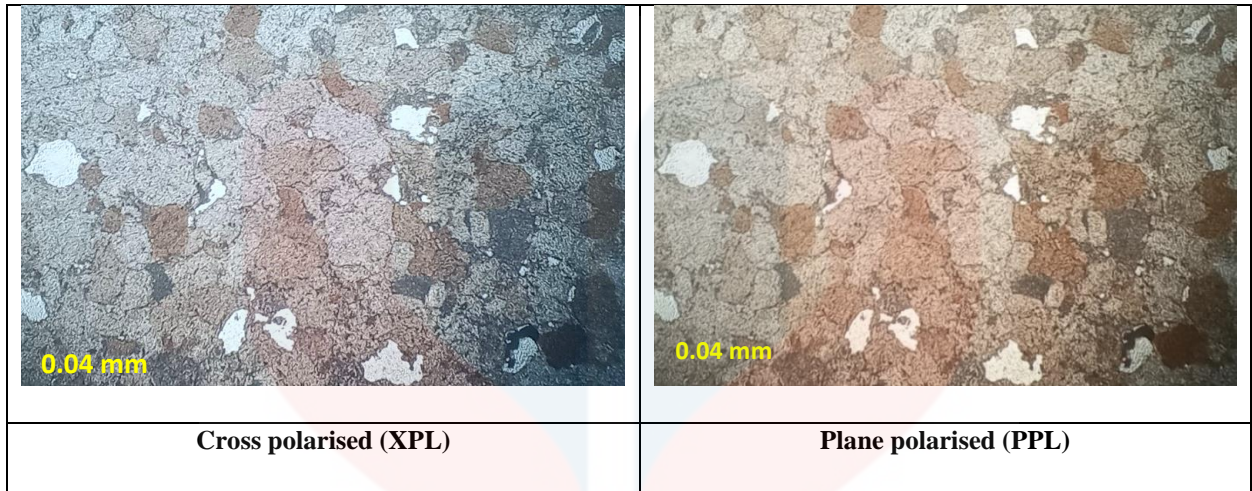


Fig 5.9: shows the rock sample with cross polarised with lable

Sample 3



Microscopic view on sample 3 (sandstone)

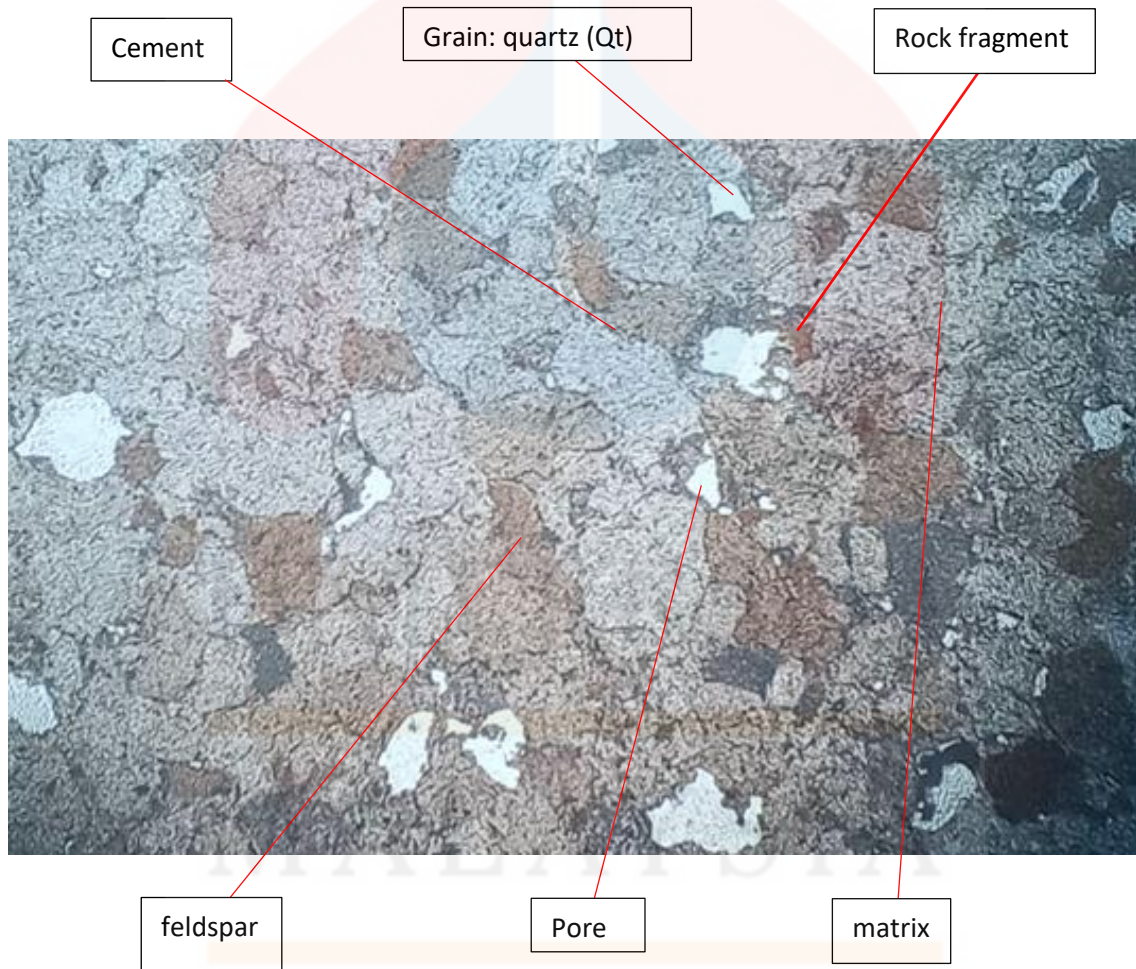
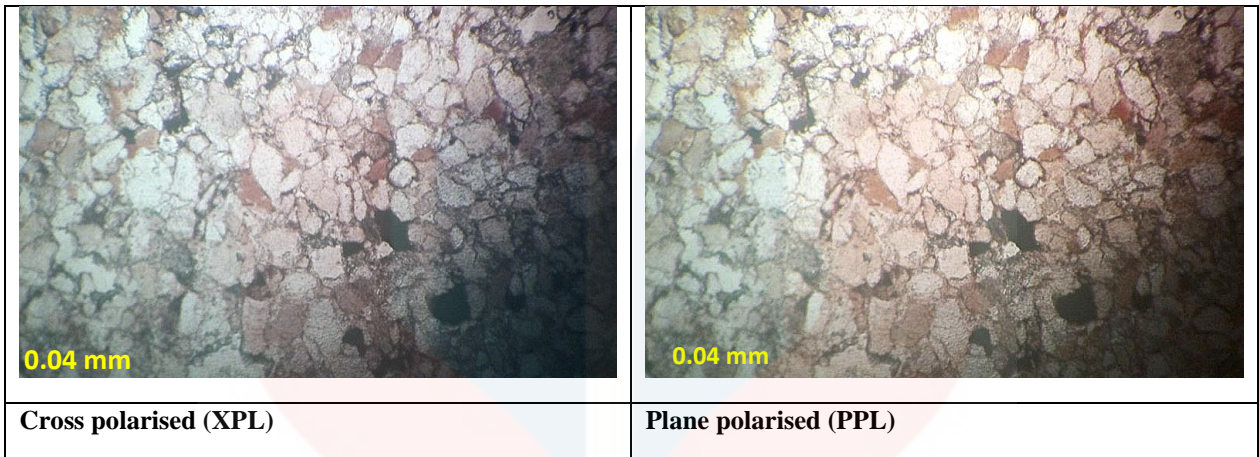


Fig 5.10: shows the rock sample with cross polarised with lable

Sample 4



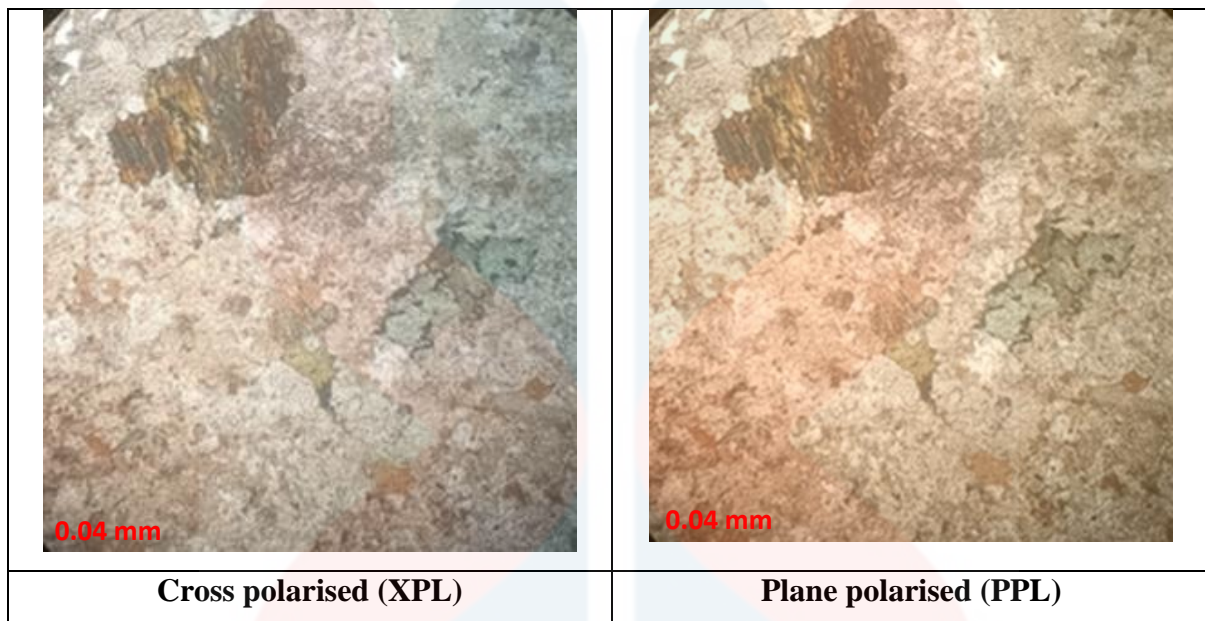
Microscopic view on sample 4 (sandstone)



Fig 5.11: shows the rock sample with cross polarised with lable

5.6.1.2 Granite

Sample 1



Microscopic view on sample 1 (granite)

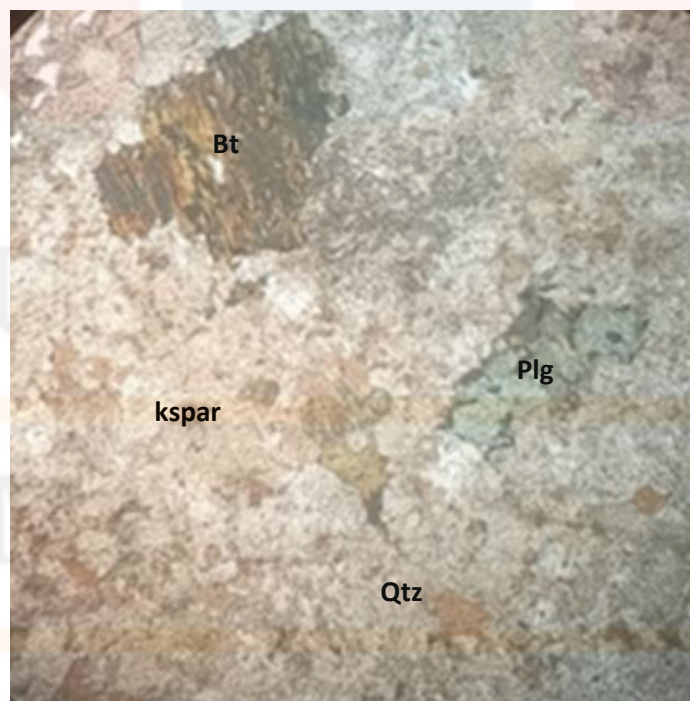
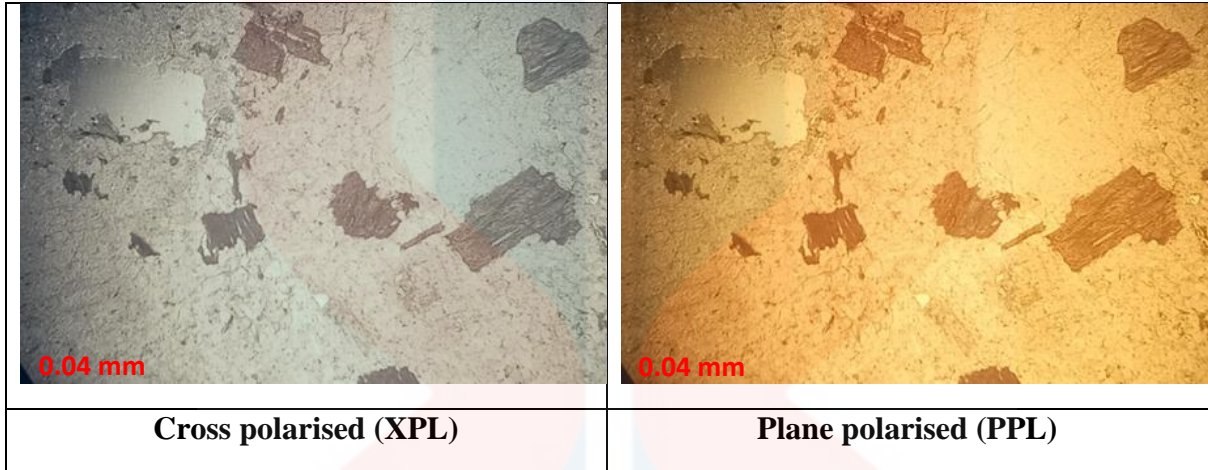


Fig 5.18: shows the Granite rock sample with cross polarised with lable

Sample 2



Microscopic view on sample 2 (granite)

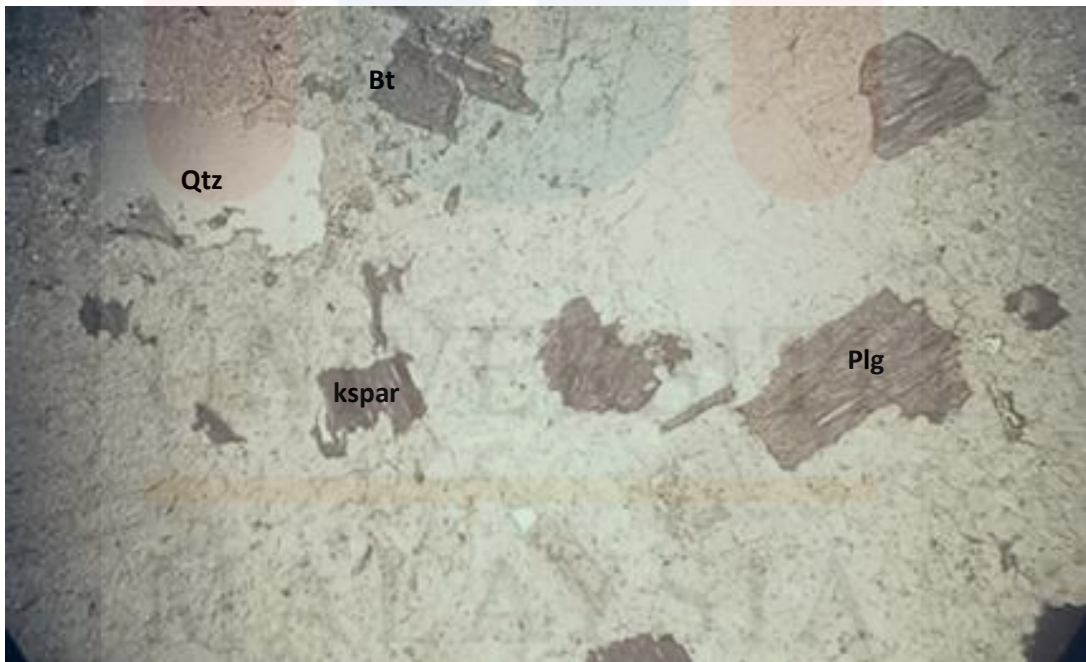


Fig 5.19: shows the Granite rock sample with cross polarised with lable

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5.6.2 Rock Classification

5.6.2.1 Sandstone classification (McBride vs Folk vs Dickinson)

Rock sample	Mineral Composition						
	Quartz (Qt) = (Qm+Qp)	Total (%)	Feldspar (F)	Total (%)	rock fragments	Total (%)	Total mineral
Sample 1	1100	65	206	13	374	22	1680
Sample 2	981	76	98	8	210	16	1289
Sample 3	1066	78	101	7	200	15	1367
Sample 4	1220	85	95	6	118	9	1433

Table 5.2: shows the point counting & percentage of mineral composition of sandstone of Panau Formation in the study area

McBride

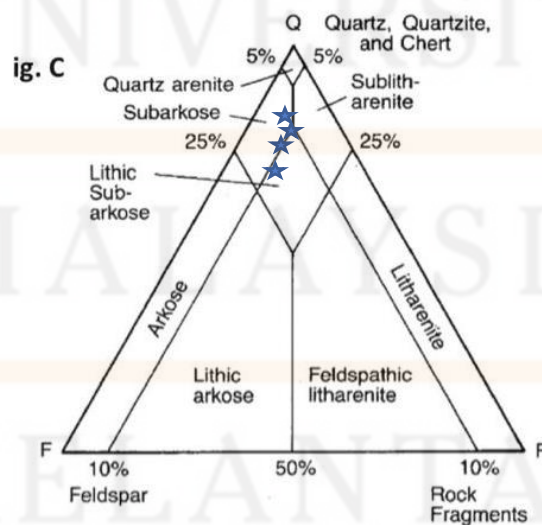
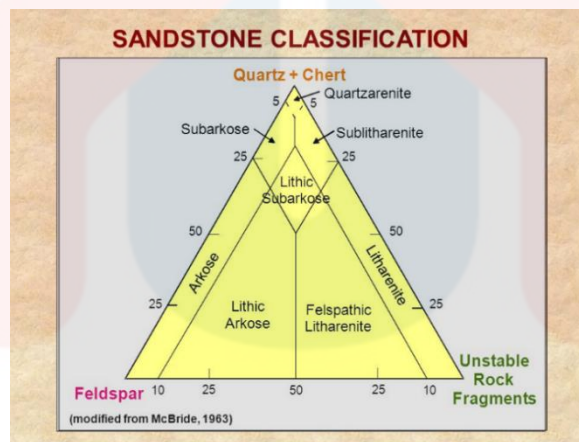


Fig 5.20: the triangle diagram of mcbride (Garzanti, 2019)

Name of rock:	lithic subArkose sandstone
Magnification:	4 x 10
Type of rock:	Clastic sedimentary rock
Classification:	McBride (1963)
Microscopic:	This is thin section of sandstone, the colour is brownish (ppl), dark brown (xpl)

Mineral composition	Total (%)				Description of mineral
	Sample 1	Sample 2	Sample 3	Sample 4	
Mono(QM)+Poly(QP) = Quartz (Q)	65	76	78	85	low relief true colour is colourless anhedral shape no pleochroism hexagonal
Alkali Feldspar (A)	13	8	7	6	Monoclinic Conchoidal True colour is colourless No pleochroism Moderate relief
Rock Fragments/lithics (L)	22	16	15	9	Detrital particles formed by the combination of two or more mineral grains

The petrographic study of a sandstone sample found that quartz is the most prominent detrital mineral, accounting for approximately 60-70% of the total. Quartz grains are massive anhedral crystals with angular to subrounded shapes. Cement contains silica and iron oxide as minerals. The feldspars observed are mostly alkali feldspar that has been worn substantially, giving it a brown appearance. They account for around 13%. The rock pieces or lithic elements account for around 22% of the total. The sample comprises mica, which has more biotite than

muscovite. This might be caused by the reduction or oxidation of iron oxide. Based on quartz, feldspar, and rock fragment classifications McBride (1963), the rock was classed as lithic subArkose sandstone.

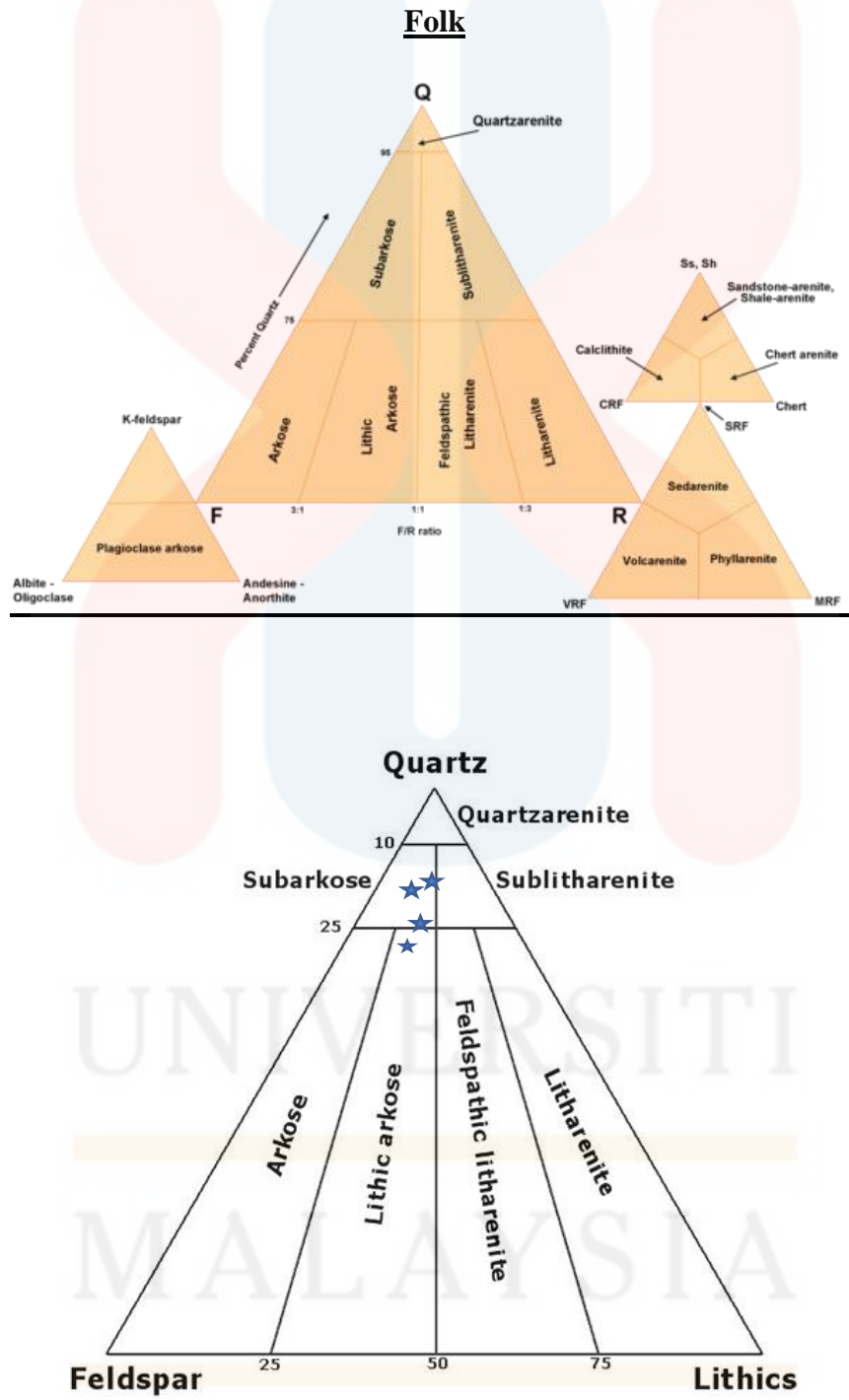


Fig 5.21: the triangle diagram of Folk (Garzanti, 2019)

Name of rock:	lithic Arkose sandstone
Type of rock:	Clastic sedimentary rock
Classification:	Folk (1970)

Based on the petrography comparison between McBride and Folk that have been conducted, There are several issue regarding this two classification which is naming of classification of rock that differ between folk and McBride. Lithic arkose and lithic subarkose are two types of sandstone that differ in the types of rocks that make up their grains. Sandstone is a type of sedimentary rock that is made up of small grains of minerals and rocks. These grains are held together by a natural cement, such as calcite or silica.

Lithic arkose is a type of sandstone that contains a high percentage of feldspar, a type of rock-forming mineral. It is called "lithic" because it contains a high percentage of rock fragments, or lithics. Arkose is a type of sandstone that is formed from weathering and erosion of granitic rocks, which are rocks that are rich in feldspar.

Lithic subarkose is similar to lithic arkose, but it contains a lower percentage of feldspar. It is also made up of rock fragments, but these fragments are derived from a different type of rock than those in lithic arkose. Subarkose is a type of sandstone that is formed from the weathering and erosion of rocks other than granitic rocks, such as metamorphic or sedimentary rocks.

In summary, the main difference between lithic arkose and lithic subarkose is the type of rock that makes up the grains in the sandstone. Lithic arkose is made up of grains that are derived from granitic rocks, while lithic subarkose is made up of grains that are derived from other types of rock.

Conclusion

Folk, McBride, and Dickinson are three different classification systems that are used to classify sandstones based on their characteristics.

The Folk classification is based on the textural characteristics of the sandstone, such as grain size, sorting, and roundness. It divides sandstones into four main categories: quartz arenites, arkoses, graywackes, and lithic wackes.

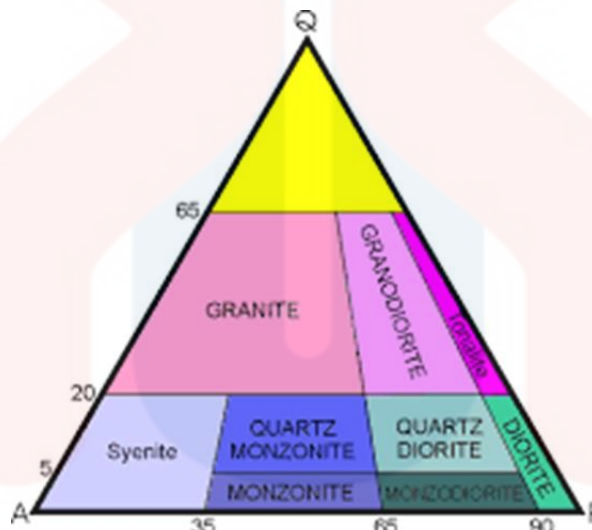
The McBride classification is based on the composition and texture of the sandstone, as well as the composition of the matrix (the material that surrounds the sand grains in the rock). It divides sandstones into four main categories: quartzose, feldspathic, lithic, and rock-fragment-rich.

The Dickinson classification is based on the depositional environment of the sandstone, taking into account the source of the sediment, the transportation process, and the final depositional setting. It divides sandstones into five main categories: fluvial, aeolian, shallow marine, deep marine, and lacustrine (lake).

Each of these classification systems has its own set of characteristics that are used to distinguish one type of sandstone from another, and they are often used in combination to provide a more comprehensive understanding of the rock.

5.6.2.2 Igneous rock classification QAPF Diagram

Name of rock:	Granite
Magnification:	4 x 10
Type of rock:	Igneous rock
Classification:	Streckeisen (1973)
Microscopic:	This is thin section of igneous rock, true colour is brown and the interference colour is greyish black, compose of minerals biotite, plagioclase, quartz ,olivine and feldspar



Highly Modified IUGS Classification of Phaneritic Igneous Rocks

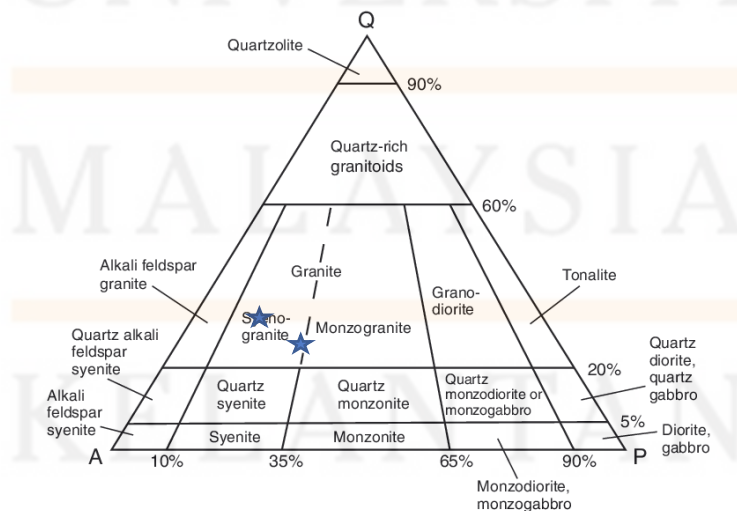


Fig 5.21: the triangle diagram of IUGS classification Streckeisen, A. (1991).

Mineral composition	Total (%)		Description of mineral
	Sample 1	Sample 2	
Quartz	29	25	low relief true colour is colourless anhedral shape no pleochroism hexagonal
Alkali Feldspar	34	40	Monoclinic Conchoidal True colour is colourless No pleochroism Moderate relief
Plagioclase	20	17	Colorless No Pleochroism Inclined extinction Euhedral or anhedral grains Triclinic
Biotite	12	6	Monoclinic Pseudo-hexagonal prisms Brownish Parallel extinction No twinning
Olivine	3	7	Orthorhombic Colorless irregular fractures
Muscovite	2	5	Colorless No Pleochroism Very perfect cleavage

5.7 Discussion & Interpretation

5.7.1 Tectonic Setting & Provenance

Dickinson triangle model relating provenance and tectonic provinces

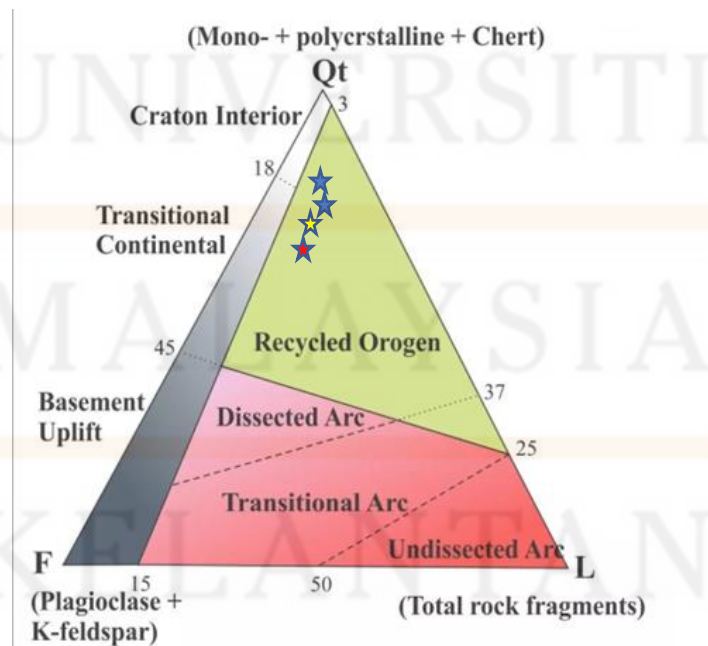
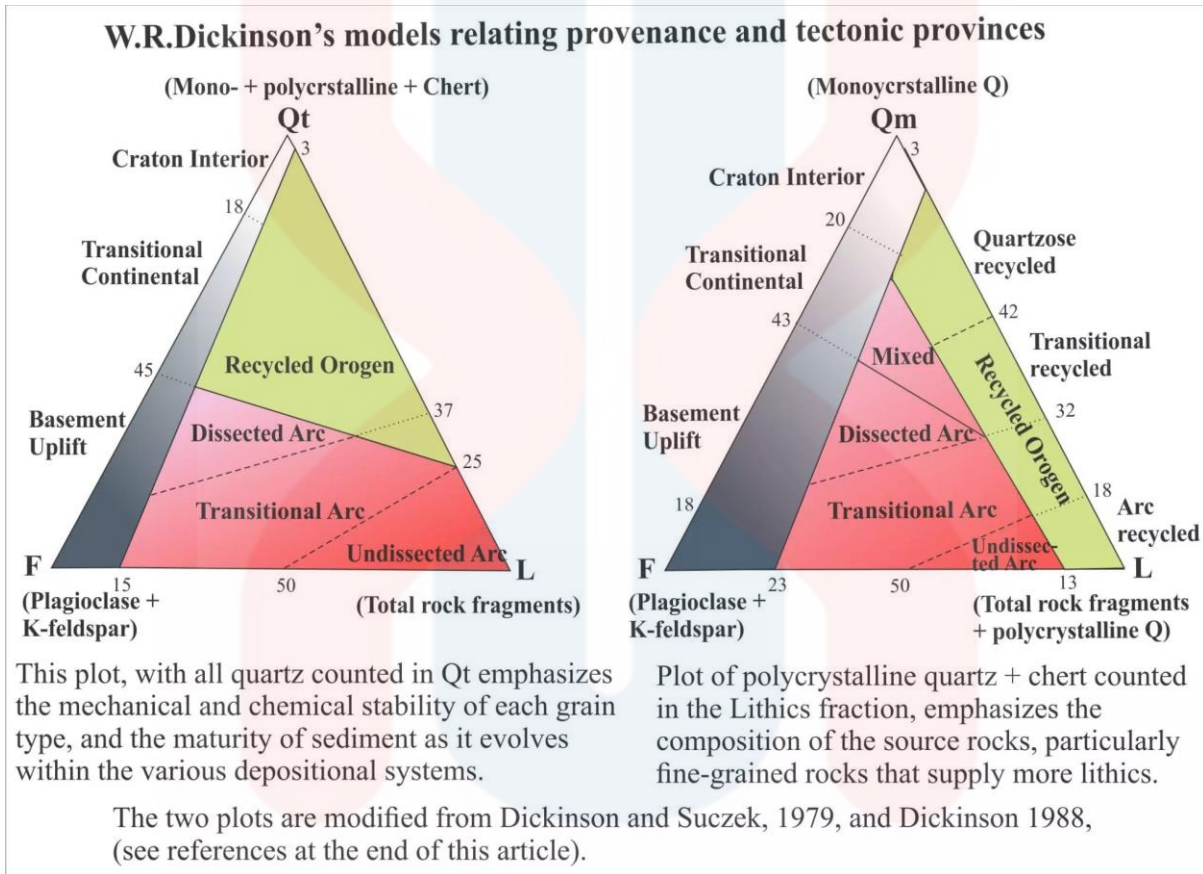


Fig 5.21: the triangle diagram of Dickinson model Weltje, Gert. (2006).

The Dickinson classification is a system for categorizing sedimentary rocks based on their tectonic setting and provenance. It was proposed by geologist K.G. Dickinson in 1979.

According to this classification, sedimentary rocks can be divided into four main categories:

1. Cratonic: These are sedimentary rocks that form in the stable, interior regions of continents, known as cratons. They are typically low in grade metamorphism and have a low tectonic setting.
2. Oceanic: These are sedimentary rocks that form in the deep ocean basins, far from any continental influence. They are typically high in grade metamorphism and have a high tectonic setting.
3. Continental margin: These are sedimentary rocks that form along the edges of continents, in the shallow seas and coastal plains. They have a moderate tectonic setting and may be subjected to moderate grade metamorphism.
4. Island arc: These are sedimentary rocks that form in the arc-shaped chain of islands that can sometimes be found along the edges of tectonic plates. They have a high tectonic setting and may be subjected to high grade metamorphism.

The provenance of a sedimentary rock refers to the place where the sediment was originally deposited. This can be used to infer the tectonic setting and geologic history of the rock. For example, rocks with a cratonic provenance may have formed in an area of low tectonic activity, while rocks with an oceanic provenance may have formed in an area of high tectonic activity. Based on plotting on Dickinson triangle, its located on recycled orogen.

A recycled orogen is a mountain range that has been subjected to multiple periods of orogenesis, or mountain building, over the course of its geologic history. This can occur when a mountain range is subjected to tectonic forces that cause it to be uplifted and then subsequently eroded, followed by a later period of uplift and erosion.

During each period of orogenesis, sediment is typically eroded from the mountain range and deposited in nearby basins. Over time, this sediment can be subjected to various geologic processes such as lithification, deformation, and metamorphism, leading to the formation of new sedimentary rock layers.

The term "recycled orogen" is often used to describe mountain ranges that have undergone multiple episodes of uplift and erosion, and whose geologic history is characterized by repeated cycles of sedimentation and tectonic activity. These mountain ranges may exhibit a complex geologic structure, with layers of sedimentary rock from different periods of orogenesis stacked on top of one another.

5.7.2 Depositional Environment

According to field observations at Bukit Panau, the hill is mostly red to maroon sandstone and mudstone successions. The depositional environment of mudstone and sandstone refers to the table 5.3 which is geological setting in which the rocks were formed. The characteristics of these rocks, such as their composition, texture, and the presence of any fossils or other features, can provide clues about the depositional environment in which they were formed.

Even though, the outcrop seems to be highly weathered, it can be determined the red to maroon strata are caused by iron in the sediments during detrital burial and hematite conversion during early diagenesis in non-marine environments like Bukit Panau in fig 5.12. The location of the lithology can be found at the base of the Bukit Panau hill. In addition to that, it is made up of layers of arenaceous and argillaceous rocks that are interbedded. The rock is referred to as being of the Panau Formation. Parallel lamination in sandstone and mudstone made Bukit Panau a floodplain depositional in fig 5.13.

Sand, gravel, and even some larger rocks are sometimes deposited in the point bars and channel beds of rivers that meander, while mud is typically deposited in the floodplains. Because of this, the deposits left behind by meandering rivers eventually take the form of huge sand masses, which take the form of lenses and shoestrings. A meandering river can be identified by its lateral accretion surfaces, and these surfaces are frequently accompanied with a relatively high proportion of overbank facies.

A floodplain is the term used to describe the low-lying land on either side of a river. When rivers flood, the floodplain will be covered with fine-grained material that has been carried there by the water. As the floodplain is greater than the channel, deposits of meandering river systems are dominated by fine-grained material whereas coarse-grained channel deposits tend to be relatively modest.

Since the oldest formation was deposited before the youngest formation, the entire sequence of rock units that make up the Panau Formation is interpreted as the result of regression that took place across the entire research area at some point after the deposition of the oldest formation and before the deposition of the youngest formation. According to one theory, the Panau Formation was laid down in an alluvial setting, which can be conceptualised as a winding river.

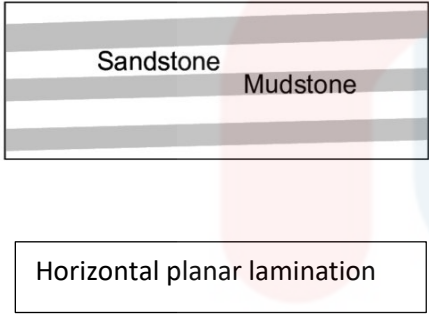
OBSERVED SEQUENCES	DEPOSITIONAL ENVIROMENT	LITHOFACIES	LITHOFACIES ASSOCIATION	
 <p>The diagram shows a vertical sequence of rock layers. From top to bottom, there are alternating layers of Sandstone (light brown) and Mudstone (grey). The layers are labeled 'Sandstone' and 'Mudstone'. Below the layers, a box contains the text 'Horizontal planar lamination'.</p>	<p>FLOOD-STAGE DEPOSITION OF SAND SILT AND CLAY</p>	<p>INTERBEDDED SANDSTONE MUDSTONE</p>	<p>MEADERING CHANNEL SEQUENCE</p>	<p>FLOODPLAIN VERTICAL ACCRETION</p>

Table 5.3: shows the overall of the lithofacies analysis in the foothill of Bukit Panau

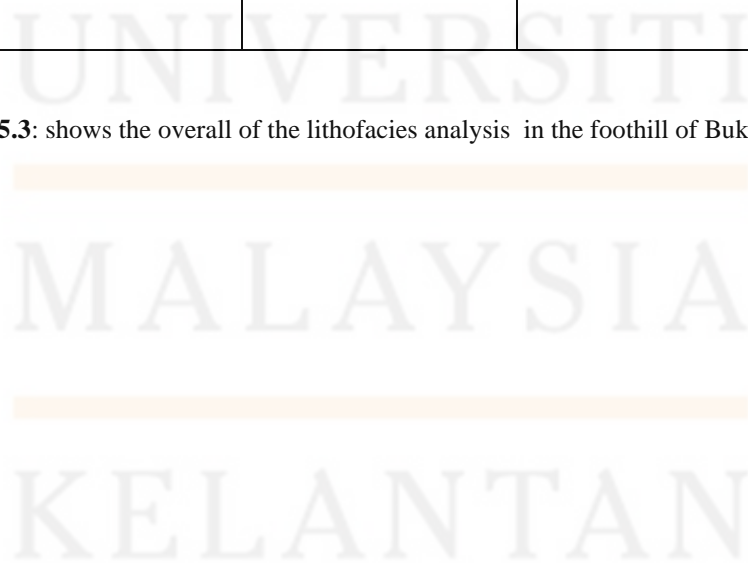




Fig 5.12: The outcrop shows the depositional environment in Bukit Panau.

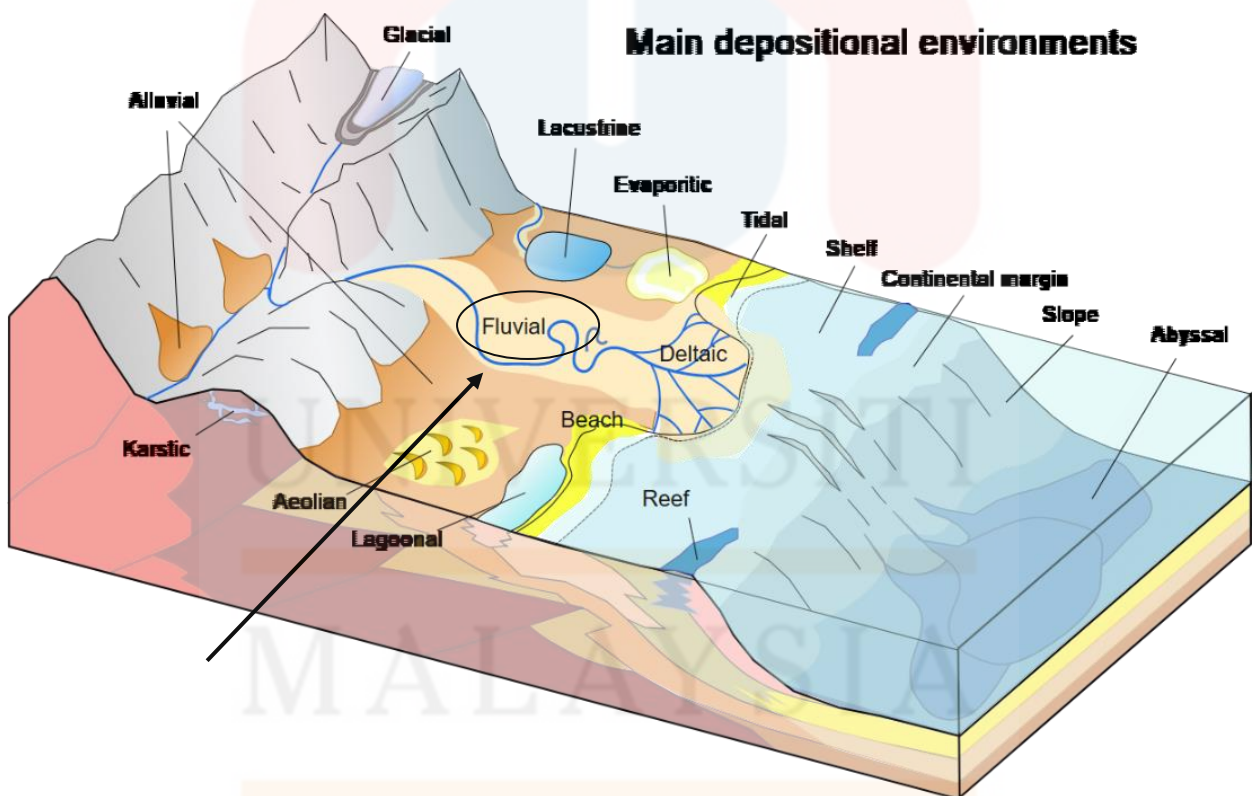


Fig 5.13: This pic shows the fluvial environment on that circle area (McGoldrick, S.2021)

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study has established three aims. Research undertaken was capable of achieving all three aims. The primary objective is to construct and update a 1:25,000-scale geological map of the Bukit Panau region. This chapter will finish the findings of a field investigation and petrographic analysis of thin sections prepared from Bukit Panau-area rock samples. The mapping area covers roughly 25 km². The geological map of Bukit Panau, Tanah Merah, Kelantan with a scale of 1:25,000 is developed based on the general geology, lithostratigraphy, and sedimentology of the studied region.

Determine the stratigraphic relationship between the Panau Beds and the granite at Bukit Panau. Alluvium, Panau bed (sandstone interbedded mudstone), and granite are the four lithostratigraphic units of the research region. In the studied area, the lithostratigraphic ages are Jurassic, Cretaceous, and Quaternary. According to The Malaysian and Thai Working Groups (2006), prior evidence suggested that the overlaying rock units at Bukit Panau were Cretaceous in age. However, according to the most recent research, the age of Bukit Panau, which is said to be younger than granite based on its formation, can be correlated as there are no detectable intrusions and it has been demonstrated that the nonconformity between granite and Panau bed contact is visible despite the fact that the outcrop is highly weathered.

The depositional environment of Bukit Panau was identified with the aid of petrography on 36 sedimentary logs done in the study region in accordance with the depositional environment specification of this study. The sandstone and mudstone rocks discovered at Bukit Panau serve as an indicator for determining the depositional environment in the area under study. The area under study is characterised as a fluvial depositional ecosystem. The existence of graded bedding with fining upward sequence and horizontal lamination structure in the sedimentary rock sequence of the Bukit Panau region suggested that the rock series was deposited in a meandering river of a fluvial environment. By evaluating petrographic thin sections of sandstone, it is possible to determine the origin of the research region, which consists of recycled orogens based on grain size and shape. The plots of Panau Formation sandstones on the Qt-F-L diagram indicate that the sandstones' detritus was formed from

recycled orogens that shed quartzose and mixed continental debris. Recycled orogens are zones of plate convergence, where the collision of large plates produced raised source regions along the collision suture band.

6.2 Recommendation

In the future, researchers will need to do additional exploration and identify the numerous bedrock characteristics. Because the research does't not covered all of study area. It is recommended that more research be done on Bukit Panau's hill in order to learn more about the unconformity contacts, determine the numerous bedrock of the slope sequence at the foothill of Bukit Panau, and determine which formation it is a part of because it is thought that Bukit Panau has more than one formation. While the north-west of Bukit Panau has not yet been explored or examined, it is recommended that the study's continuation take place there.

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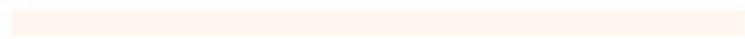
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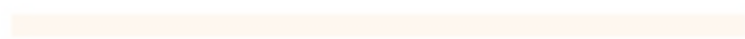
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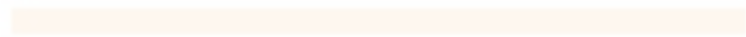
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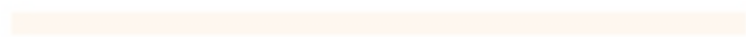
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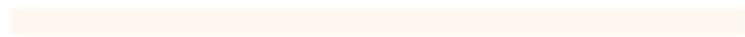
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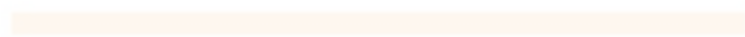
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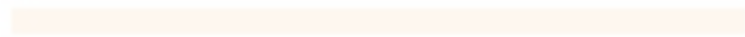
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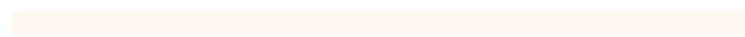
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