GEOLOGICAL MAPPING AND POTENTIAL SEAWATER INTRUSION IN KELANTAN USING ELECTRICAL RESISTIVITY IMAGING METHOD

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DECLARATION

I hereby declare that the work embodied in here is the result of my own research except for the excerpt as cited in the references.

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GEOLOGICAL MAPPING AND POTENTIAL SEAWATER INTRUSION IN KELANTAN USING ELECTRICAL RESISTIVITY IMAGING METHOD

ABSTRACT

The geophysical analysis of groundwater exploration mainly focused on Kota Bharu coastal area. The study area is located in Kota Bharu with the centre coordinate of N 6°12'65.980", E 102°33'06.340". The study area covers from the bottom part of Pengkalan Chepa to the upper part of Bachok. The study area covers a 25 km2 of box. The study area has settlements scattered all over which indicates the annual withdrawal of groundwater is high. The objectives of the research are to produce an updated map of Lojing, Gua Musang, and to perform the geophysical analysis of seawater intrusion in the study area. The geology of the study area in Lojing was determined by carrying out ground mapping to construct geological map. The study area has 4 types of lithology which are mostly mudstone, followed by marble, slate and feldsphatic wacke. New geological map produced by ArcGIS software based on the geological data. In order to carry out geophysical analysis, three places with high human settlements were chosen and conducted electrical resistivity imaging technique and 2-D resistivity profiles were produced. Sea water intrusion evaluated by using the result obtained from the analysis of resistivity profile. All three results show intrusion of seawater in the second aquifer where the depth is more than 50 metres. The level of intrusion indicates that the study area is experiencing early stages of seawater intrusion. In future, scientists are recommended to utilize increasingly modern research centre instruments to build the exactness and accuracy of the after effect of the investigation.

PEMETAAN GEOLOGI DAN PENILAIAN PENCEROBOHAN AIR LAUT DI KELANTAN MENGGUNAKAN KAEDAH PENGIMEJAN RESISTIVITI.

ABSTRAK

Analisis geofizik mengenai penerokaan air bawah tanah terutamanya memberi tumpuan kepada kawasan pantai Kota Bharu. Kawasan kajian terletak di Kota Bharu dengan koordinat pusat N 6 ° 12'65.980 ", E 102 ° 33'06.340". Kawasan kajian merangkumi bahagian bawah Pengkalan Chepa ke bahagian atas Bachok. Kawasan kajian meliputi 25 km2 kotak. Kawasan kajian mempunyai penempatan yang tersebar di seluruh yang menunjukkan pengeluaran tahunan air bawah tanah tinggi. Objektif penyelidikan ini adalah untuk menghasilkan peta terkini Lojing, Gua Musang, dan melaksanakan analisis geofizik pencerobohan air laut di kawasan kajian. Geologi kawasan kajian di Lojing ditentukan oleh pemetaan tanah untuk membina peta geologi. Kawasan kajian mempunyai 4 jenis lithology yang kebanyakannya adalah batu lapis, diikuti oleh marmar, sabak dan feldsphatic wacke. Peta geologi baru yang dihasilkan oleh perisian ArcGIS berdasarkan data geologi. Untuk menjalankan analisis geofizik, tiga tempat dengan penempatan manusia yang tinggi dipilih dan dijalankan teknik pencitraan resistif elektrik dan profil resistif 2-D dihasilkan. Pencerobohan air laut dinilai dengan menggunakan keputusan yang diperolehi daripada analisis profil rintangan. Ketiga-tiga hasil menunjukkan pencerobohan air laut di akuifer kedua di mana kedalamannya lebih dari 50 meter. Tahap pencerobohan menunjukkan bahawa kawasan kajian mengalami tahap awal pencerobohan air laut. Di masa depan, saintis disyorkan untuk menggunakan instrumen pusat penyelidikan yang semakin moden untuk membina ketepatan dan ketepatan kesan penyelidikan selepas itu.

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CHAPTER 1

1.0 INTRODUCTION

1.1 BACKGROUND OF STUDY

Water plays a critical role in human life because human need water to stay alive and to carry out daily activities either as in domestic uses or economic uses. As human population keeps growing over time, the demands for water keep increasing as well. For Malaysia, it is a tropical country and thus, receiving an adequate amount of rainfall throughout the year. Supposedly, available water should be enough to cater the needs of its people. Usually people obtain freshwater by digging deep down the subsurface and obtaining the groundwater. Groundwater is regarded as subsurface water which can be stored both in confined or unconfined aquifer (Klassen & Allen, 2017). Groundwater aquifers can be characterised using water components, subsurface water interaction and the type of surface. Origin of groundwater starts from the surface layer. Water that is being absorbed from the surface, will flow down and collect as groundwater. The silo of a groundwater consumes a very long period of time. In contrast, groundwater can be extracted easily by drilling a well into aquifer. This drilling process may cause imbalance to the recharging rate and discharge rate which directly leads to a negative impact to the water resource (Muqtada et.al, 2014)

The current issue is the contamination of groundwater. Besides, groundwater aquifer is also vulnerable to seawater contamination or intrusion. This threat can usually be found in aquifers which is located near or along the coastline and which in

term is referred as coastal aquifers. Theory says that groundwater and seawater have different densities and so, these waters does not mix up. Well at least logically. Instead, freshwater and saltwater are separated by a zone. This zone is forever known as the transition zone. This zone actually contains the brackish water (Klassen et.al, 2017). The transition zone keeps both type of water at equilibrium state. The transition zone is not fixed because as it depends on several factors. It may move further inland towards the land or may be pushed towards the sea. Mapping is done to visualize the movement of water into this transition zone. It can be done by adopting hydrogeochemical and geophysical technique.

Generally, groundwater will usually find its way to the sea. But, there are numerous of cases reported happening vice versa, seawater is intruding into groundwater. This may occur under the influences of natural events and anthropogenic activities. These are the industrial, agricultural and domestic activities. This unfavourable situation caused a huge look back for the peoples who reside by the sea. Movement of saltwater toward the land will lead to saltwater intrusion into coastal aquifer that containing their main freshwater supply. This seawater intrusion may and will cause contamination of two percent to three percent of saltwater into the coastal aquifer. This will change the salinity of the fresh groundwater. Increase in the water salinity level will reduce its quality.

In recent times, it is found that the people live along the coastline of Kota Bharu, Kelantan also faces the scenario in their daily life. Therefore, coastal areas of Kota Bharu, Kelantan is chosen to carry out the study of seawater intrusion into groundwater to identify the potential of intrusion and its contamination level. Through this study, it is expected to identify the intensity of intrusion along the coastline and coastal areas of Kota Bahru, Kelantan. Drilled wells are the main source of water

supply to the residents in this area to date. Watering crops and giving their livestock drinking water are the basic uses of the water. This place also suitable to carry out this study as the agricultural activities at these coastal areas are still in active mode. Seawater intrusion into groundwater will cause unhealthy growth in plants and loss to the farmers. In order to identify the aquifers of seawater intrusion, the electric resistivity imaging method will be used. When an aquifer has high percentage of salinity due to seawater, the resistivity will be low and vice versa if the salinity percentage is low. Therefore, we can visualize the intensity of seawater intrusion in these aquifers.

1.2 PROBLEM STATEMENT

The problem that have been thriving in this research area is the existing geological data on that particular area is outdated and the most recent research done there dates back to long time ago. The study area lacks reliable data about history of land use changes. By doing this research, a new geological map can be produced and people who want to conduct researches there can refer the map that has been produced.

Next, the changes on and also beneath the land. The last few decades have seen more human activities than usual. So the consequences from this human act is not written and recorded. Other than that, the study about the land use changes in the study area was conducted by previous research for a long time ago and does not have an updated data about land use changes. In Kota Bharu, every consecutive five years' map was done at the coastal area and found that coastal erosion took place. By using the geophysical method, we can see the latest changes of seawater movement under the land in that particular area. By doing this research, we can safely say if there is any seawater intrusion or not. If yes, from where it is generating and so on.

1.3 Objective

. Research objective:

i. To update geological map in study area of Gua Musang and Sungai Peng Datu, Kota Bharu coastal area to the scale of 1: 25,000.

ii. To access the potential seawater intrusion and seawater contamination in the groundwater

1.4 Scope of study

In this study, we must know one thing first. Kelantan has some potential groundwater aquifers. And these serves as daily water supply to some rural areas. The coast of Kelantan is facing the South China Sea. The seawater may intrude beneath the land and contaminate the fresh aquifers. By using electrical resistivity imaging, one can clearly see the activities below subsurface. A 2D image will be produced to discuss the results. If this seawater contamination persists, the supply of fresh groundwater will cut off.

1.5 Significant of study

The significance of this research is it could add more geological data of the study area and more detailed geological map can be produce. The map that is generated from collecting samples of rock around the area, any human activities, and the geomorphology. The main theme of this research is to find the possible location of seawater intrusion. The recognition and mapping of this intrusion will provide much more insides to upcoming researches and in the coming years, researchers may come up with an idea to stop the contamination.

1.6 Study Area

Lojing is a small area located about 15.1km from Gua Musang town. Lojing or known as Lojing highland is a hill village in the Gua Musang constituency of Kelantan, Malaysia. That place is located near to Cameron Highland in Pahang, along the second East-West Highways. The biggest ethnics of the indigenous people in Lojing is mainly Temiar tribe of the Senoi nations (Rao et.al, 2016). The figure below shows the base map of Lojing.

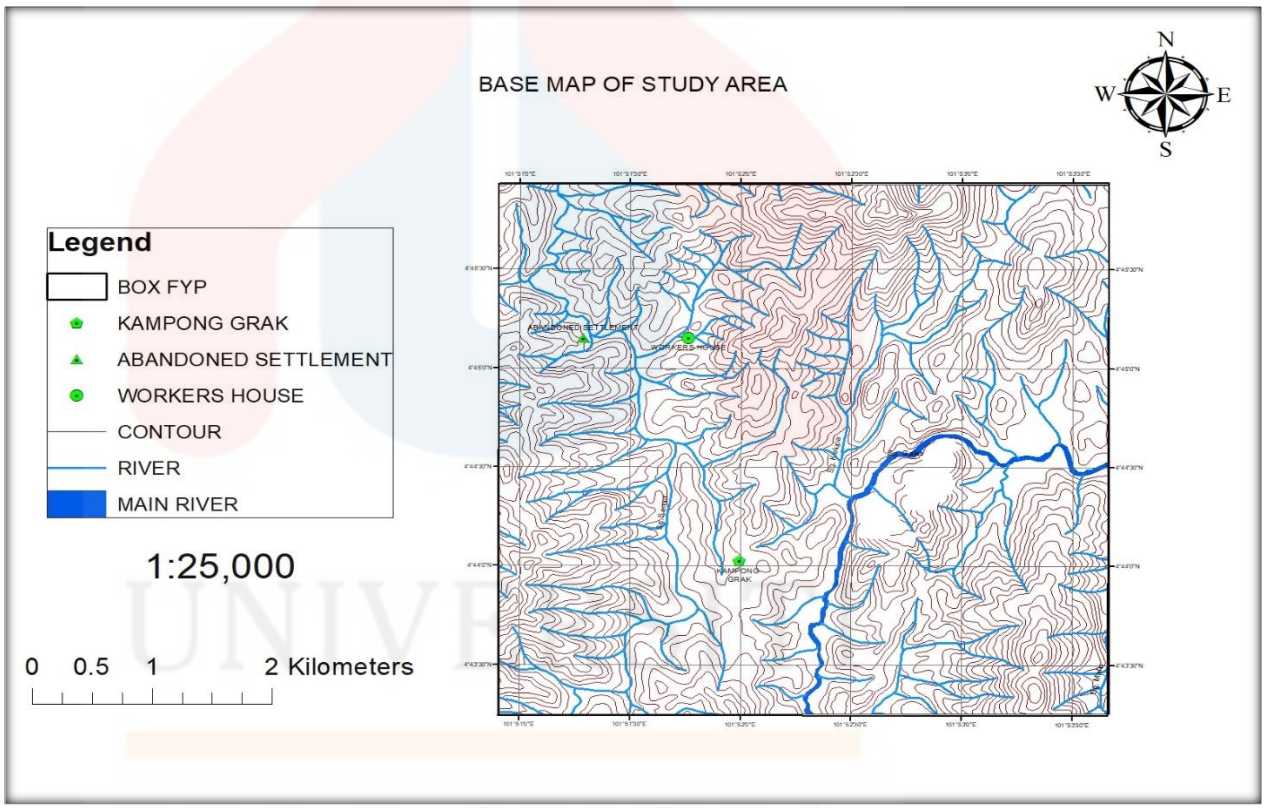


Figure 1.1: The base map of Lojing.

The study area of seawater intrusion is around Sungai Peng Datu, Kota Bharu in Kelantan. The study area is very near to sea which is actually a coastal area. The study area is a 25 km^2 box. The vertex of the box is at the coordinates of N 6 ° 09'39.0", E 102 ° 20'59.3", N 6 ° 08'19.5", E 102 ° 17'48.6", N 6 ° 12'65.980 ", E 102 ° 33'06.340", N 6 ° 06'13.1", E 102 ° 23'01.7" and N 6 ° 04'43.0", E 102 ° 19'28.9". The figure 1.2 below shows the google earth map of eri box.

Figure 1.2: The ERI box map of Sungai Peng Datu, Kota Bharu.

1.7.1 Lojing landuse

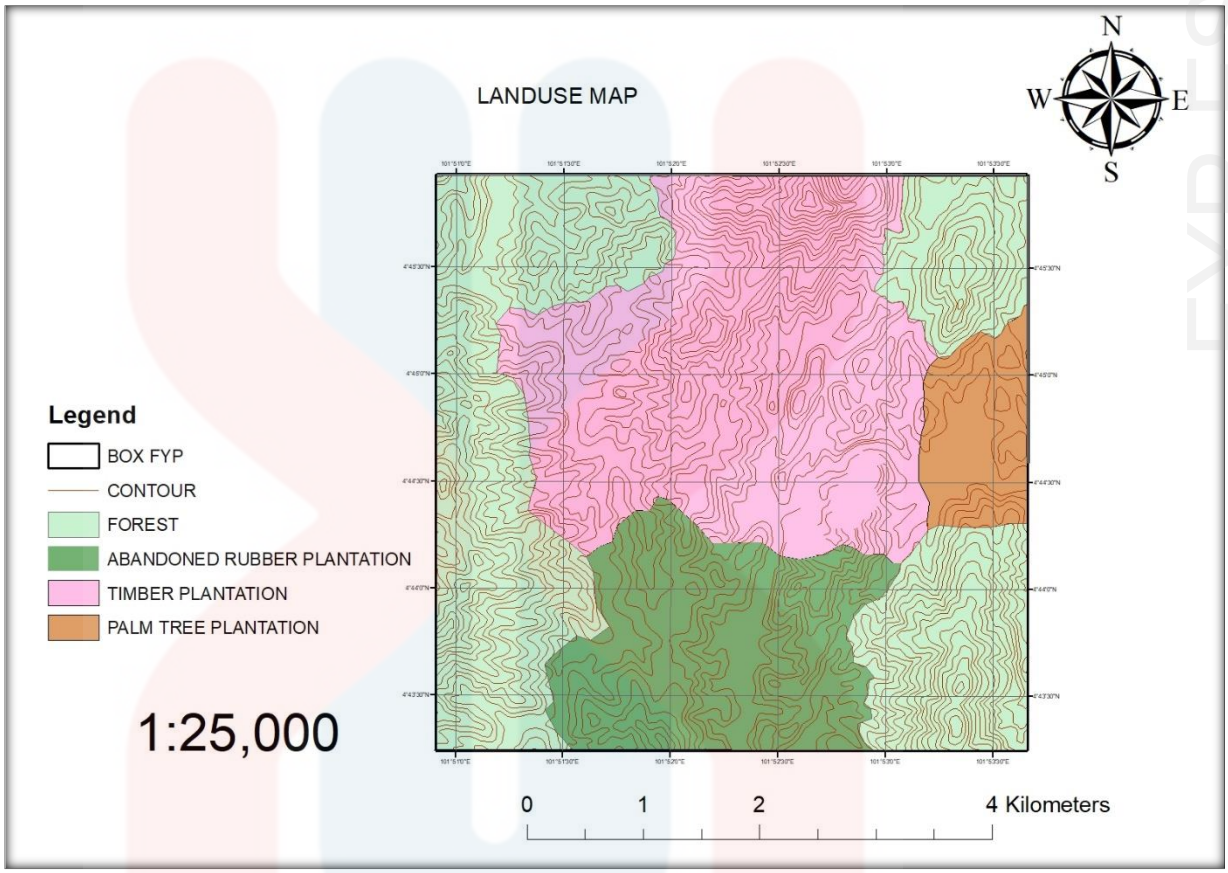


Figure 1.3: The landuse map of Lojing.

Figure 1.3 above, shown below is the landuse map of Lojing in Gua Musang where the study is carried out. Lojing is very well known for its nature wealth. Minerals, forest wealth, soil fertility all is present there. Kelantan forest including the reserved forest holds some of the pioneer floral and faunal of Malaysia. That's the very reason Kelantan forest is usually called as virgin forest. There are two types income from the plantation for Kelantan. Industrial type plantation and conventional plantation. Industrial plantation includes rubber tree, oil palm tree, paddy plantation. But those plants are being planted on an equal scale compared to conventional planting. Conventional plants include timber wood, vegetables and some root vegetables. Because of mother nature's generosity, Kelantan holds some of Malaysia's

export quality timber wood. *Medang Sawa, Mersawa, Sanai* (Ho et.al, 2009) are some of the commercially planted woods in Kelantan. Logging is one of the main activities in Kelantan. So, Lojing area is not an exceptional for logging. The landuse of the base is highly effected to logging activity. Roughly, half of the area is used for logging activity. The other part is under reserved forest. So, logging is prohibited there.

1.7.2 Landform of Lojing

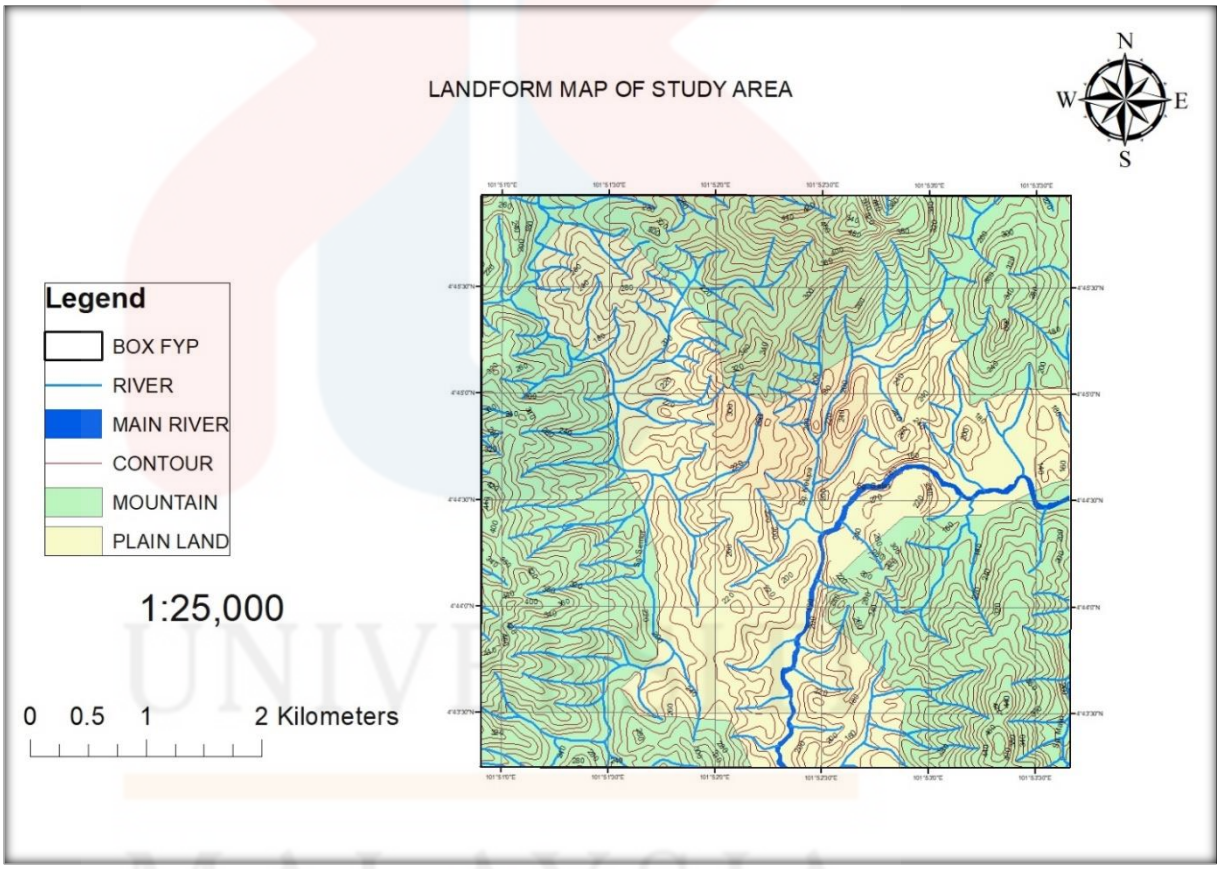


Figure 1.4: The landform map of Lojing.

Kelantan comprises of Titiwangsa, Benom, Tahan and East Coast mountain trenches. So, practically Kelantan is full of mountains, hills and high grounds. Plain land is presented along with it. Figure 1.4 shows the landform of Lojing. These highlands are products of ancient tectonic activities. When a continental crust collides with another continental crust, the pushing stress from both sides will still remain. One

of the crusts, with low density compared to the other, will sink under the plate. The collision will push and create folding of land. As millions of years pass, these folding will grow and create mountains and high lands (Seik, 2017).

1.7.3 Litholog of Lojing

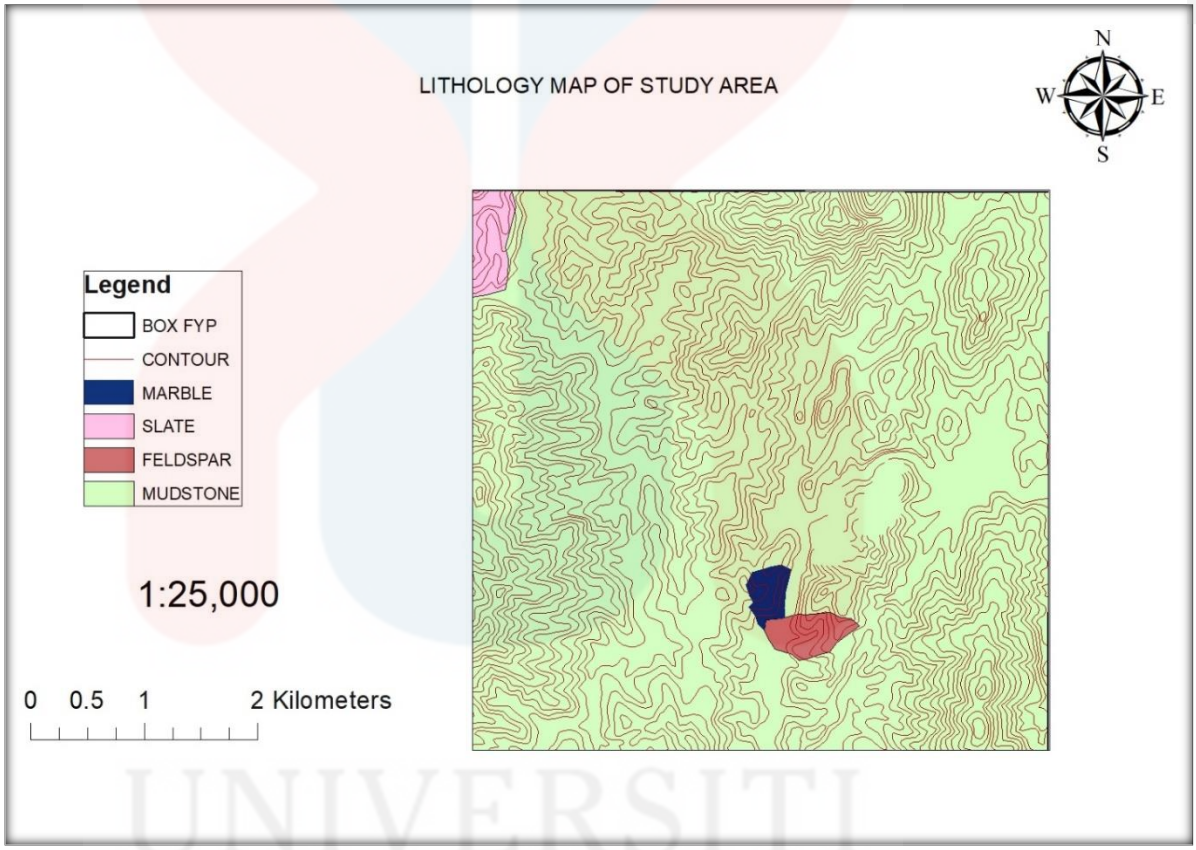


Figure 1.5: The lithology map of Lojing.

Figure 1.5 above shows the lithology map of Lojing. The rock unit that is presented in Lojing can be categorised under 2 type. Metamorphic rock and sedimentary rock. Sedimentary rock is made up of broken stones which ends being cemented and compacted under great pressure. Metamorphic rock is the rock formed from sedimentary rock and also igneous rock under great pressure and temperature beneath the earth surface. These rocks are the type of rocks that usually forms as gem

stone as the minerals in the rock undergoes metamorphism. Diamond, limestone, schist, gneiss and so on are examples of metamorphic rocks. The rock unit present in Kelantan is greatly comprises these three-rock type. But in Lojing, the rock unit present is mostly sedimentary rock. Metamorphic rock is also presented. The lithology unit is simple, which holds sedimentary rock such as mudstone, and feldspathic wacke and for metamorphic its slate and marble.

1.7.4 Watershed of Lojing

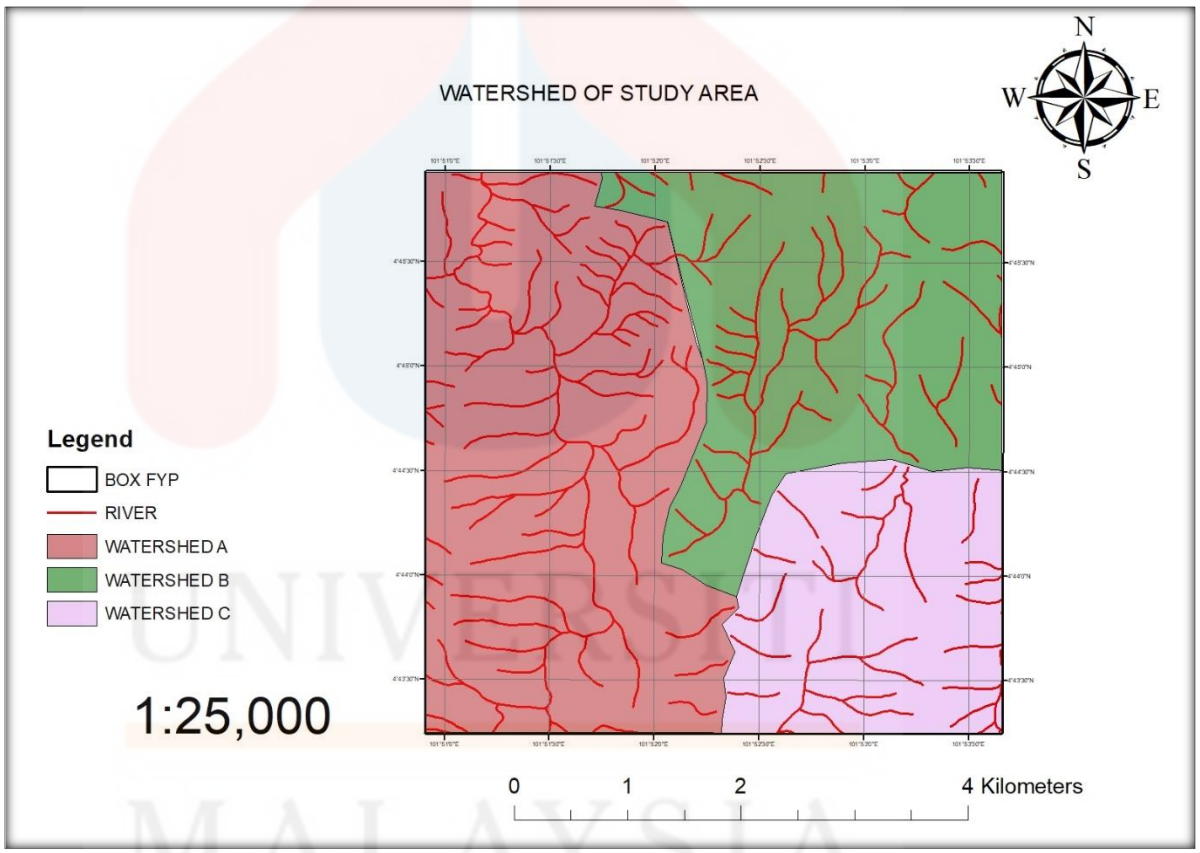


Figure 1.6: The watershed map of Lojing.

Kelantan holds many water channels within it. As this land is rich with high lands, the forest serves as rain catchment area. These waters that is collected, flows under the earth surface and also flows on the top as river channels. Rivers, channels, brooks, creeks and streams are found at every nook. Lojing is mostly covered with

forest and the water flow is steady. There are three different watersheds in Lojing area. Figure 1.6 shows the watershed map of Lojing. A watershed is an area of land that feeds all the water running under it and draining off of it into a body of water. It combines with other watersheds to form a network of rivers and streams that progressively drain into larger water areas (Samsad et.al, 2017).

1.7.5 Drainage pattern of Lojing

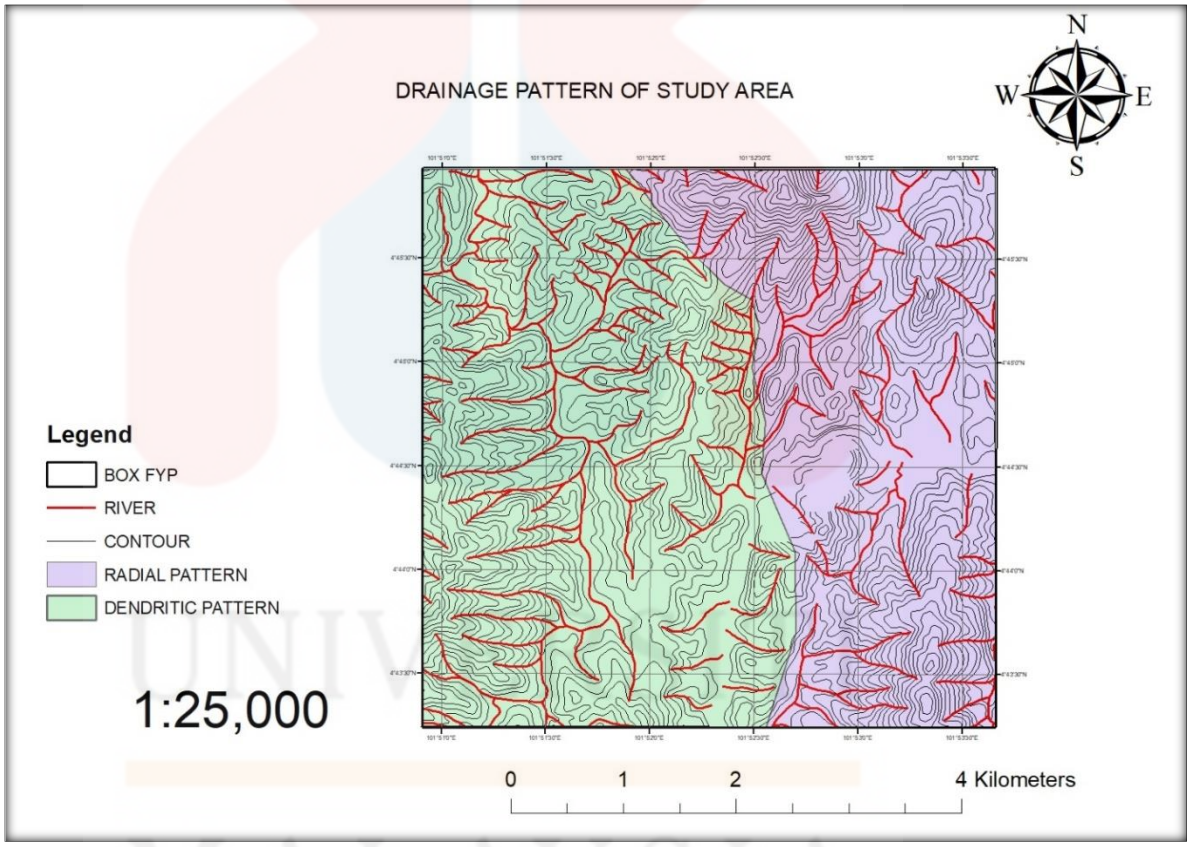


Figure 1.7: The drainage pattern map of Lojing.

The drainage pattern of Kelantan varies from place to place. Dendritic, deranged, centripetal and trellised are some of the drainage patterns commonly found in Kelantan (Nazaruddin et.al, 2014). Lojing is not an exception from it. The drainage pattern in Lojing is mostly dendritical and radial. Figure 1.7 shows the drainage pattern

map of Lojing. A drainage pattern in which the streams branch randomly in all directions and at almost any angle, resembling in plan the branching habit of certain trees. It is produced where a consequent stream receives several tributaries which in turn are fed by smaller tributaries. It is an indicative of in sequent streams flowing across horizontal and homogeneous strata or complex crystalline rocks offering uniform resistance to erosion (Khair, 2016). This pattern may form on top of the land surface or below the land surface in karst aquifers with anastomoses forming the smaller tributaries (Sruchika, 2018). This is because the area is mostly covered by forest and the water flows in anyways possible from high lands to low lands as the gravity pulls and later on intersect at one point and flows into the main river.

1.7.6 Demography of Lojing.

The total population of people living in Gua Musang, Kelantan is shown in Table 1.1. This data is obtained from the official website of Department of Statistics Malaysia. The study area is located in Lojing, Gua Musang and the population pool below comprises of people that settle in Lojing too. The data of the people distribution in Gua Musang district is from the year 2010 and the latest one was the year 2014. In 2010 there were about 90,057 people in Gua Musang. In 2013, there was a drastic increase from 90 057 to about 111,700 people in Gua Musang. In 2014 there was an increase in number but in the same pace of residents in Gua Musang is 114,500 people.

Table 1.1: Population of Gua Musang

Year	2010	2013	2014
Total populations	90,057	111,700	114,500

(Source: Jusoff et.al, 2010)

Table 1.2 shows the percentage of total population of Gua Musang based on their respective ethnic groups. Based on the data, there are four major ethnic groups in Gua Musang which can further divide into Malay, Chinese, Indian and Native people. Malay peoples are the dominant race in Gua Musang where the total percentage of Malay population record is 60.44%. Next is followed by the Chinese with a 22.83% and Indian residents shows a percentage of 14.88% and the Native ethics shows just 1.85%. Figure 1.8 shows the percentage of the distributions of the different ethnics in Gua Musang.

Table 1.2: The total population based on ethnic group in Gua Musang.

Race	**Percentage**
Malay	60.44
Chinese	22.83
Indian	14.88
Native	1.85

(Source: Jusoff et.al, 2010)

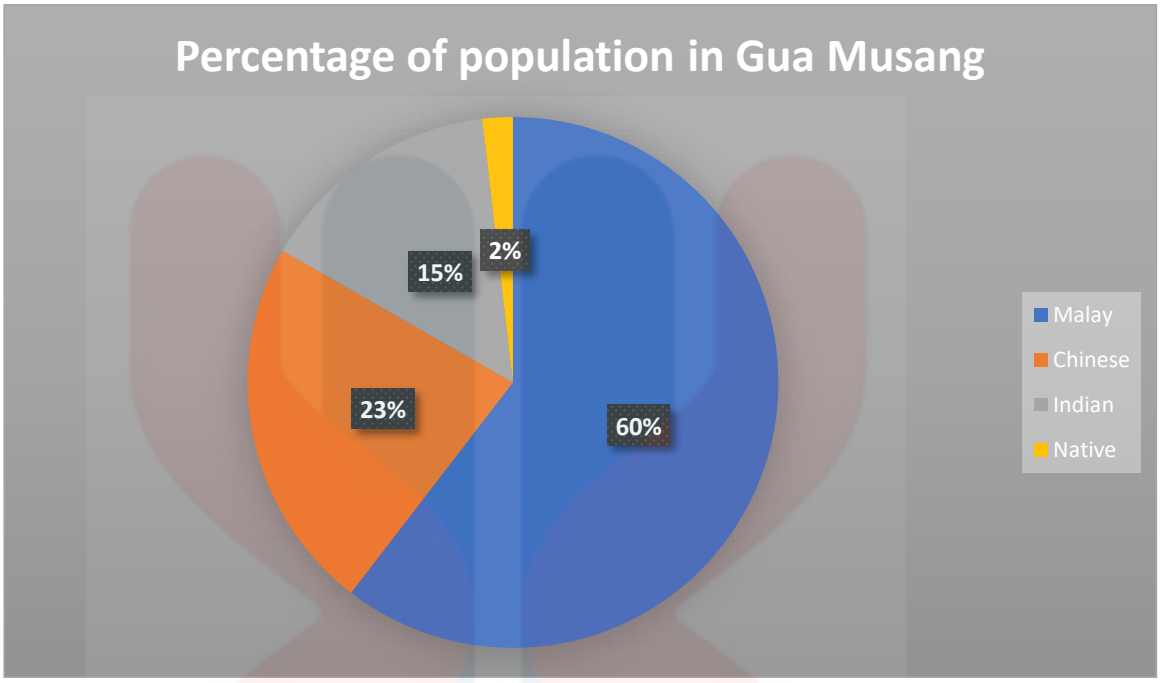
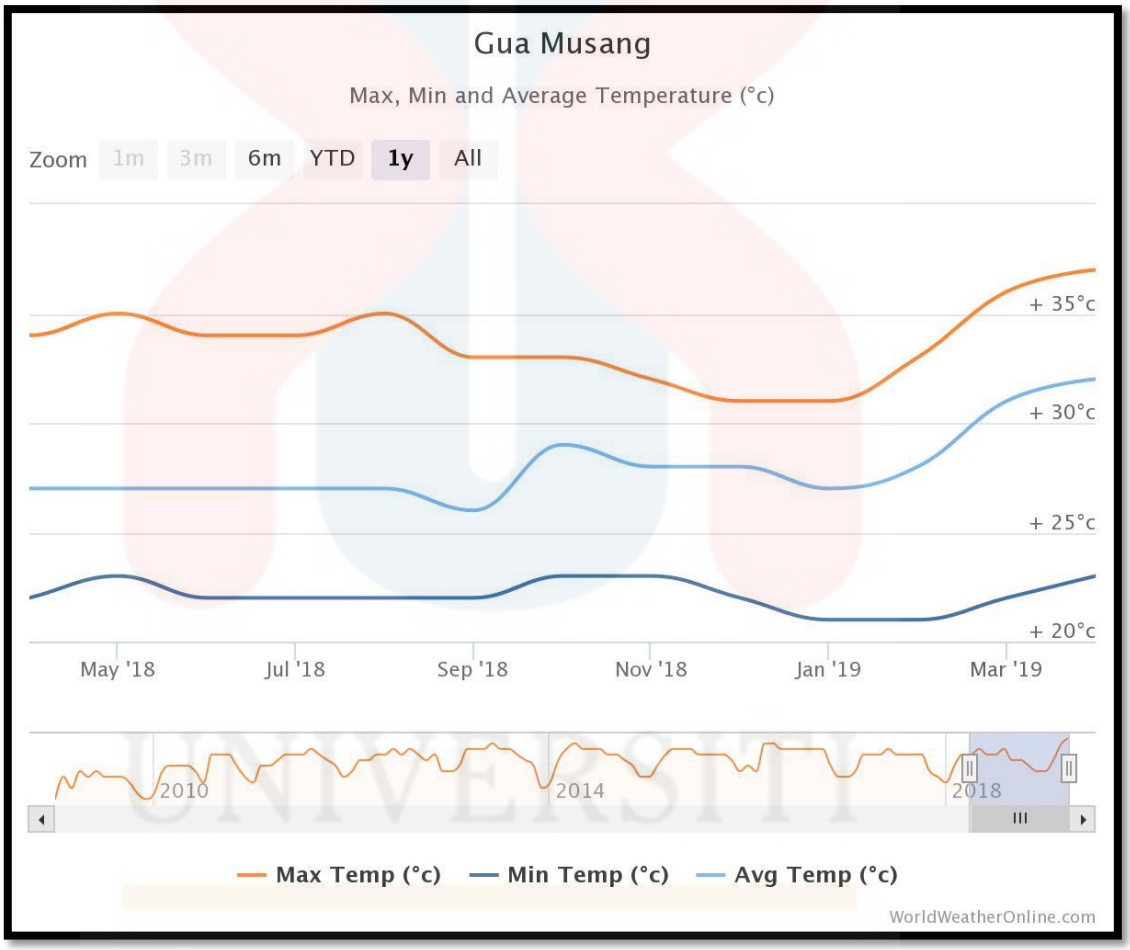


Figure 1.8: The population distribution of Gua Musang.

Figure 1.8 represents the population distribution according to races in Gua Musang. The natives here were the original people that used to live in Gua Musang Area. During the age of Sultans, ruled by Malay rulers and before the invasion of British colony, Malay people lived in Kelantan also. Later Chinese people was brought to Kelantan by the British Government to work in the mines. Kelantan is still very rich with ore minerals like tin ore. British Government had a good understanding with Chinese government and the Chinese lent their equipment and also their people as labours. Slowly these Chinese people begin to settle down at Kelantan mainly in the towns. Indians arrived here mostly as estate labours. To manage the crops like rubber plantation, oil palm plantation and many more their also after the British announced independence to Malaysia, they settled down in Kelantan. Now they work as shop owners or as employees mostly.

1.7.8 Rainfall and temperature in Gua Musang

Overall, Malaysia is situated near the Equator line. This effects the temperature, rainfall, and so on. Throughout the year, Malaysia experience hot and humid. The weather more or less just about the same. Precipitation rate is not equal throughout the year. Figure 1.9 shows the temperature in Celsius (°C). The figure is obtained from World Weather Online.



(Extracted from : *WorldWeatherOnline.com*, 2010)

Figure 1.9: The temperature of Gua Musang from April 2018 to April 2019.

The variations in temperature of Gua Musang from April 2018 to April 2019 is presented in a line graph by figure 1.9. Malaysia receives a high rainfall which in turn makes it one of the rich country in water resources. As per the statistic result of 2016 released by the Department of Statistic in 2017, Kuching had experienced the

highest annual rainfall of 5,423.0 mm with an increase of 877.5 mm as compared to 2015 (4,545.5 mm). Meanwhile, the lowest annual rainfall was recorded at Temerloh station with 1,397.8 mm in 2016 (2015: 1,193.2 mm). Tropical climate is the climate experienced by Gua Musang. Even during the driest month, Gua Musang experience rainfall and that plays a very vital role in adjusting the weather there (Alias et.al, 2016). This climate is considered to be a type A according to the Köppen-Geiger climate classification. The average annual temperature is 26.4 °C in Gua Musang. In a year, the average rainfall is 2365 mm. The Köppen climate classification divides climates into five main climate groups, with each group being divided based on seasonal precipitation and temperature patterns. The five main groups are A (tropical), B (dry), C (temperate), D (continental), and E (polar) (Beck et.al, 2005). Table 1.3 shows the average annual rainfall in Gua Musang for the past five years. Figure 1.10 shows the rainfall in Gua Musang from April 2018 to April 2019.

Table 1.3: The average annual rainfall in Gua Musang.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Precipitation / rainfall (mm)	152	85	130	161	217	163	159	173	245	309	290	281

(Source: Alias et.al, 2016)

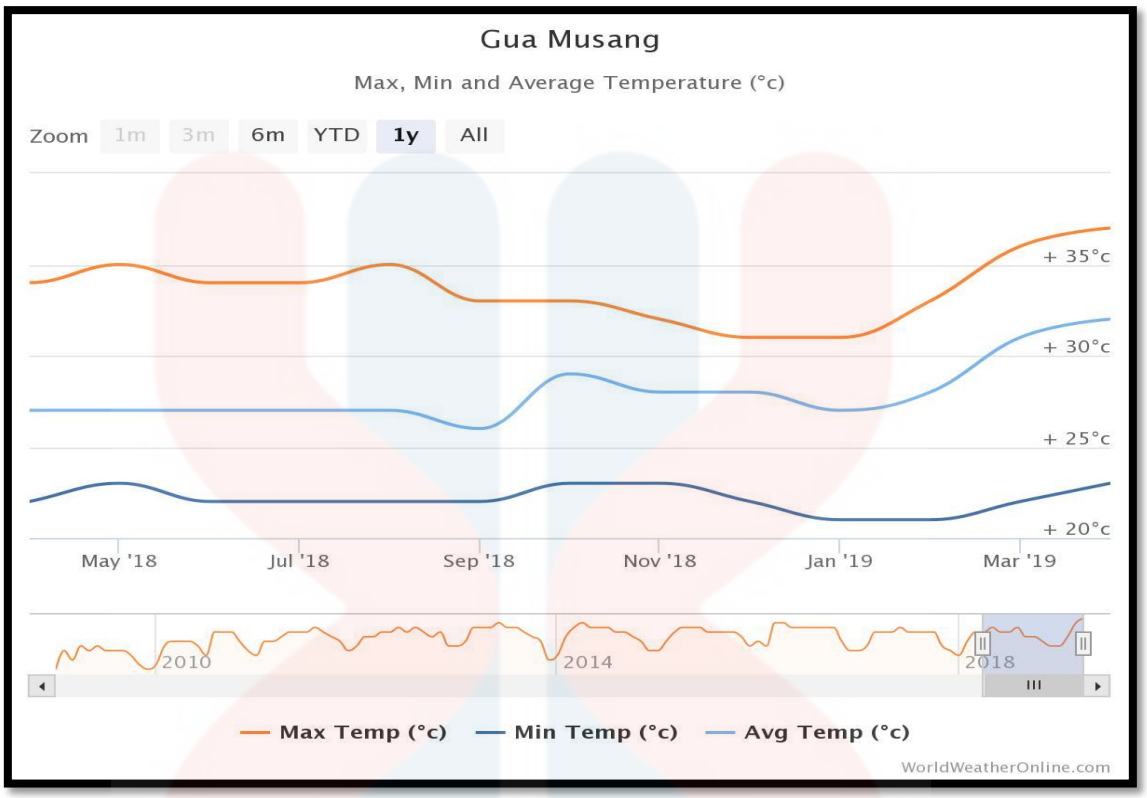


Figure 1.10: The rainfall of Gua Musang from April 2018 to April 2019.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Regional Geology and Tectonic Setting

Kelantan covers approximately 14 922 km^2 and it is situated in north-east Peninsular Malaysia. Kelantan holds 10 districts within it. 1 288 362 people resides in Kelantan. Gua Musang is one of the districts and it is located in the south of Kelantan. The total area of Gua Musang is 8104 km^2 with a population of about 143 258. The land use mainly composed of forest, oil palm, rubber, cleared land, logging activity, mixed horticulture, homestead garden and villages. Gua Musang is an ideal place to conduct mapping activity because of the rapid changes taking place there (Mohamed, 2016).

Around Gua Musang area, argillite rocks are commonly found which have been metamorphed to low grade metamorphic rock such as slate or phyllite, limestone that have been metamorphed to marble, sandstone and some conglomerate. Most of the argilitic unit and sandstone are tuff and contains vocanic traces. In general, argilitic unit is abundantly found here. However, limestone outcrop dominates in Gua Musang and produce karst topography. This rock unit is known as Gua Musang Formation. In the east of Gua Musang Formation, there is one more rock formation from Triassic age and is known as Gunung Rabong Formation (Mohamed, 2016).

2.2 Stratigraphy

Stratigraphy of Lojing explained that the state of Kelantan has a wide variety of rocks. This includes igneous, sedimentary and metamorphic rocks. Distribution of rocks in Kelantan are in a north-south trend. Distribution of igneous rocks in Kelantan is in the west and east borders of the state the Main Range Granite and the Boundary Range Granite. It also occurs in the centre of the state. The granitic rocks in Kelantan can be divided into two main bodies which are the Main Range and the Boundary Range. This is also stated by the Department of Minerals and Geoscience themselves. The Main Range Granite is generally of a Late Triassic age, between 200 and 230 million years ago. (Metcalfe, 2013)

The Easthern part of Kelantan map consists of districts such as Tumpat, Pasir Mas, Bachok, Kota Bharu and Pasir Puteh. Based on researches and field findings done by previous geologists, these parts of Kelantan Map contain rock types from the Quaternary Period. The most common examples of the rocks found in these locations are clay, silt, sand, peat and minor gravel. Since all these rocks were formed during the Quaternary and recent period, they are all considered as young rocks in geological rock strata.

The southern part of Kelantan map comprises another study area involved in this project which is Gua Musang. Based on the earlier research and evidences, geologists have classified the rock types at Gua Musang area according to the geological time scale chronology. Besides that, the igneous rocks found here were dominantly of acid intrusive (undifferentiated) type.

The Permian is a geologic period which extends from 299 to 252 million years ago. It is the last period of the Palaeozoic Era after the Carboniferous Period and occurred before the Triassic period of the Mesozoic era in geochronology. During that time our world was dominated by a single supercontinent which was called as Pangaea and surrounded by a global ocean that was named as Panthalassa. The vast tropical rainforests of the Carboniferous period had all disappeared, leaving behind major regions of dry desert surrounding the interior continent. The ocean depth during the Permian remained mostly low, and near-shore environments were restricted by the collection of all the dominant landmasses into one continent which was the Pangaea. This could have been the reason for the major marine species extinctions during the final time of the period by critically decreasing shallow coastal areas that contained varieties of marine organisms. The rocks formed during Permian period were stained red because of iron oxides as the result of severe heating by the sun since there was lack of vegetation and the land was bare (Mohamed, 2016).

The Triassic Period was the very first period of the Mesozoic Era and it occurred between 251 million and 199 million years ago. It was followed by the great mass extinction called the Permian-Triassic extinction at the final stage of the Permian Period. This period of time was when simultaneously the marine species began to form and diversify (Erwin, 2015). By the end of the Triassic period, which was about 199 million years ago, the earth's supercontinent began to split into two major parts because of the tectonic forces and plate movements. The first continent was called as Laurasia which is situated in the north meanwhile the second continent was named as Gondwana which is located in the southern part.

Quaternary period is the most recent time of Geological time scale and it began 2.6 million years ago and continues till present. Climate change and developments

caused by this period are stated in Earth's history. At the beginning of the Quaternary period, all the continents were almost about the similar location they are in today, but little by little moving here and there because of the forces of plate tectonics that are pushing and tugging them about (Frisch, 2010).

Normally the Quaternary period is one of the best-studied parts compared to other time scale in the geological record. The is because it was proven that majority of the parts were very well preserved and undisturbed when comparing to the other geological time scale. For instance, significantly a very little amount had been lost due to natural disasters such as erosion. Furthermore, rock forming processes did not alter the sediments present.

Gua Musang Formation was introduced by Yin, 1965 for the rocks that was found around Gua Musang, South Kelantan. Yin 1965 suggested the stratigraphy unit of Gua Musang are listed in the Table 2.1. (Peng, 1983).

Table 2.1: Shows the stratigraphy unit of Gua Musang Formation.

Time	Lithology
Middle Triassic	Limestone, shale and volcanic rock
Early Triassic	Argilitic limestone, shale and volcanic rocks
Late Permian	Shale and siltstone
Middle Permian	Limestone with some shale

(Source: Mohamed, 2016)

Yin 1965 stated that the rock sequence in Gunung Rabong Formation consists of shale, mudstone, siltstone, sandstone and conglomerate. These sequences are of Flysch type, which is deep ocean turbidite sediment deposits.

2.3 Structural Geology

Structural geology is the study of the any geological features that formed during the rock formation. Many factors actually contribute to the formation of structural geology like tectonic process, force of energy, deposition of sediment and others. There are many possibilities for the structural geology to form. It may form either before the formation of the rock, during or after the formation of the rock. The formations have different faults. A fracture or a zone of fractures between two blocks of rock are called as a fault. The blocks are able to move relative to each other when there is a fault. There are two types of movements regarding to fault. Earthquake occurs when the movement is really rapid where as if it occurs slowly then fault will happen in the form of creep. Furthermore, faults can be ranged in length from a thousand of kilometers to a few millimeters. Most of the faults will normally produce repeated displacements over geological time. The rock on one side of the fault slips with respect to the other side all of a sudden when an earthquake strike. The surface of the fault can either be vertical or horizontal or even some arbitrary angle in between. The angle of the fault with respect to the surface which is known as the dip and the direction of slip along the fault are used by earth scientists to classify the types of faults (USGS, 2014).

The rocks are generally striking NW-SE. Dips are generally moderately steep to sub-vertical and eastward. Numerous anastomosing faults cut across these rocks. The great number of faults that pervade the area make up a complex pattern. Faults trend in various directions. However most of these faults are trending NNW, parallel-sub-parallel to the suture zone trend. Most faults appear in conjugate sets. Dip

displacements are much in evidence, especially the low angle faults that evidently show the typical low angle fold-thrust geometry. These are the older faults and most of them dip to the NE. Some low angle faults and most high angle faults do not exhibit the typical fold-thrust geometry. They often exhibit positive flower structures with drags along the faults ranging from moderate to steep and sub-vertical. Vertical displacements seen along the faults are variable and may change in sease and magnitude along an individual fault. All these features suggest a significant strike-slip motion is involved in the development of these faults. The rocks within the suture appear to occur as several tectonic units. The tectonic units may range in width from a few meters to kilometres. The great number of high angle faults which exhibit significant strike-slip motion may suggest that the tectonic units may be bounded by strike-slip faults. Therefore, the juxtaposition of different stratigraphic units within the suture zone can be explained by strike-slip movements. This juxtaposition can equally well be explained by imbrications and nappe tectonics. However, no systematic repetition of lithologies that can be made out due to imbrication are found. Moreover, nappes have never been described within the suture zone and the straight course and vertical dip of the zone is in contrast with such an assumption (Shuib, 1994). To create a clear picture of geological structure of Kelantan, the general geology of Kelantan is presented in Figure 2.1.

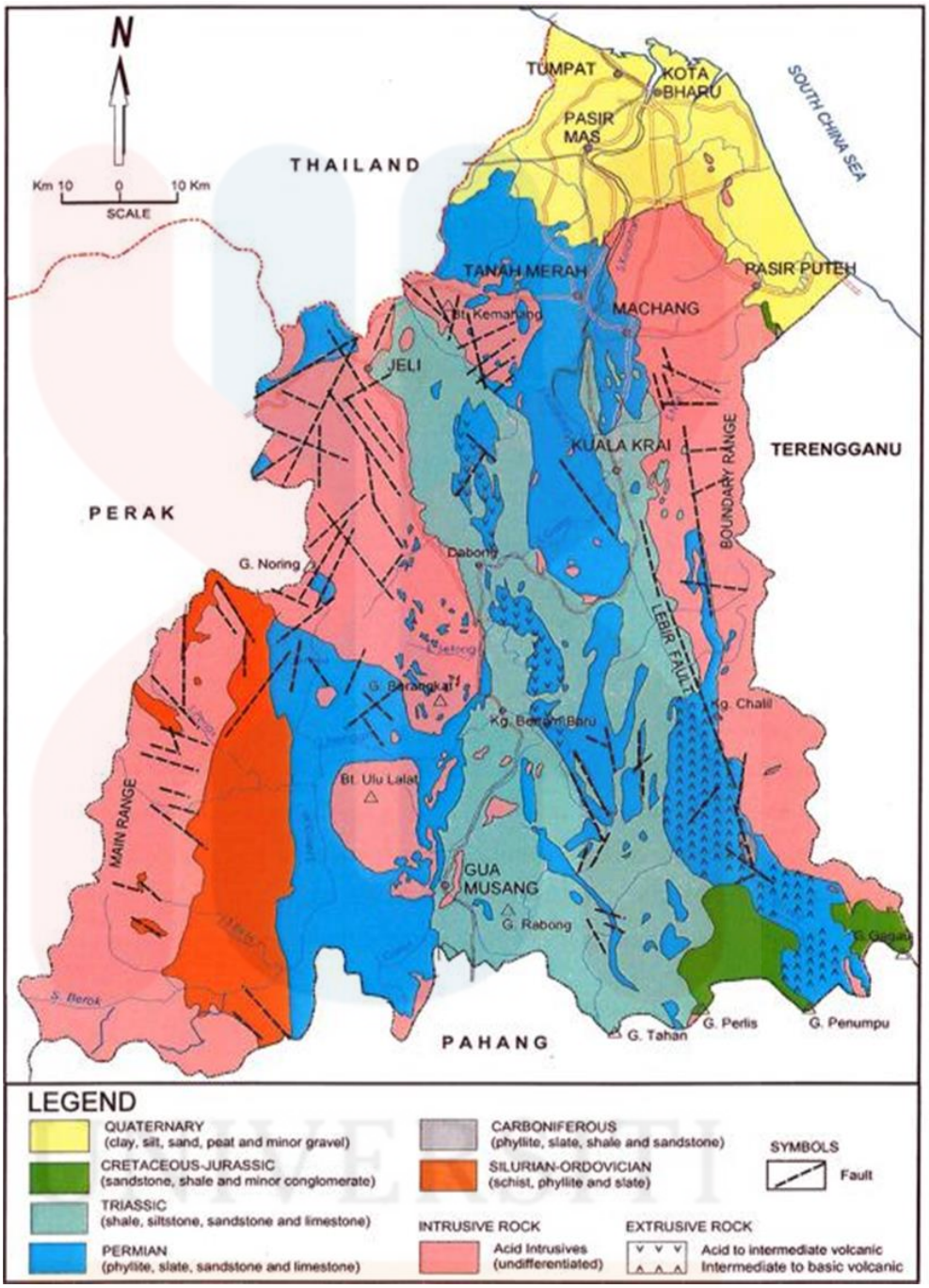


Figure 2.1 shows the general geology of Kelantan.

(Source: Pour, 2017)

2.4 Research Specification

2.4.1 Seawater Intrusion at Coastal Areas

Seawater intrusion in coastal areas of Kelantan is found to be one of the important environmental issues raised and expected to be causing a negative impact on groundwater resources in the future. Saltwater intrusion occurs when saltwater moves into a freshwater aquifer. Technically, this is seawater intrusion because "saltwater" can derive from different sources. Study by Essink, 2005 shows that the coastal areas of the world accommodate high population with about 50% of the world population lives within 60 km of the shoreline. The same scenario can be seen along the shoreline of coastal areas in Kelantan. It is also proven by the high number of flood victims every year during monsoon season. Overexploitation of the groundwater has become a common issue along the coastal areas of Malaysia specifically in Kelantan. Consequently, many coastal regions around the world and locally experience extensive saltwater or seawater intrusion in aquifers resulting in severe deterioration of the quality of groundwater resources.

Accordance to the purpose of this study, this test is carried out to find the potential contamination of seawater in groundwater. Affected aquifers have to be identified to access and mitigate seawater intrusion. As much aquifers as possible needed to be characterised for this study. To evaluate seawater intrusion, integration of geophysical investigation and multivariate statistical analysis off the hydro chemical data have to be done. This study will be conducted at Kelantan coastal areas including various locations. In directly this contamination affects agricultural activities at specific areas. Impact on agricultural activities cannot be misled as it contributes a nigh portion to the country's economic growth.

Seawater intrusion into coastal aquifers can be detected through several methods. In most of the case studies, the electrical method has been universally recognized (Kuria, 2010) as the electrical conductivity (EC) of a saturated subsurface depends primarily on three major factors: porosity, the connectivity of pores, and the specific conductivity of water in the pore (Cai, 2017). The difference between the EC of the seawater saturated subsurface and freshwater saturated subsurface is significant; thus, the electrical resistivity survey was well suited for evaluating the relationship between freshwater and seawater in coastal areas (Sherif, 2006). The electrical method analysed with hydrogeological measurements can map interfaces of fresh water and seawater in coastal aquifers more precisely (Zarocca, 2011).

2.4.2 Electrical resistivity imaging

Electrical resistivity monitoring of injections is traditionally performed with subsurface electrodes (Ramirez, 1993). These experiments can significantly enhance quantitative characterization of subsurface properties but have limited spatial coverage and high costs. Surface monitoring using ERI is much more flexible and cost effective, but additional knowledge may be needed a priori, for a particular site or contaminant. In previous studies, ERI monitoring method was also used in at study at Ohio. That study not only proves the infectiveness of using this method, whereas also mentions the difficulties in applying ERI at some areas due to complicated subsurfaces. For this study, ERI technology was utilized in an attempt to quantify the distribution of the permanganate following injection and to potentially record groundwater reactions that generated resistivity changes in the subsurface.

The electrical resistivity technique is widely used to measure the resistivity and conductivity of materials in the subsurface. Variations in these two parameters are

caused by changes in the soil characteristic structures, clay content, degree of water saturation and conductivity of this water (Samsudin, 2002). The electrical resistivity of seawater will be aiding the attempt to map seawater intrusion at chosen aquifers locations at Kota Bharu, Kelantan using 2-D resistivity imaging techniques. The low electric resistivity shows the presence of seawater at the specific area.

2.4.3 Causes and Effects of Seawater Intrusion

Previous studies by Samsuddin, 2018 show that the intrusion of seawater into groundwater gives an impact to the quality of groundwater and indirectly effects the salinity of the soil. Seawater intrusion may be caused by various activities such agricultural industrial and domestic activity. The issue of groundwater contamination is not new to the headlines of local newspapers and the solution is yet to be found. This study will give a lead in finding the right solution to reduce the percentage of groundwater contamination due to seawater intrusion using electrical resistivity imaging technique. As we all know, the development of industrial sites can cause destruction to the ground surfaces. This indirectly increases the chance of seawater intrusion to groundwater. In addition, the Kota Bharu, Kelantan is located along the shorelines with several beaches making it look like a partial island. The farmers are extremely concerned about the amount of seawater that is being intruded into groundwater as it effects their paddy field. Their concerns relate to the problems of seawater intrusion into the groundwater (1.5 - 2 m below surface) as well as into the productive paddy fields in the area. Seawater is not suitable sources of water for plants or crops to grow (Kamal, 2015).

The mapping of saltwater intrusion in coastal aquifers in Kota Bharu have traditionally relied upon observation and collection of water samples. This approach

may miss important hydrologic features related to seawater intrusion in areas where boreholes or wells are limited and widely spaced, such as the chosen locations in Kota Bharu, Kelantan (Samsudin, 2002). This study emphasizes not only on the salinity of groundwater in the chosen aquifers, but it also involved studying the aquifer properties and salinity of the groundwater in much wider area. To map seawater intrusion in this area, a different approach has been used. The electrical imaging will be helpful in order to map lateral variations of electrical resistivity, which are directly related to water quality. Because the bulk resistivity of geologic formations is highly dependent upon pore-water salinity, the resistivity data can give an indirect measure of water quality in the study area.

2.5 Historical Geology

The Gua Musang formation in South Kelantan – North Pahang was mapped to describe Middle Permian to Late Triassic argillite, carbonate, and pyroclastic /volcanic facies within Gua Musang area. Now, the term has been often used for nearly all Permo-Triassic carbonate-argillite-volcanic sequences in the northern part of Central Belt Peninsular Malaysia (Mohamed et al, 2016).

Widespread distribution of argillite-carbonate-volcanic across northern Central Belt has triggered issue regarding current names assigned. For an example, similar lithologies to the Gua Musang formation in Felda Aring is called as Aring Formation, where as those at Sungai Telong is named as Telong formation. These lateral facies changes could be gathered within the same group as long as these sediments were deposited in shallow marine environment of the Gua Musang platform during the Permo-Triassic period. The relevance of grouping these formations is based in terms of paleontological and sedimentological aspects. The authors find the need to reassess the usage of the informal 'Gua Musang formation' for future rank elevation,

formalization, and clearer understanding on the geology of the northern Central Belt, particularly with regards to deposition of various lithostratigraphic units within the Gua Musang platform.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Introduction

Fieldwork equipment consist of geological hammer, brunton compass, Geological Positioning System (GPS), hydrochloric acid (HCl), hand specimen sample bag, hand lens and field notebook. The above equipments are for mapping use. For ERI survey, ABEM, electrodes, spread cable take outs and clips will be used. Collecting data on the field known as primary data while software is secondary data. Whereas for the secondary data, ArcGIS version 10.2 is used to digitize the map of study area and to produce a new map of the study area.

For laboratory equipment's, the thin section machines were used to produce the thin section from rock samples as well the microscope will be used for thin section observation.

3.2 Methods

Geological mapping and the specification study are the two part of research study, which specified in Geographical Information System (GIS) by using software. Geological mapping was done in study area to collect the new collect a new data and review the previous map for updates. Geological mapping and fieldwork were conducted to identify the type of lithologies and the changes in drainage system in the study system. The traverse routes throughout the study area are tracked by using GPS.

After mapping was done, the information and traverse routes was gathere88d for data analysis by using Arcgis 10.2 software.

3.3 Preliminary Studies

3.3.1 Methods for geological mapping

Fieldworks

a. Sampling

Rock sampling is a method of collecting small chunks of rocks. The rock sample that collected used for further studies. Sampling method are done to examine the outcrop in field for their physical characteristics like the type of rock, texture, grain size, colour, degree of sorting, the minerals and others. Random sampling will be used because of some area in the study area is impossible to be reached by using normal traverse.

b. Electrical resistivity method

Electrical resistivity imaging technique is a surveying technique for an area of complex geology where the use of resistivity sounding, and other techniques are unsuitable for providing detailed subsurface information in a limited area. Electrical resistivity surveys are normally carried out with multi-electrode system. Such surveys use a number of electrodes (25 to 100) deployed in a straight line with constant spacing, connected to a multicore cable. In this survey, field data will be obtained using ABEM Terrameter that connected to the electrode selector with Schlumberger configuration (Figure 3.1). This equipment will be linked to the 400 meter spread cable takeout. 41 electrodes will be connected to the cables with a fixed distance of 10m spacing for each electrode. All the instruments mentioned previously is shown in Figure 3.2. One survey line will be carried out in this survey. The field data obtained

from the survey were processed using RES2DINV software in order to get the resistivity profile of the survey line.

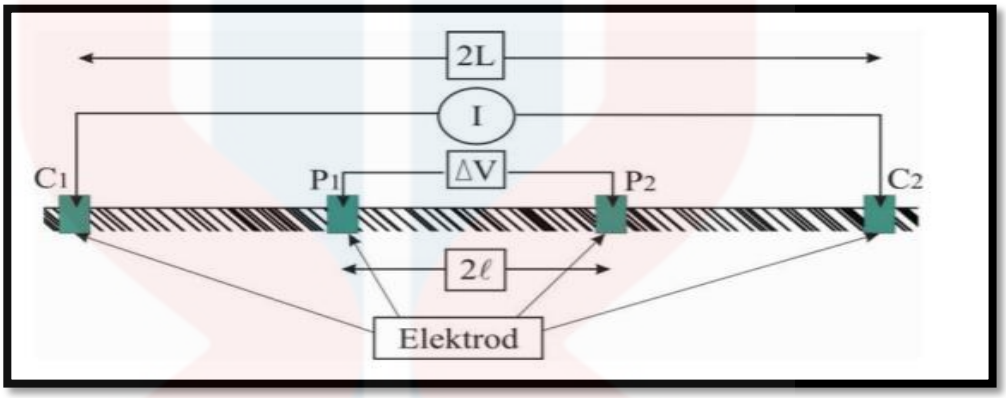


Figure 3.1: The Schlumberger configuration.

INSTRUMENT

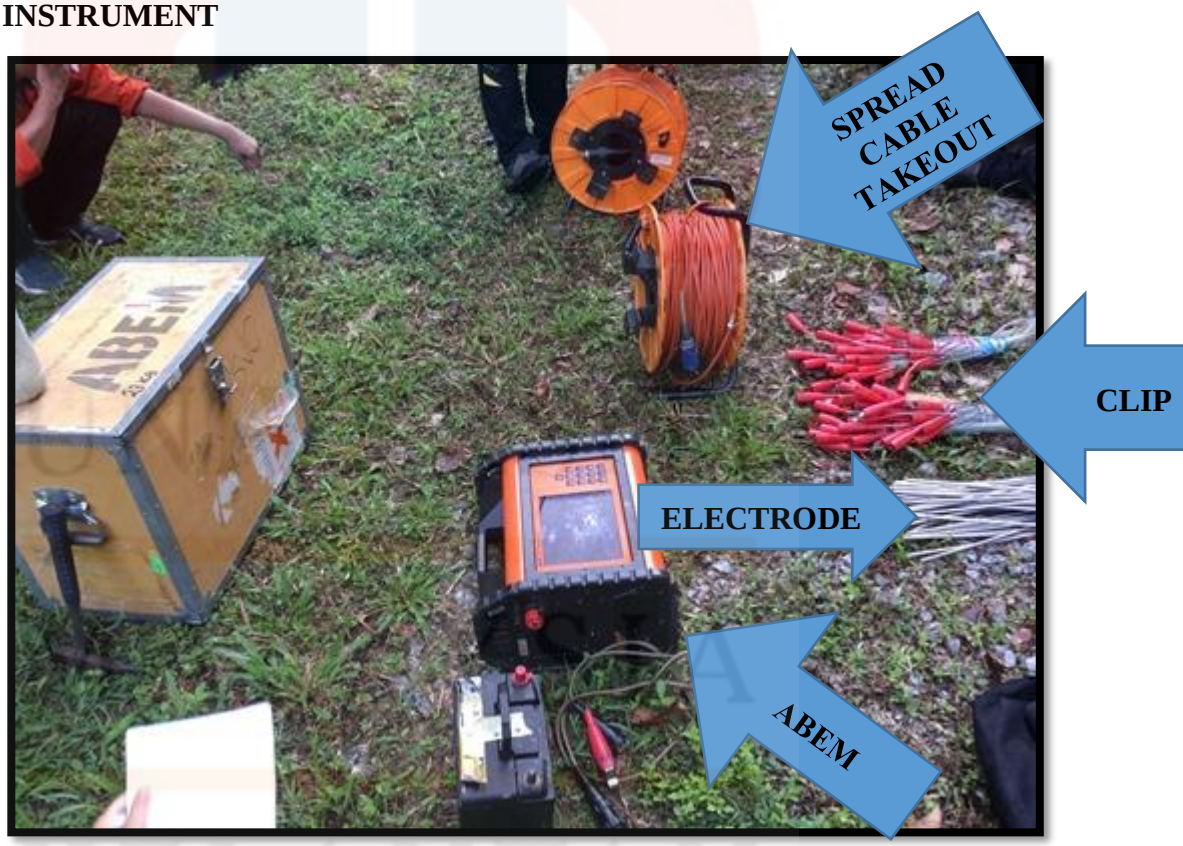


Figure 3.2 shows the instrument used for ERI survey.

3.3.2 Laboratory works

a. Petrological studies

The step involved identification of mineral, texture, clast, and matrix as well as classification of rock. The samples that were collected at the field was then examining using laboratory investigation. Rock sample that collected need to cut into smaller piece. After that, process such as grinding, and polishing was done. Then the sample were presented in the thin section. Then, under the polarized microscope, texture of the rock was examined.

b. Thin Section

Laboratory investigation is generally a process of the laboratory work where thin section is taken part in the laboratory and the geological map of study area was updated by using the ArcGIS software. Thin section is the main step in obtaining petrography analysis. Main steps of thin section preparation are including preparing sample, cutting, polishing, and final cutting.

RESEARCH FLOW CHART

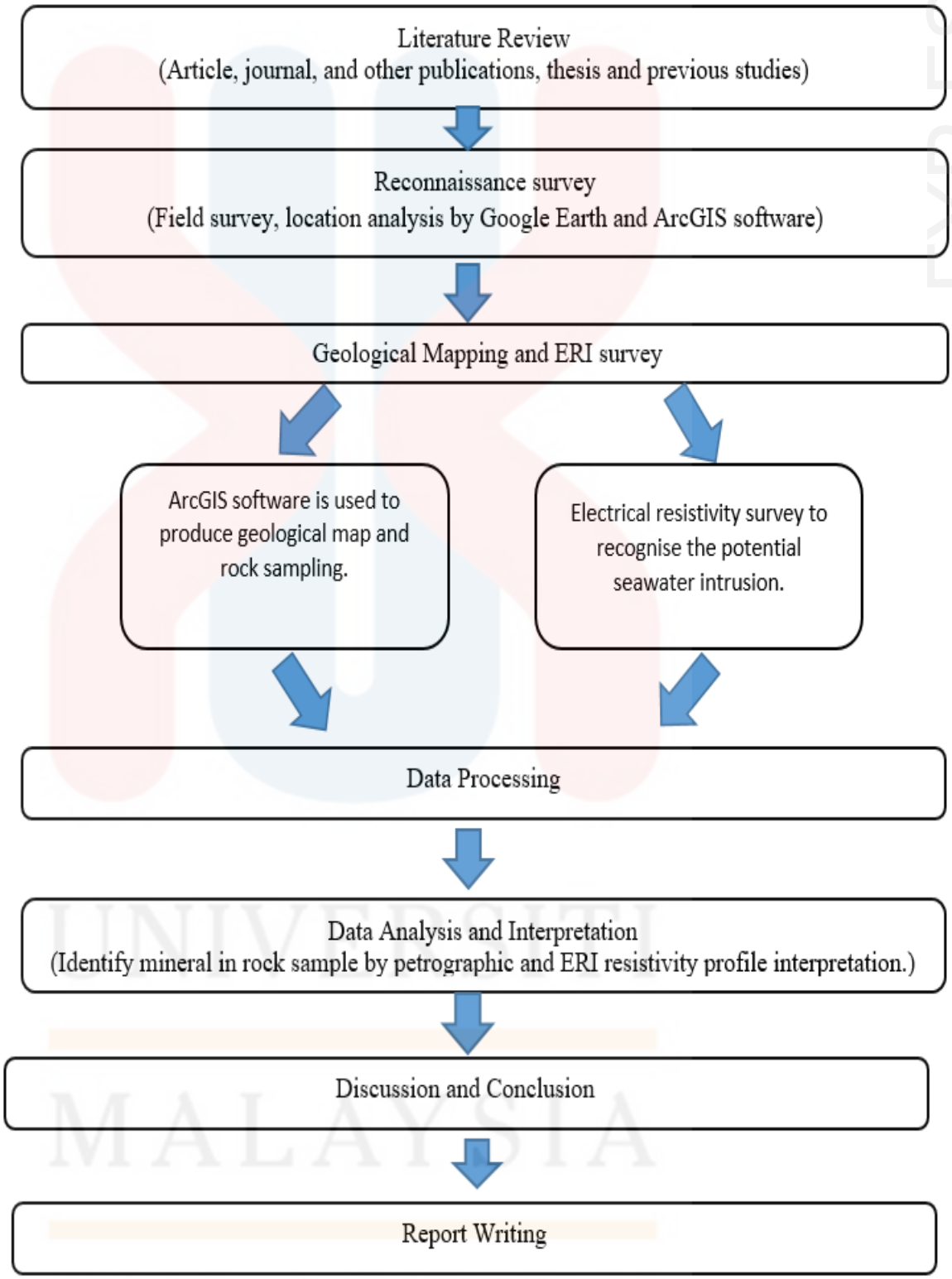


Figure 3.3: The overall flow chart.

CHAPTER 4

GEOLOGY OF STUDY AREA

4.0 Introduction

Science that focuses on Earth materials such as the rocks and materials it is composed of and the changing process it undergoes over time. Apart from just rock composition, geology also comprises of Earth history and origin story of the Earth structures. Under geology there are branches of it such as stratigraphy, geomorphology, structural geology, historical geology and many more. All these individual information is very important to know general geology of a geological site. Stratigraphy arranges layers of rock spatially and chronologically depending on the rock characteristics. Even if a layer of rock isn't connected to another layer, stratigraphic principle is used to correlate them. Earth's history can be reconstructed to know its origin and the events but only with stratigraphic. Lithostratigraphy is under stratigraphy which focuses on the study of rock layer. Geomorphology is the scientific study of topographic features created by physical, chemical or biological processes, the origin and also the evolution the Earth's surface underwent. Next is structural geology which is the study of deformations on the Earth's surface. Past events of deformation, currently undergoing deformation process, the principle and mechanics behind the deformation are covered by structural geology. Lastly, historical geology governs the principles and techniques to understand more of geological history of Earth.

Lojing is a small area located about 15.1km from Gua Musang town. Lojing or known as Lojing highland is a hill village in the Gua Musang constituency of Kelantan, Malaysia. That place is located near to Cameron Highland in Pahang, along the second East-West Highways. To access this place is by motor vehicle. The study area is accessible from Jeli to Gua Musang road. Then need to take Jelawang street to Kg Pulai. From there can reach the study area.

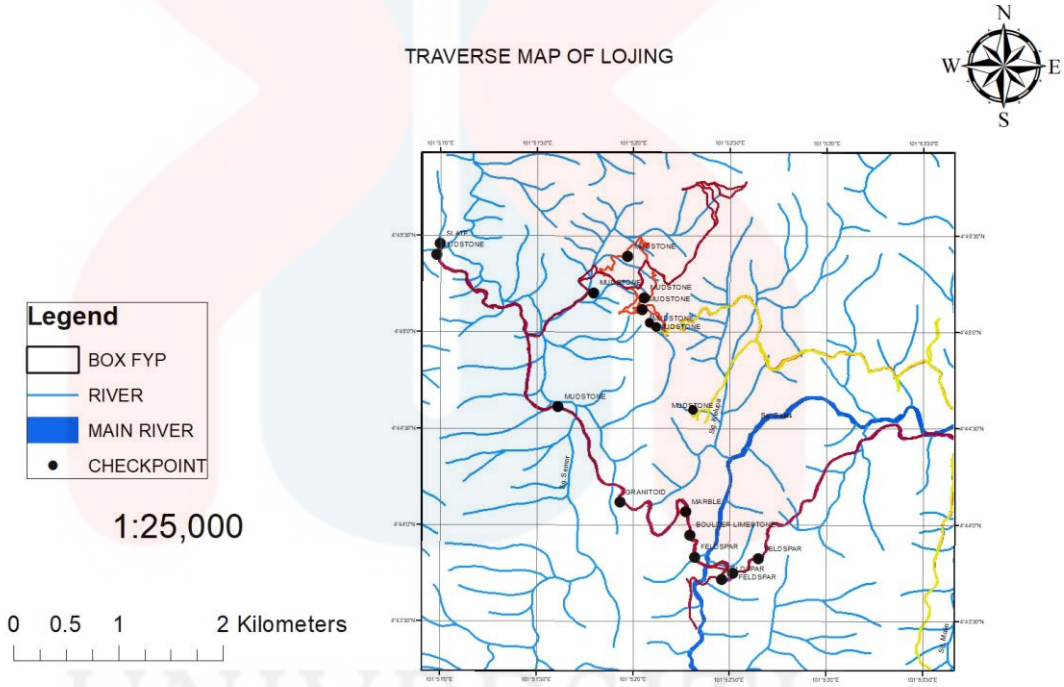


Figure 4.1: The traverse map of the study area.

Figure 4.1 above shows the traverse map of study area. The map reveals the whole traverse from day one until the last day of mapping the study area. The study area was traversed walking so that even the slightest details is not missed. This way all the important information was not missed. Some of the areas was impossible to access since the forest is so dense and thick. There were some abandoned unpaved roads but the access was blocked either by landslide or high grown vegetation. The collected

data was very useful in updating the geological map of study area. The outcome fulfilled the specification of the research. Figure 4.1 also shows the location of rock samples collected. Samples of shale, limestone, granite boulder were very close to the main river. Mudstone samples were quite far from water source and mostly found at foot of highlands. The rock samples were collected every time a different type of rock was encountered.

Figure 4.2 below shows the landuse map of study area. The study area was mostly covered with think and dense forest. The east part of the study area is being used for palm tree plantation. But the plantation covered just a small area of the study area. The northeast, southeast, northwest and southwest parts are dense forest. Rubber plantation covers the southern part and in the middle until north of the study area is covered by timber plantation. The owner has cleared up a large area of the forest and even made terraces out of the hills in his premise. He imports a specific seed of timber plant from Indonesia and plants it here. The main river that was flowing thru the study area is the Galas river.

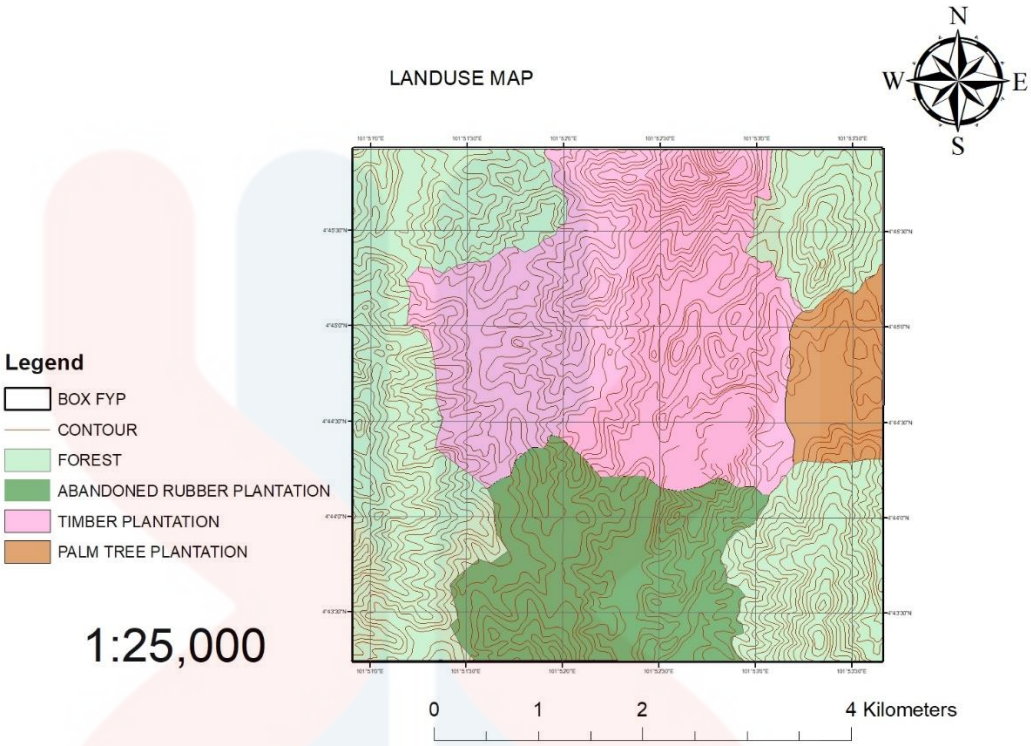


Figure 4.2: The landuse map of the study area.

4.2 Geomorphology

Earth's surface undergoes lots of transformations over time. The change in Earth's surface with features is known as landforms. Terrain is the combination of landform in that locality. Study of the terrain on the landscape on an area is known as topography. Hills, mountains, valleys and floodplains are examples of on-land landforms that was common on the study area in Lojing area. Orientation elevation, rock exposure, slope, stratification, and soil type are the basic physical attributes used to categorize these landforms.

Figure 4.3: Geomorphology of the study area.

Figure 4.4: Hills surrounding study area.

Figure 4.5: Flowing river in study area.

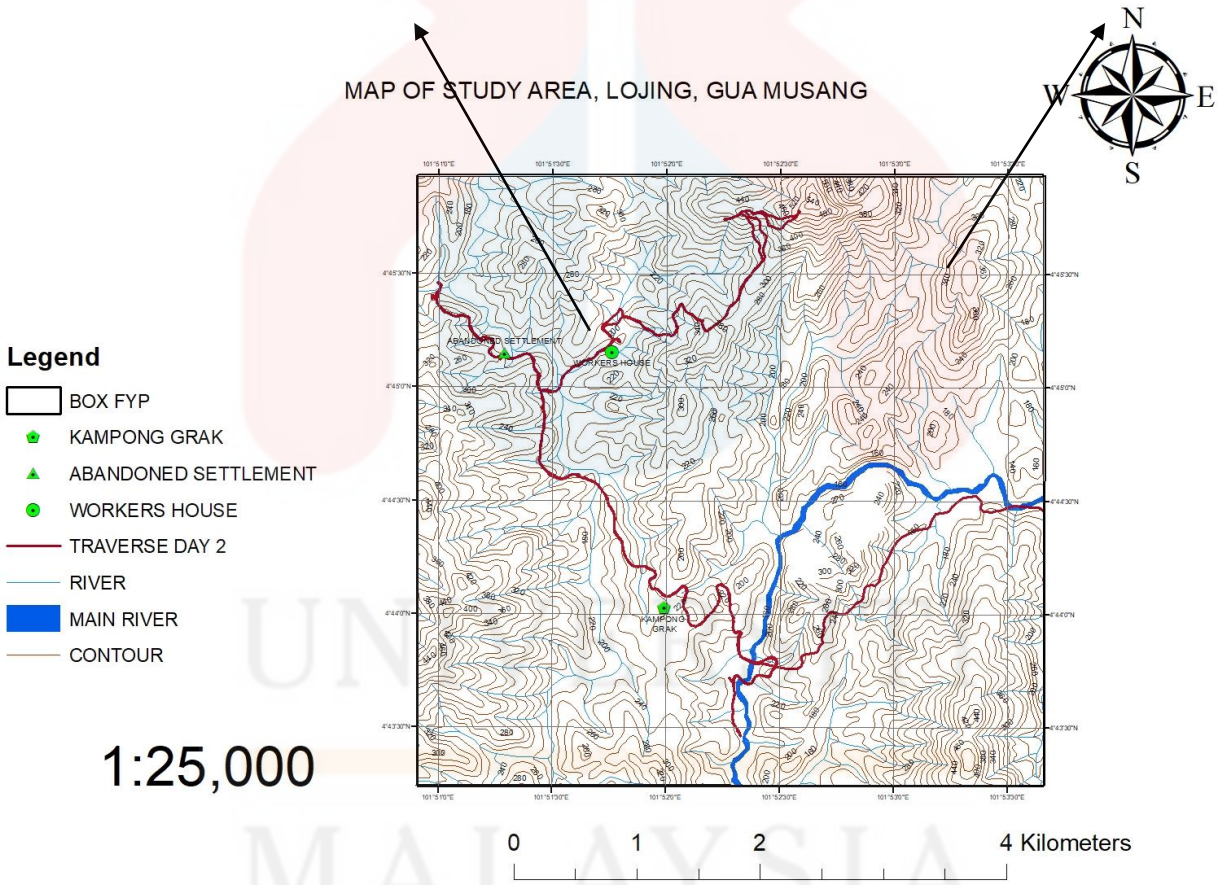


Figure 4.6: The observation point of geomorphology in study area.

The Earth's surface is always moving but very slowly. These changes are there but hardly noticed because a major change takes hundreds of years. The tectonic plate movement under the Earth's crust plays the major role in the Earth's surface changes which include breakdown and also formation. Weathering process has taken its place in Lojing. Weathering here took place because of the tectonic movements, formations breakdown or weather down due combination of weathering agents such as rainfall, wind and gravity. The breakdown happens chemically and physically. Weathering process can be classified into three, respectively biological, chemical and physical weathering. There are chances that all these weathering processes happened simultaneously. Some outcrops were weathered with second class weathering. The factor that contributes to this weathering process is the resistance of the rock. Resistance to weathering is a measure of how well the rock resist erosive factors, which primarily depends on hardness, chemical reactivity and cohesion. The more hardness, less reactivity and more cohesion a rock is to its environment, the longer it will stay intact.

The study area reveals some hills have close contour and some highlands have far contour pattern. In a nutshell, close contour pattern resembles steep slope of elevation and far contour pattern have gentle slope elevation. Knowing these, a simple conclusion can be made that gentle slope is weak in resisting erosion while steep slope shows high resistivity towards weathering. Generally, all types of rocks have their own resistivity towards erosion. The higher the hardness of rocks the longer it takes to erode.

Physical weathering and biological weathering does not change the rocks mineral composition during or after the weathering process. Physical weathering in study area is by far from the excavation process and exposure to the atmosphere. These type of

weathering just disrupts the mechanics of the rock. For example, granular disintegration, separation of joint blocks, exfoliation. Physical weathering is induced by fluctuation in temperature and pressure, grinding between other materials. While biological weathering results from living organisms. A root growing through the cracks of a rock while eventually break it down one day. These two type of weathering were commonly found in the study area. Figure 4.7 shows an example of biological weathering caused by tree roots. Figure 4.8 shows an example of physical weathering caused by the flowing water.

Figure 4.7: Biological weathering.

Figure 4.8: Physical weathering.

River system, also known as drainage system, is a sort pattern formed by the flowing rivers, streams and also lakes which in particular are drainage basins. The drainage pattern of the study area is dendritic and radial. Topography of the land is the influence of these patterns formed because the pattern solely depends on the region. The drainage pattern reckons on the regions if it's made up of hard rocks or soft rocks, and gradient of the land also influence heavily in these pattern formation.

Sometimes, rivers and streams flowing pattern will be random and most likely won't represent the topography. The chronological events of the particular and the structures underlying rivers and streams influence its pattern. Drainage patterns can be classified into several types. Figure 4.9 below shows the types of drainage pattern commonly found.

Figure 4.9: Classification of drainage patterns

(Source: Argialas et.al, 1988)

Figure 4.10 below reveals the drainage pattern of the study area as radial drainage pattern and dendritic drainage pattern. The most common drainage pattern is the dendritic pattern. This pattern forms in areas where the rock or unconsolidated material underlying the stream has no structure or fabric. This type of pattern develops in areas where the materials can be easily eroded in all direction. In this pattern, all the tribute rivers join together and flow into the main stream later. They develop where the river channel follows the slope of the terrain. The streams radiate outwards from a central high point is known as the radial drainage pattern. Volcanoes and other high points usually display excellent radial drainage. In the study area, eastern part is mostly radial drainage system.

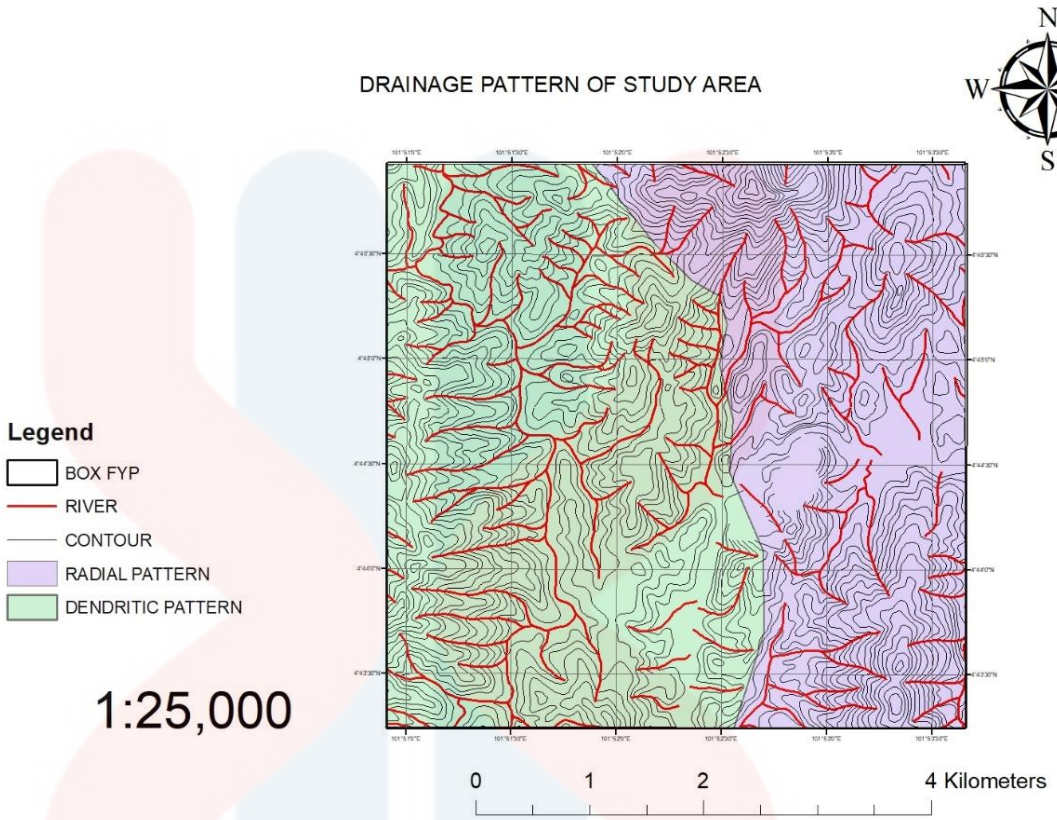


Figure 4.10: Drainage pattern of the study area.

Figure 4.11 below shows the watersheds of the study area. The different colour marks that there are three types source for the watershed. A watershed is a specific area of land that consumes all the water flowing beneath it and pouring it into a body of water. Later on it combines with another watershed system which eventually empties itself into an even larger water body. Where to flow and how the water flows is governed by the topography of the area.

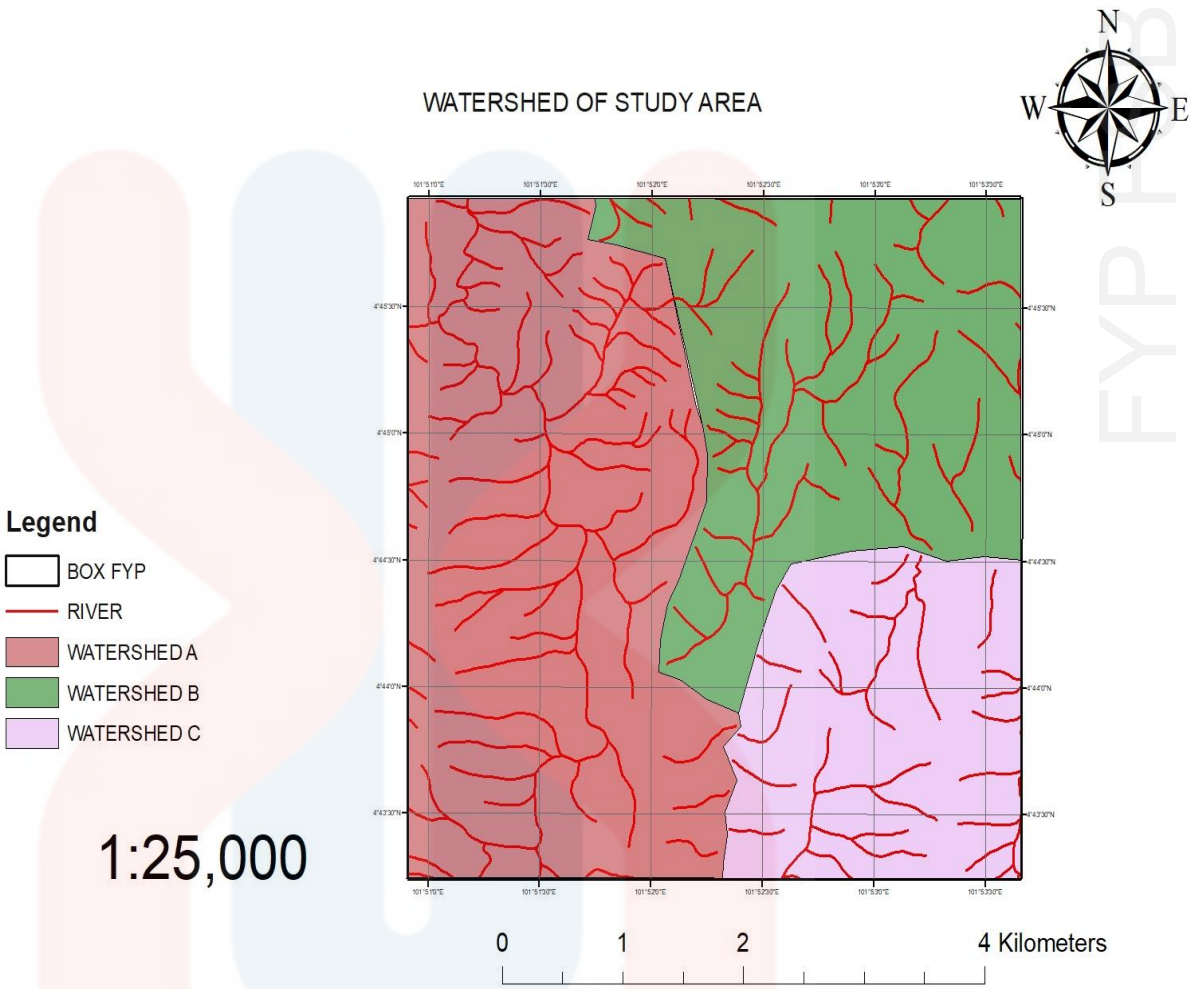


Figure 4.11: The watersheds of the study area.

4.3 Lithostratigraphy

Stratigraphy is the study of strata or rock layers. It is also the study of layered sedimentary rocks. Geochronology, comparative geology, and petrology are the main discussing branches of stratigraphy. Generally, a strata or stratum will be igneous or sedimentary strata is the first and foremost stratum to form which depends on how the rock was formed. There are a number of principles that are used to explain the appearance of stratum.

First, principle of superposition. This principle defines that in undisturbed sequence of strata, the oldest layer lays at the bottom followed by younger strata as it goes upwards. Next, principle of original horizontality. All the layers either deposited or lava flow will settle down in horizontal position initially. Third is the principle of lateral continuity. Every stratum is continuous in all direction until they thin out at the edge. It's either blocked by a geological barrier or the source of deposition is too far away from the source.

Fourth is the principle of cross-cutting relationship. When an intrusion occurs, the intrusion rock is younger than then rocks being cut. Move on with principle of inclusion. When a rock formation contains pieces of another rock, it is said that that rock pieces is older than the host rock. To end up is principle of fossil succession. Succession of fossils are used to determine the age of rocks. For every age, there is a unique assemblages of fossil. Dating the fossils reveals its age and later the strata where the fossil is found is used as reference and to correlate the age of other stratum widely.

Lojing, Gua Musang is a plantation and also timber logging area. The plantation found here consist of palm tree and rubber tree plantation. Most of the area is a thick

forest. The exposed outcrops were only because of excavation. Some places are inaccessible because of landslide covering the vicinity and covered by thick vegetation. During mapping of the study area, mudstone is the dominant rock. Among mudstone rock, slate, feldspar and marble was also there. There was one huge granitoid rock boulder. The area has no granite rock nearby. So it was concluded that the rock is not *in situ.* The karst environment found there is an uplift. Since the study area is dominated by mudstone and the limestone came from nowhere, it is concluded to be an uplift. Table 4.1 shows stratigraphic column and unconformities between mudstone.

Table 4.1: The stratigraphic column of the study area.

AGE	FORMATION	ROCK UNIT	
Middle Triassic	Gua musang formation	Slate	
Early Triassic		Feldspar	
Late Permian		Mudstone	
Middle Permian		Marble	

A. Marble unit:

Marble is a metamorphic rock by nature. The formation of marble begins with limestone as this limestone get compressed by pressure and exposed to high temperature. The process it takes to form marble from limestone is metamorphism. The mineral that marble contains is $CaCO_3$. There are some other minor minerals

found in it too. During metamorphism, the calcite in the limestone recrystallizes as interlocking calcite crystals. Before crystallization process to form marble, calcite n the limestone takes the form of lithified fossil materials or other biological debris. The crystals grow larger over time. Sometimes, marbles also form due to contact metamorphism. This happens when a hot magma body heats the neighbouring limestone. Limestone and marble doesn't have any foliation or bedding. Most marbles form due to large area of earth is exposed to regional metamorphism at the convergent boundaries. Figure 4.12 and 4.13 below shows the marble rock unit in the study area. Figure 4.14 and figure 4.15 below shows the microscopic observation of the marble.

Figure 4.12: The outcrop of marble.

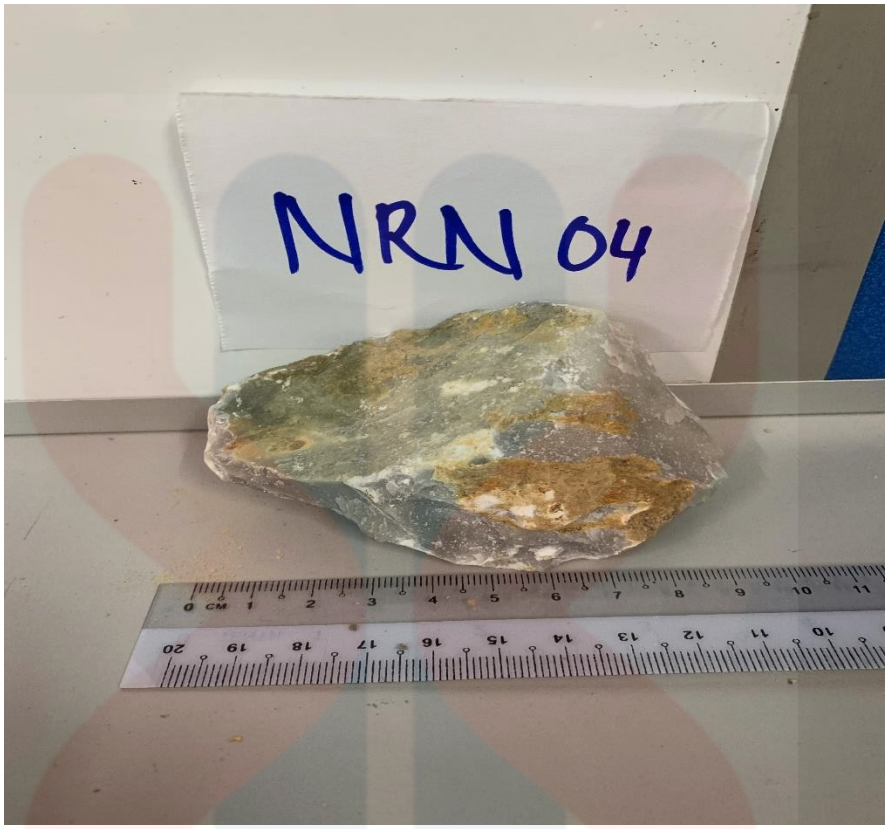


Figure 4.13: The hand sample of marble from the study area.

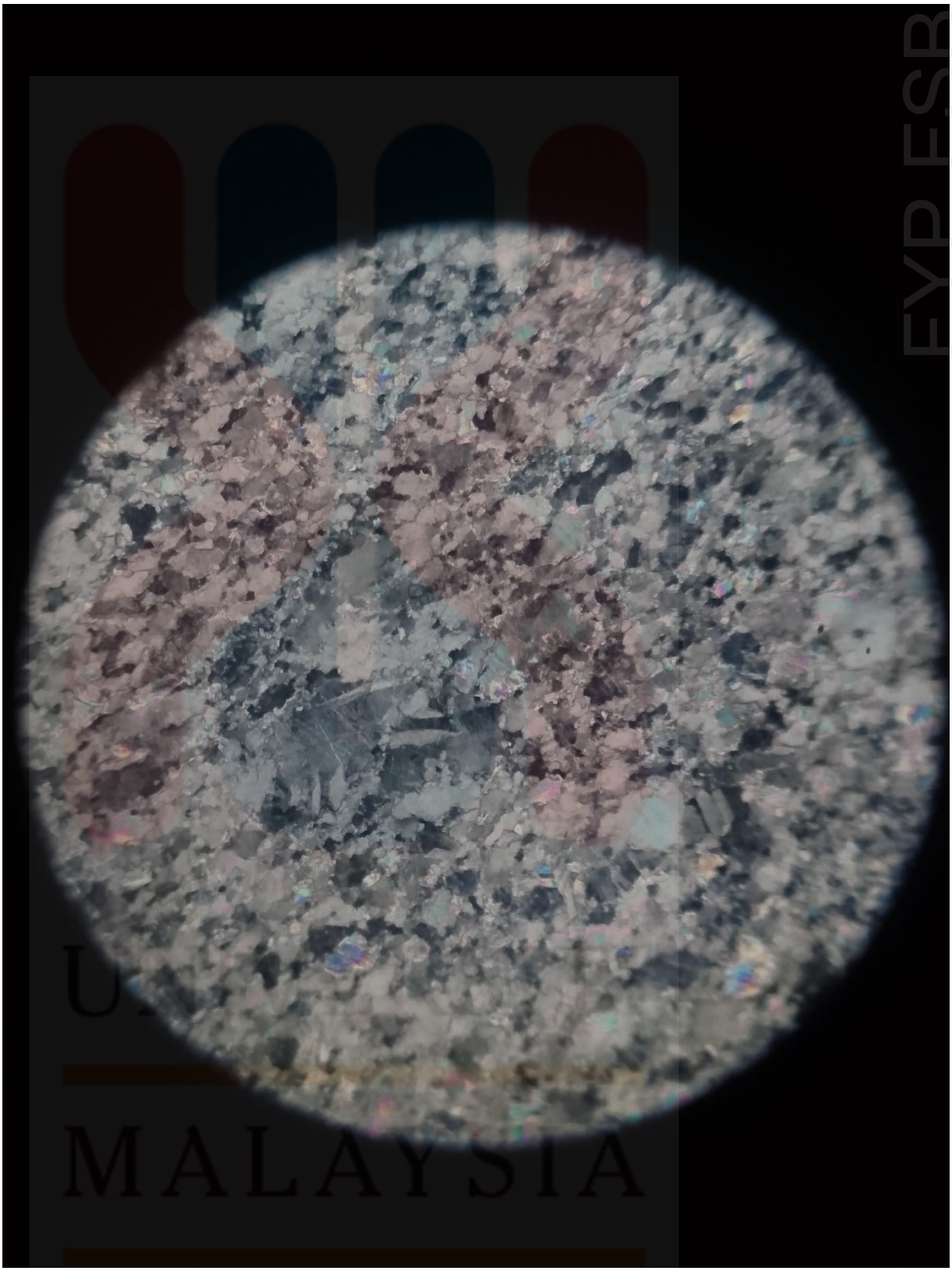


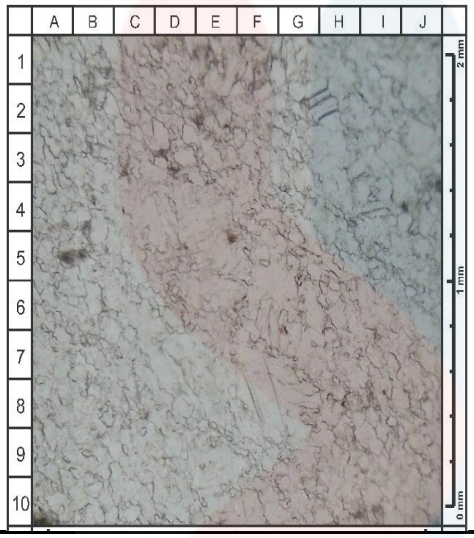
Figure 4.14: Cross polarized light of marble sample under 100x magnification.

Figure 4.15: Plane polarized light of marble sample under 100x magnification.

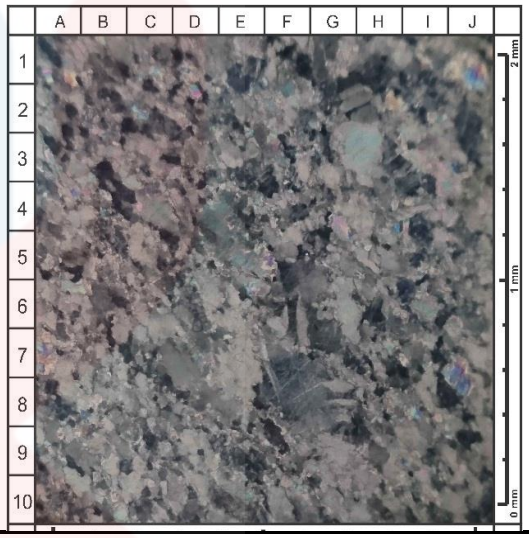
Table 4.2: Petrography analysis result of marble sample.

SAMPLE CODE: NRN 04

PPL (Plane Polarized Light)



XPL (Cross Polarized Light)



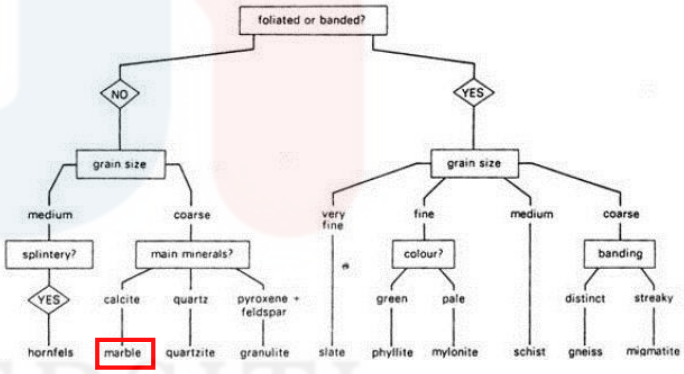
Microscopic observation:

The observations were carried out at 10x ocular magnification and 5x objective magnification and on the observation of nonfoliating structures (granulose), palimpsest textures (blastopsefit) including grain size <1/256 - 1/2 mm, medium sorting.

Mineral composition:

Calcite (A1)

In observations of PPL bright white, pink-greenish in XPL, halves 1-2 directions, have very high-low relief (double reflection), strong pleochroism, present spread in the incision. 100% abundance.



ROCK NAME: MARBLE

B. Mudstone unit:

Mudstone is a fine-grained siliclastic sedimentary rock. The particles of the mudstone are too small right away at field. The rock types of mudstone families look identical to each other but they all vary in composition and nomenclature. When fine sediments erode and deposit, over time with extensive pressure and heat the clay minerals align themselves giving the appearance of parallel layering. Figure 4.16 and 4.17 shows the mudstone sample unit. Figure 4.18 and figure 4. 19 shows the polarised picture of the sample. Table 4.3 shows the petrography

Figure 4.16: The rock unit of mudstone in the study area.

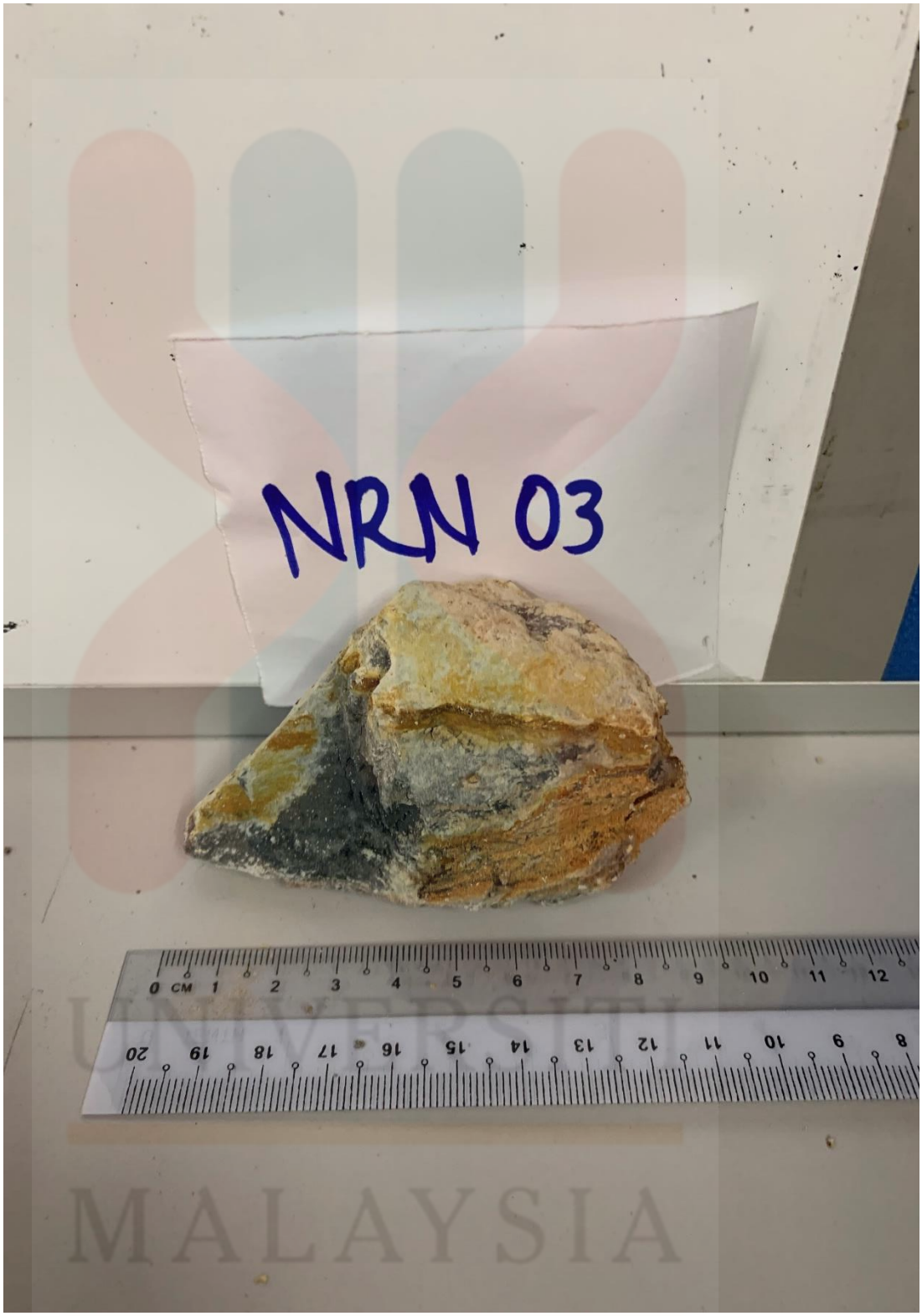


Figure 4.17: The hand sample of mudstone.

Figure 4.18: The cross polarized of mudstone under 100x magnification.

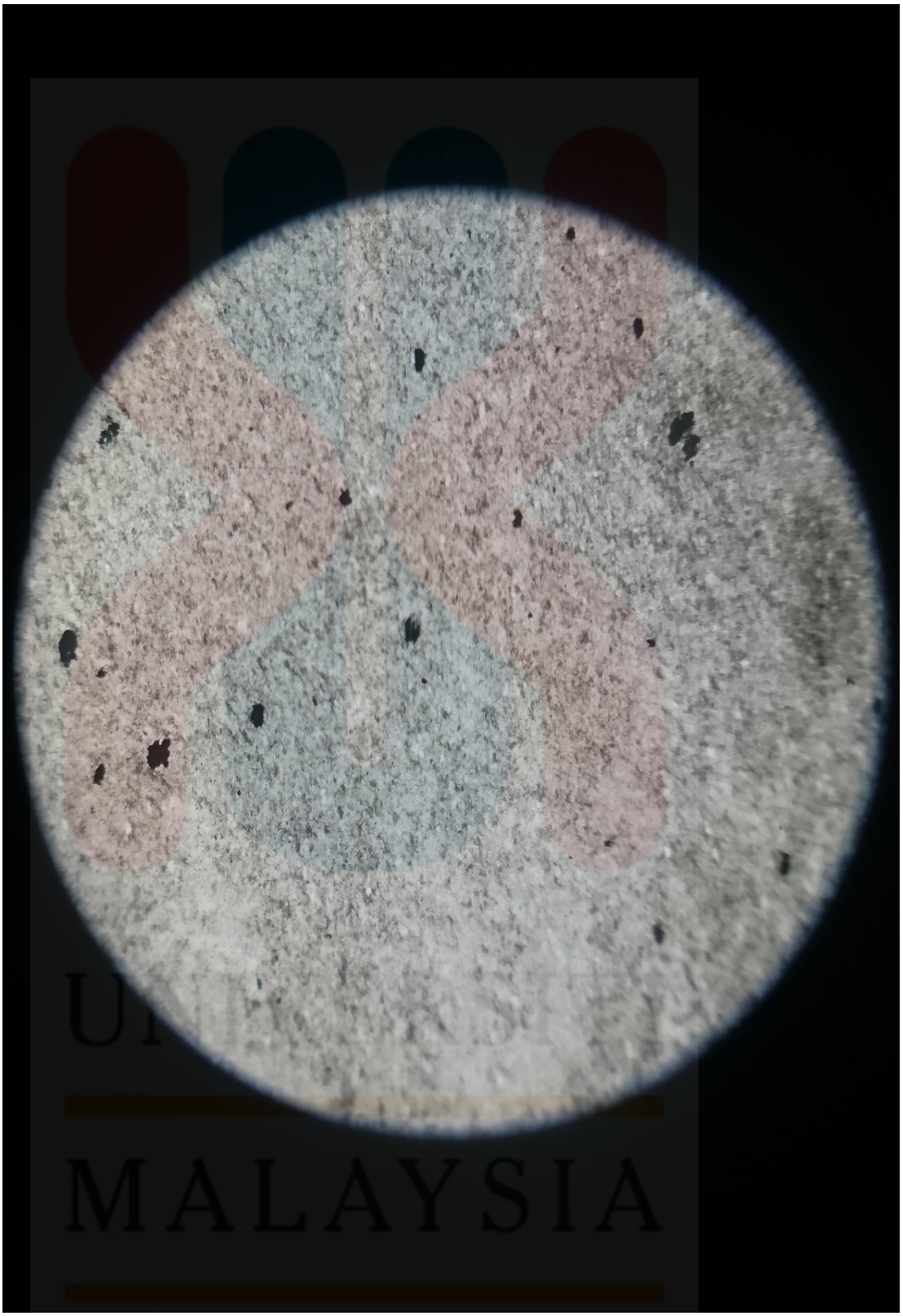
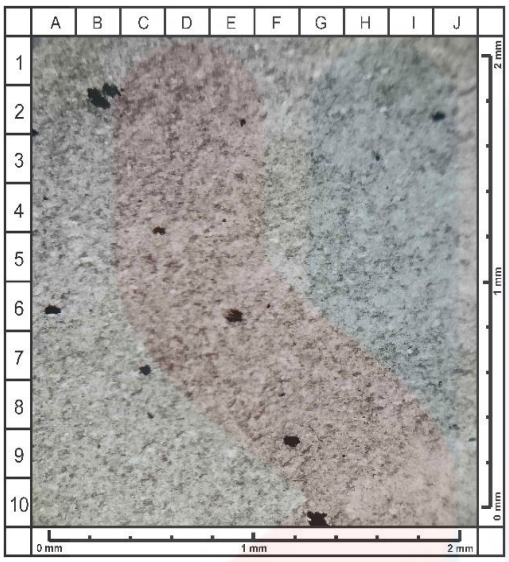


Figure 4.19: the plane polarized of mudstone under 100x magnification.

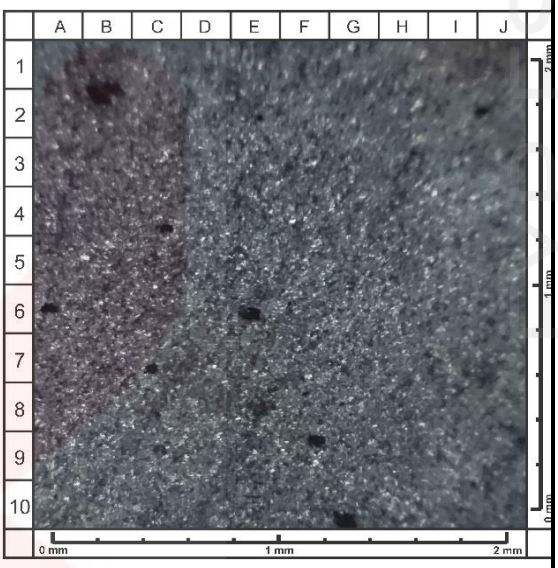
Table 4.3: Petrography analysis of mudstone.

SAMPLE CODE: NRN 03

PPL (*Plane Polarized Light*)



XPL (*Cross Polarized Light*)



Microscopic observation:

The observations were carried out at 10x ocular magnification and 5x objective magnification and the observations were known of massive structure, texture including grain size <1/256 - 1/64 mm, good sorting, closed packing. Began to appear mineral alignment.

Mineral composition:

Quartz (F4)

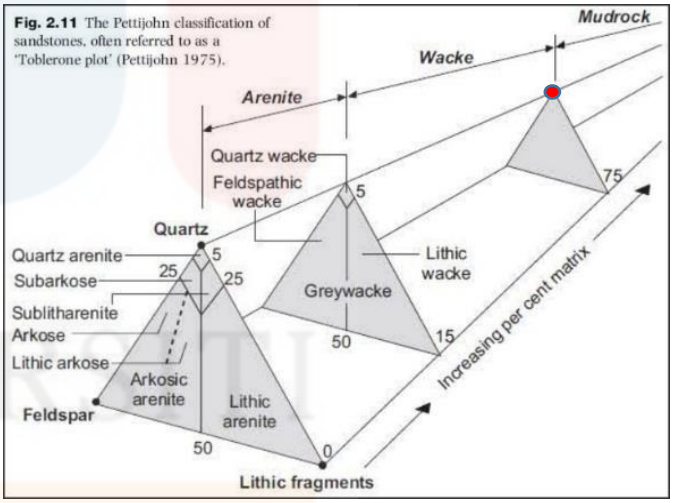
In the observation of PPL is white, XPL - gray - black, low relief without cleavage, low pleochroism, anhedral crystalline form, present spread in the incision. 1% abundance.

Silica clay mineral (A1)

In the case of PPL white-gray, in XPL the gray-black color, relief-pleochroism-shape crystals and parts are not visible, present spread in the incision. 97% abundance.

Opaque mineral (B2)

In observations PPL and XPL look dark, present in the incision spread. 2% abundance.



ROCK NAME: META MUDROCK (MODIFIED FROM PETTIJOHN, 1975)

C. Feldsphatic wacke unit:

rock unit contains at least 25% of feldspar of any type. Wackes have more than 15% of matrix. This type of wackes are mostly common in proximity to granitic source terrains. They are mostly found in alluvial fan deposition environment. These types of rock is typically immature to sub-mature texturally. They are usually from first generation sediment. Figure 4.20 the outcrop of the feldsphatic wacke, Figure 4.21 shows the hand sample of the feldsphatic rock unit, Figure 4.22 and Figure 4.23 shows the polarized picture of the thin section. Table 4.4 shows the pictography analysis of the sample.

Figure 4.20: The outcrop of Feldsphatic wacke.

Figure 4.21: The hand sample of the feldsphatic wacke.

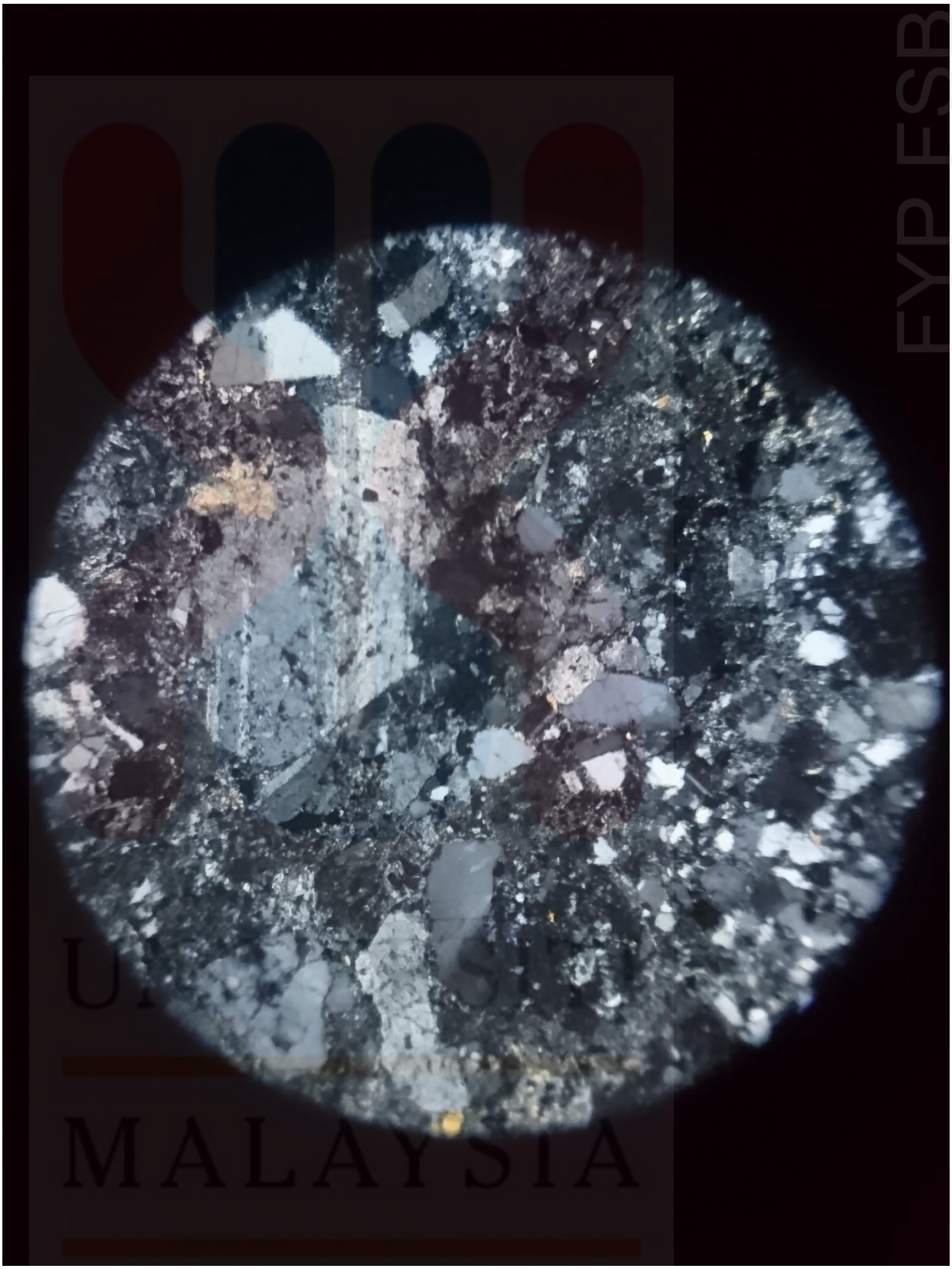


Figure 4.22: Cross polarized light of feldsphatic wacke under 100x magnification.

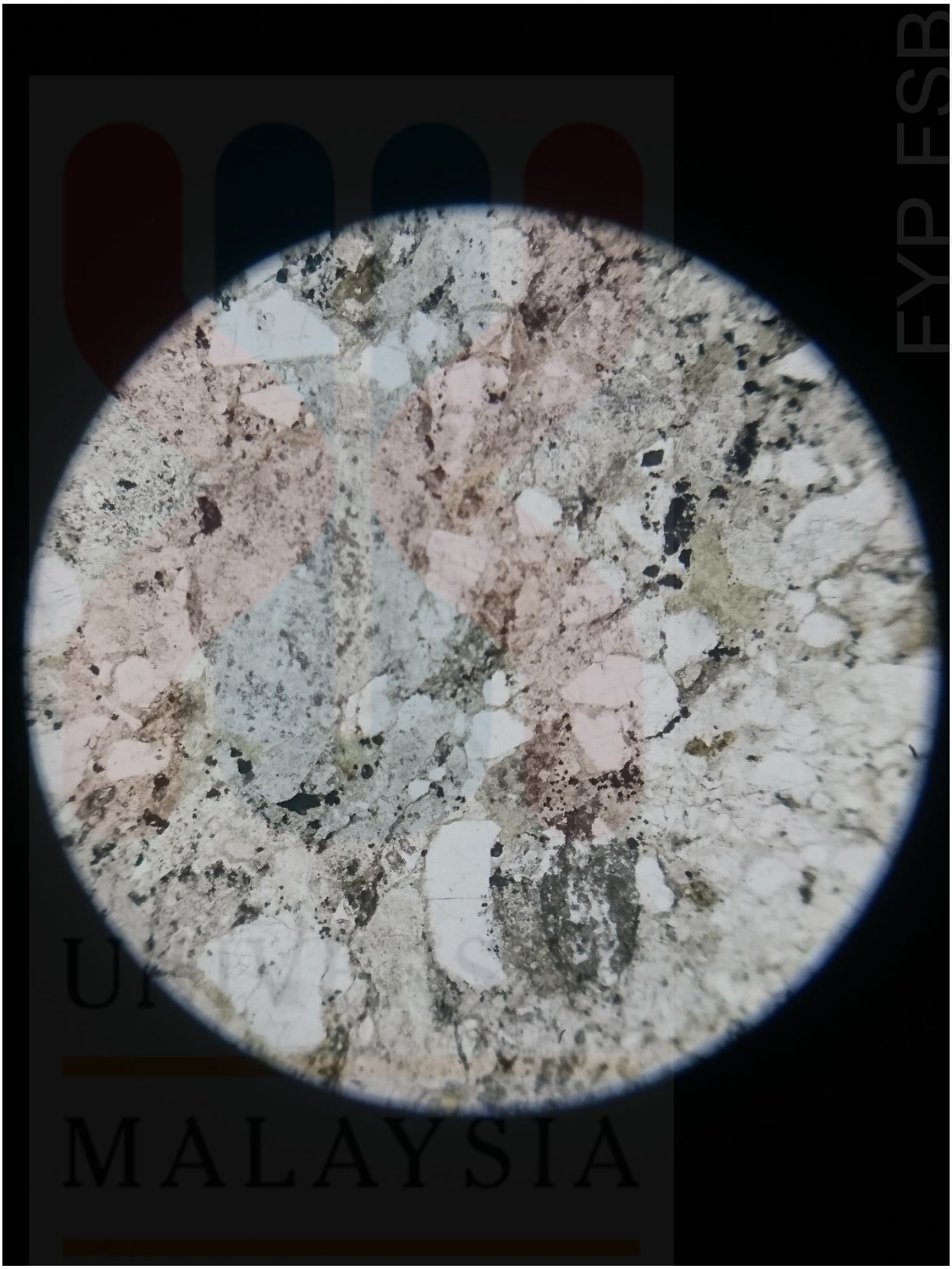
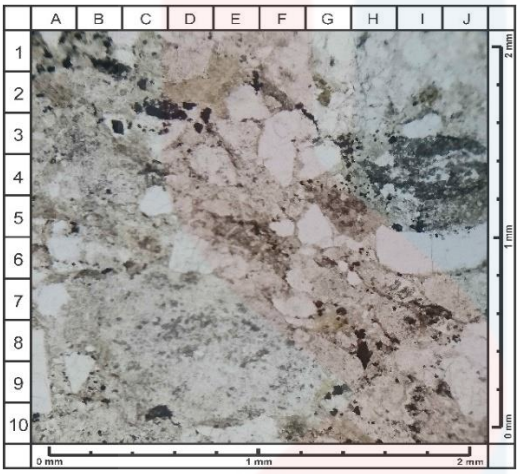


Figure 4.23: Plane polarized light of feldsphatic wacke under 100x magnification.

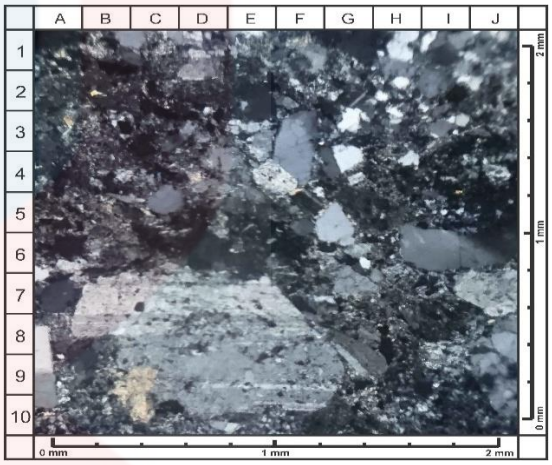
Table 4.4: The petrography analysis of the sample.

SAMPLE CODE: NRN 05

PPL (*Plane Polarized Light*)

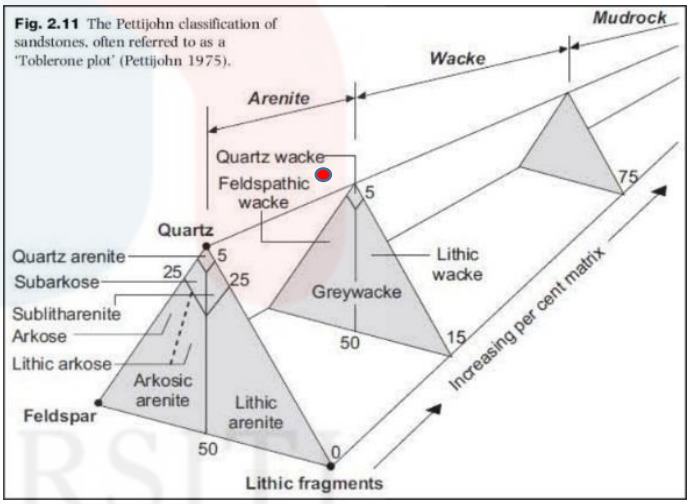


XPL (*Cross Polarized Light*)



Microscopic observation:
The observations were carried out at 10x ocular magnification and 5x objective magnification and the observations found that the structure is massive – banded, texture includes grain size <1/256 – 1.2 mm, medium sorting, closed packaging.

Mineral composition:
Quartz (I6)
In the observation of PPL is white, XPL white – gray – black, low relief without cleavage, low pleochroism, anhedral crystalline form, present spread in the incision. 25% abundance.
Feldspar (D3)
In the observation of PPL is bright color, XPL pink-gray, subhedral-euhedral, twin orbit, moderate pleochroism, one-way hemisphere, present to spread in the incision. 22% abundance.
Silica clay mineral (A3)
In the case of PPL white-gray, in XPL gray-black color, relief-pleochroism-shape crystals and parts are not visible, present spread in the incision. 48% abundance.
Opaque mineral (H8)
In observations PPL and XPL look dark, present in the incision spread. Abundance of 5%.



ROCK NAME: META FELDSPATHIC WACKE (MODIFIED FROM PETTIJOHN, 1975)

D. **Slate rock unit:**

Slate is fine-grained rock. Alteration of shale or mudstone created this foliated metamorphic rock. It is a low grade regional metamorphism process. Main of composition of slate is mica or clay minerals. The clay minerals in shale is subjected to high heat and pressure to form slate. Late usually occurs in area of former sedimentary basin which was involved in convergent plate boundary. Shales and mudstone are then compressed horizontally with low heat. Foliation then develops at right angle to the forces towards north. Figure 4.24 shows the outcrop of slate, Figure 4.25 shows the hand sample of slate, Figure 4.26 and Figure 4.27 shows the light polarized picture of the petrographic analysis of slate. Table 4.5 shows the petrography analysis of the slate.

Figure 4.24: The outcrop of slate.

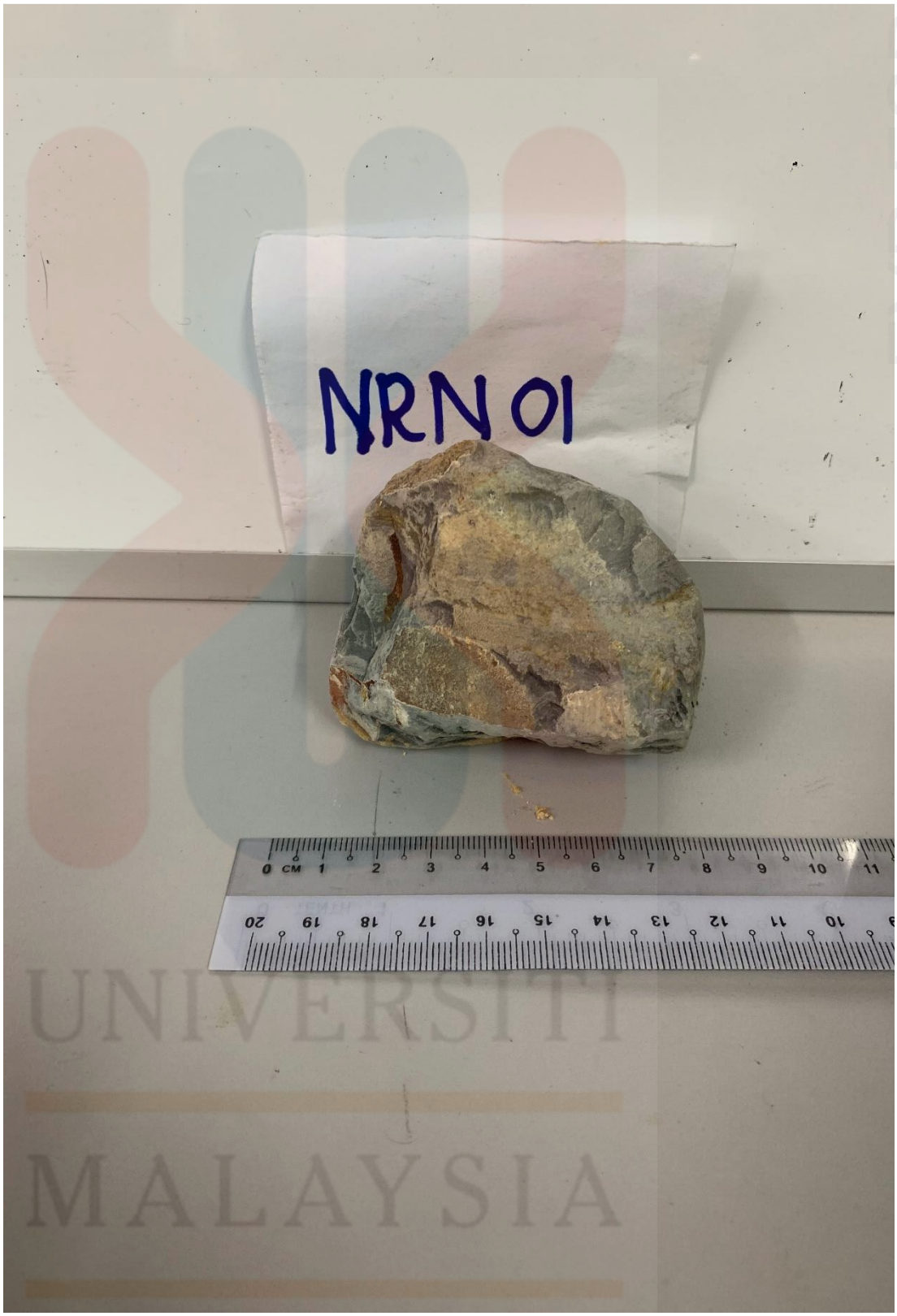


Figure 4.25: The hand sample of slate rock.

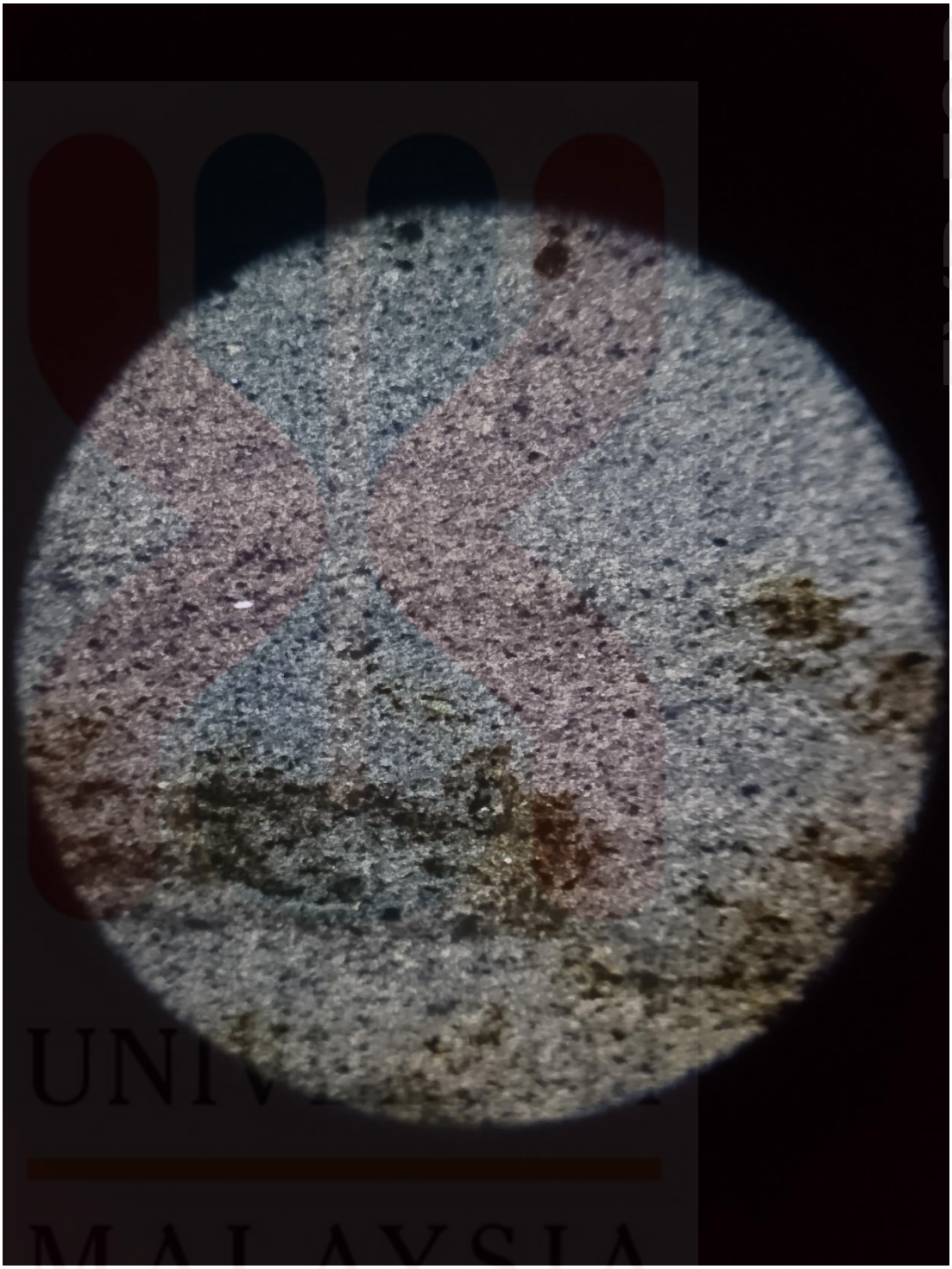


Figure 4.26: Cross polarized light of slate under 100x magnification.

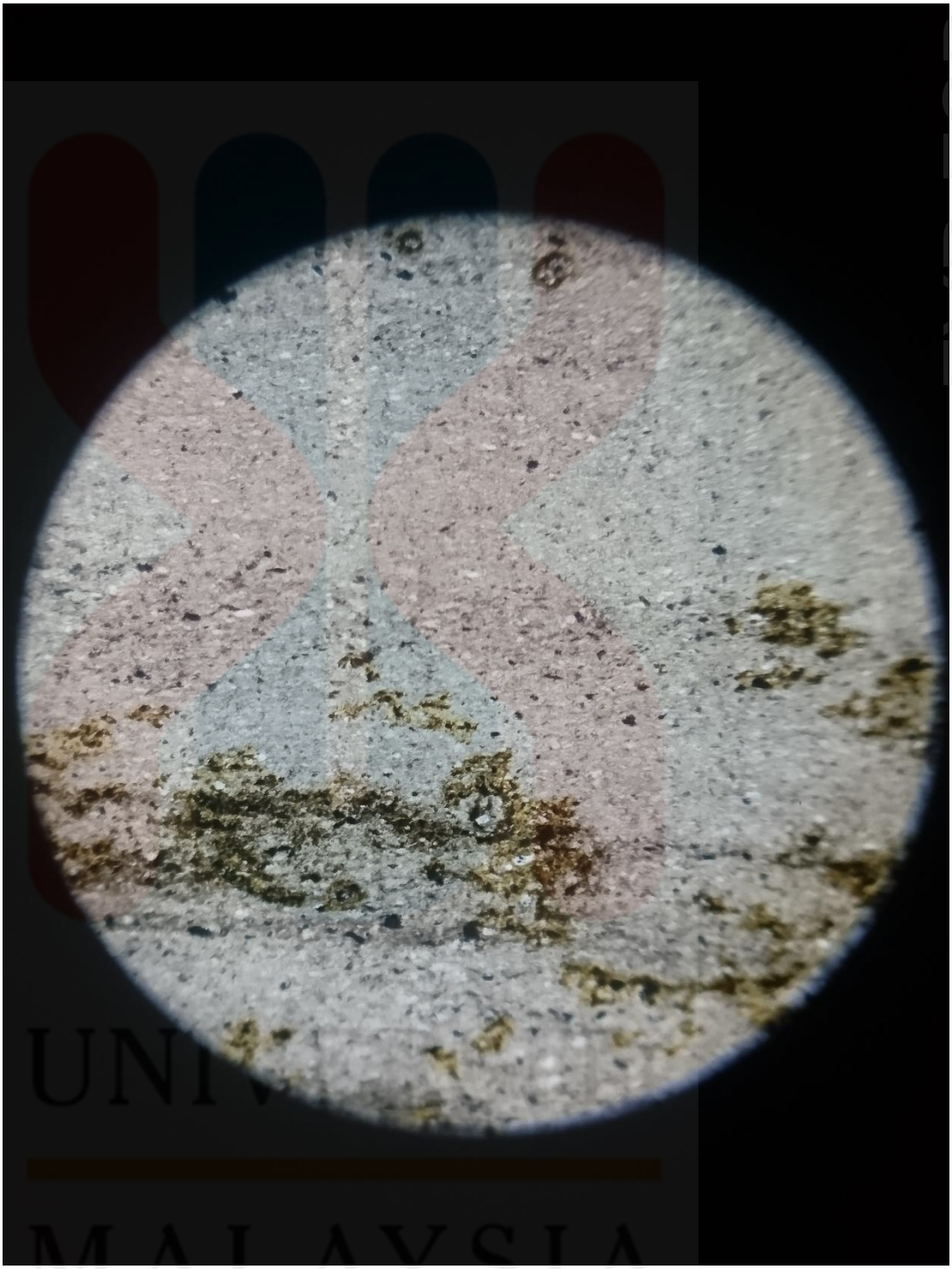
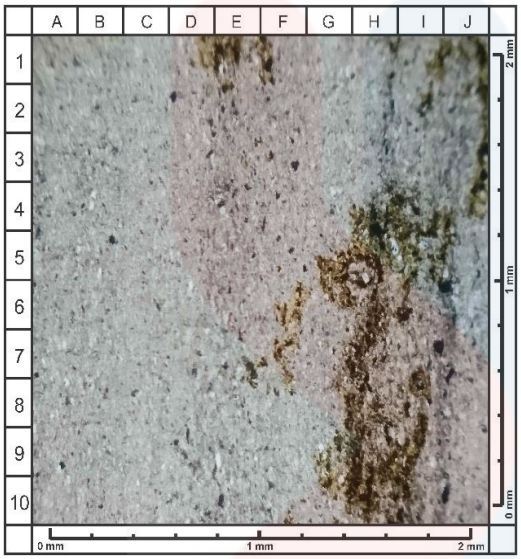


Figure 4.27: Plane polarized light of slate under 100x magnification.

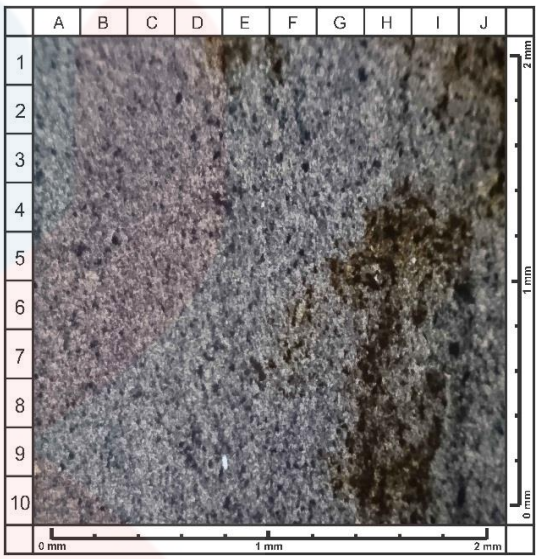
Table 4.5: The petrography analysis of slate.

SAMPLE CODE: NRN 01

PPL (*Plane Polarized Light*)



XPL (*Cross Polarized Light*)



Microscopic observation:

The observations were performed at 10x ocular magnification and 5x objective magnification and on the observation of the foliation structure (slaty), the palimset (blastopellite) texture covered with grain sizes <1/256 - 1/32 mm, well sorted.

Mineral composition:

Quartz (E9)

In the PPL observations is white, XPL white - gray - black, low relief without hemorrhoids, low pleochroism, anhedral crystalline form, are present dispersed in incisions. 1% abundance.

Silica clay mineral (A1)

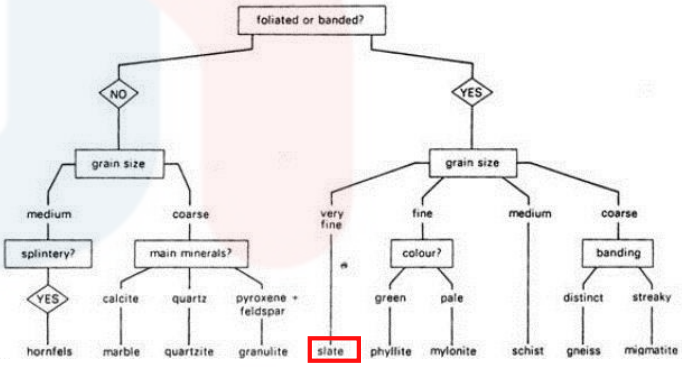
In the case of white PPL -gray, in XPL the gray-black color, relief-pleochroism-shape crystals and parts are not visible, present spread in the incision. 86% abundance

Oxide clay mineral (H9)

In the case of PPL brown, in XPL the grayish-brownish-blackish color, relief-pleochroism-crystalline form and invisible cleavage are present in the incision. 10% abundance.

Opaque mineral (D2)

In observations PPL and XPL look dark, present in the incision spread. 3% abundance.



ROCK NAME: SLATE (GILLEN, 1982)

CHAPTER 5

RESULTS AND DISCUSSION

5.1 INTRODUCTION

The method used for seawater intrusion identification is electrical resistivity imaging method. The resistivity survey was conducted around Sungai Peng Dan, Bachok. This study area contains both first and second layer aquifers. The first layer is from the depth of 3 metres to 40 metres. The layer aquifers are from 30 to 70 metres below earth. The intrusion here occurs at the second layer aquifers. Intrusion of saltwater into fresh water aquifers, leads to contamination around the area. Contamination lead to health issues to human body if the contaminated water is consumed. In these types of coastal aquifers, saltwater intrusion occurs naturally to a certain degree. This owes to the hydraulic connection between groundwater and seawater. The result of resistivity test reveals different values and concentration for each location.

5.2 STUDY AREA

The study area is located in the north part of the of Kota Bharu, Kelantan. Three resistivity survey lines were conducted in various places in the study area. All three lines were conducted in highly populated area and was also considered that the shore is near.

Table 5.1: Details of Resistivity survey lines.

No of survey lines	Location	Array	Distance from shoreline (km)
Line 1	Mentuan	6°09'29.1"N 102°20'36.2"E	0.8
Line 2	Sering	6°07'35.8"N 102°19'50.3"E	3.6
Line 2	Kota Jembal	6°06'30.8"N 102°19'01.4"E	4.4

Figure 5.1: The location of resistivity lines.

a) Resistivity Survey Line 1

From the top soil, the test shows presence of water at a very large quantity. It is actually the surface water that is stored in the loose soils. This test was conducted in a place where the soil was alluvium. So water particles are trapped in between grain particles making it a good potential area to store water. The resistivity test reveals the highest value as 4725 Ωm while the lowest reading is 0.28 Ωm. The highest value represents the hard rock resistivity at the bottom right corner while the lowest reading shows the seawater resistivity value. The resistivity of the soil ranges from 4 Ωm to 10 Ωm. This shows that there is abundant water on the surface. Based on the test, the value from 0.2 Ωm to 10 Ωm is actually saltwater resistivity reading. The figure 5.1 below shows the resistivity image of the line.

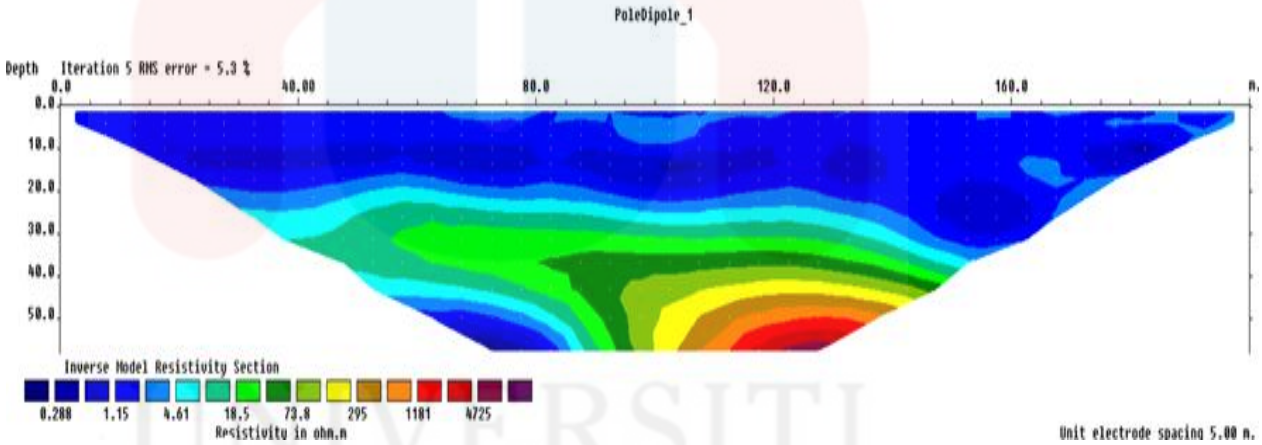


Figure 5.2: The resistivity profile of line 1.

b) Resistivity Survey Line 2

From the top soil, the test doesn't show any presence of water. The ground was dry and wasn't damp. The resistivity image also shows that water source is very deep down. And the top layers of the soil has no water. The highest resistivity reading for this line is 125 Ωm while the lowest resistivity reading shows 0.975 Ωm. The top soil is until the depth of 25 metres. The top soil is made up of clay and alluvium. The resistivity reading for the top soil range from 10 Ωm to 130 Ωm. The only place to find water source is deep down the Earth at the depth of 60 metres. Figure 5.2 below shows the resistivity image result of line 2.

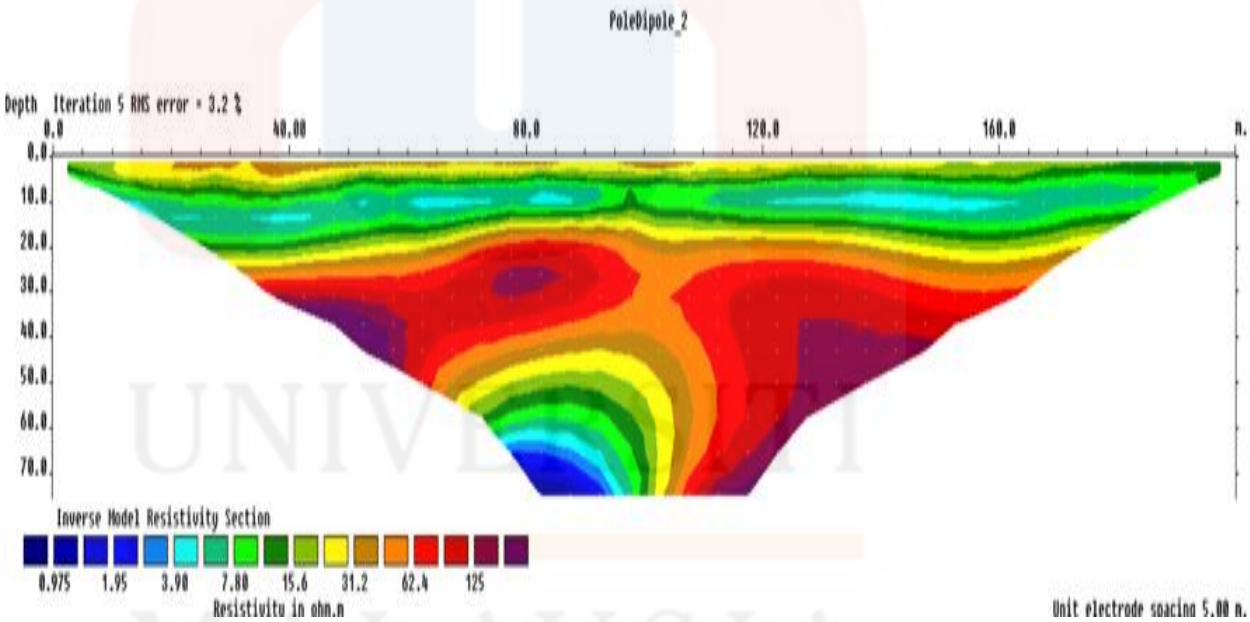


Figure 5.3: The resistivity profile of line 2.

c) Resistivity Survey Line 3

The third test was conducted at the place where clay and alluvium dominated the Earth's surface. The surface has some water contained in it. Water particles trapped in the pores of the rock unit. The top soil ranges from the surface to a depth of 20 metres. The resistivity reading of the top soil ranges from 10 Ωm to 70 Ωm. The lowest reading of this resistivity test is 0.546 Ωm while the highest shows 69.9 Ωm. water source can be clearly seen only at the bottom of the resistivity profile at the depth of 60 metres. Figure 5.3 shows the resistivity profile of line 3.

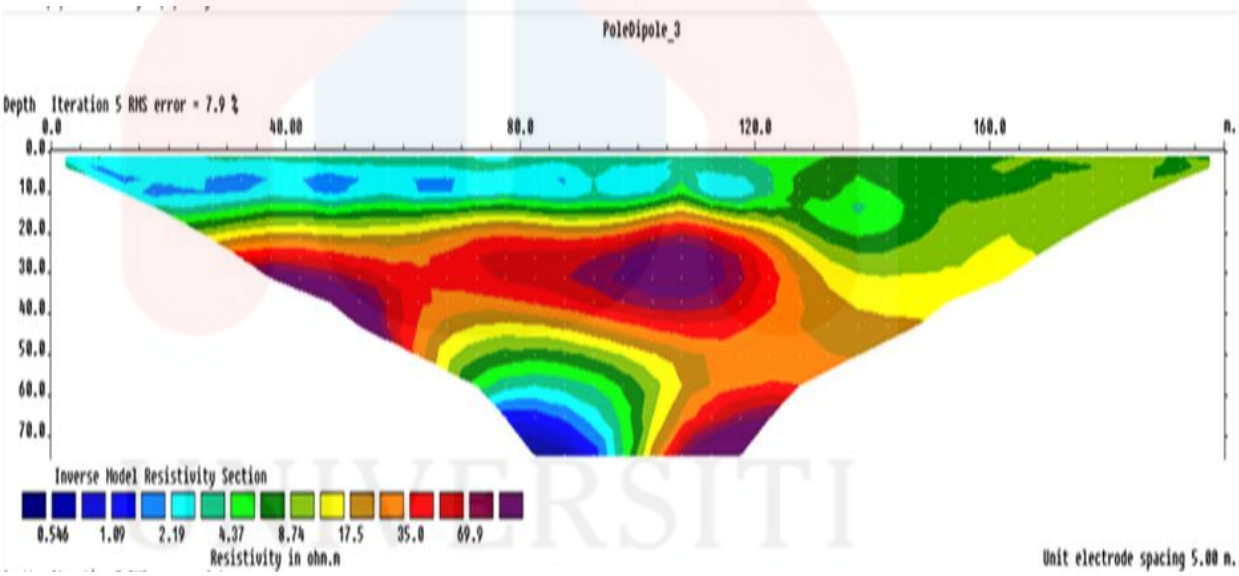


Figure 5.4: The resistivity profile of line 3.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study is to identify the geology of the study area which is conducted at Lojing, Gua Musang. The geological map produced in scale 1:25000 and the objectives are achieved. Mudstone dominated the study area followed by karst environment.

The study to determine the sea water intrusion conducted at coastal site of Kelantan, Kota Bharu, was sheltered and appropriate for use of all reasons in day by day life as per the Guidelines of Raw Water Quality Standard from the Ministry of Health of Malaysia. The result of resistivity survey shows there is sea water intrusion in aquifer. As conclusion, based on geophysical and its results, there was sea water intrusion into shallow aquifers happened around Kota Bharu, Kelantan.

6.2 Recommendation

Future research must be direct again as this wonder can occur in only a couple of years as Kota Bharu is one of the regions that experience creating stage. The requests of groundwater will be increment and the overdraw of groundwater will interrupt the harmony among seawater and freshwater interface along beach front line and add to the sea water interruption in aquifers. In future, scientists are recommending to utilize increasingly modern research centre instruments to build the exactness and accuracy of the after effect of the investigation.

REFERENCES

Klassen, J., & Allen, D. M. (2017). Assessing the risk of saltwater intrusion in coastal aquifers. *Journal of Hydrology*, 730-745.

Ali Khan, H. M., Shaari, N. A., Ahmad Bahar, A. M., & Baten, M. A. (2014). Impact of the Flood Occurrence in Kota Bharu, Kelantan Using Statistical Analysis. *Journal of Applied Sciences*.

Tiffany, C. (2016, December 7). *How Watersheds work*. Retrieved from How Stuff Works: https://science.howstuffworks.com/environmental/conservation/issues/watershed1.htm

Sruchika. (2018, september 7). *What is dendtritic drainage pattern?* Retrieved from Quora: https://www.quora.com/What-is-a-dendritic-drainage-pattern

Statistics, D. o. (2017, December 28). *Compendium of Environment Statistics 2017*. Retrieved from Department of Statistics, Official Portal: https://dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=162&bul_id=VTBLVkpvQVJ1QnJtMWdBcUdCTzlwZz09&menu_id=NWVEZGhEVlNMeitaMHNzK2htRU05dz09

Nazaruddin, D. A., Zulkarnain, Z., Md. Fadilah, N. S., Ali Khan, M. M., & Achmad Bahar, A. M. (2015). Study on Geoheritage and Water Quality of Pos Hendrop Hot Spring, Lojing Highlands, Kelantan, Malaysia. *Journal of Tropical Resources and Sustainable Science*.

F. Belknap, D. (2017, August 8). *Quaternary*. Retrieved from Encyclopaedia Britannica: https://www.britannica.com/science/Quaternary

Yin, E. (1965). *Provisional Draft Report on the Geology and Mineral Resources of the Gua Musang Area.* South Kelantan.

USGS. (2014). *What is a fault and what are the different types?* Retrieved from USGS Science for a changing world: https://www.usgs.gov/faqs/what-a-fault-and-what-are-different-types?qt-news_science_products=0#qt-news_science_products

Kuria, Z. N.-A. (2010). Imaging saltwater intrusion into coastal aquifers with electrical resistivity tomography at Lamu Island, South Coast Kenya. *African Journal of Science and Technology.*, 57-72.

Cai, J. W. (2017). Electrical conductivity models in saturated porous media. *Earth-Science Reviews*.

M. Sherif., A. E. (2006). Geoelectrical and hydrogeochemical studies for delineating seawater intrusion in the outlet of Wadi Ham, UAE. *Environmental Geology*, 536-551.

Zarocca, M. B. (2011). Electrical methods (VES and ERT) for identifying, mapping and monitoring different saline domains in a coastal plain region (Alt Empordà, Northern Spain). *Journal of Hydrology*, 407-422.

Ramirez, A. L. (1993). Monitoring an Underground Steam Injection Process Using Electrical Resistance Tomography. *Water Resources Research*, 73-87.

Samsudin, A. R., Baharuddin, B., Mustapa, M., & Soed, S. (2002). *Geophysical mapping of saltwater intrusion in the Kerpan coastal area, Kedah.* Kota Bharu, Kelantan, Malaysia: Geological Society of Malaysia Annual Geological Conference.

Samsudin, A. R. (2002). Geophysical mapping of saltwater intrusion in the Kerpan coastal area, Kedah.

Maruyama, S., Isozaki, Y., Kimura, G., & Terabayashi, M. (1997). Paleogeographic maps of the Japanese Islands: Plate tectonic synthesis from 750 Ma to the present. *Island arc*, *6*(1), 121-142.

Peng, K. H., & Ipoh, W. (1983). Mesozoic stratigraphy in Peninsular Malaysia. In *Proceedings of the Workshop on Stratigraphic Correlation of Thailand and Malaysia. Geological Society of Thailand and Geological Society of Malaysia, Bangkok* (pp. 370-383).

Rao, P. V., Lee, L. H., Mohamed, S., Wahab, I. R. A., & Soon, J. M. (2016). Ethnomedicinal knowledge of Temiar ethnic tribe of Lojing Highlands, Kelantan: a source for nutritional and antioxidant potential. In *Proceedings of the 5th World Conference on Applied Sciences, Engineering and Technology* (pp. 12-21). Basha Research Corporation.

HO, M. S., & ZARIYAWATI, M. (2009). A comparison analysis of logging cost between conventional and reduced impact logging practices. *International Journal of Economics and Management*, *3*, 354 366.

Samad, M. N. S. A., Hanafiah, M. M., AbdulHasan, M. J., Ghazali, N. F., & Harun, S. N. (2017). Ratio of water withdrawal to availability in kelantan watersheds Malaysia.

Seik, Y. S. (2017). *General geology and prediction of groundwater resources using eri method at Gua Musang, Kelantan* (Doctoral dissertation, Faculty of Earth Sciences).

KHAIR, K. G. E. M. (2016). Subsurface delineation and cavity investigation using geophysical methods in Gua Musang, Kelantan, Malaysia.

Nazaruddin, D. A., Fadilah, N. S. M., Zulkarnain, Z., Omar, S. A. S., & Ibrahim, M. K. M. (2014). Geological studies to support the tourism site: A case study in the Rafflesia Trail, near Kampung Jedip, Lojing Highlands, Kelantan, Malaysia. *International journal of Geosciences*, *5*(08), 835.

Jusoff, K., & Senthavy, S. (2003). Land use change detection using remote sensing and geographical information system (GIS) in Gua Musang district, Kelantan, Malaysia. *Journal of Tropical Forest Science*, 303-312.

Beck, C., Grieser, J., Kottek, M., Rubel, F., & Rudolf, B. (2005). Characterizing global climate change by means of Köppen climate classification. *Klimastatusbericht*, *51*, 139-149.

Alias, N. E., Mohamad, H., Chin, W. Y., & Yusop, Z. (2016). Rainfall analysis of the Kelantan big yellow flood 2014. *Jurnal Teknologi*, *78*(9-4).

Mohamed, K. R., Joeharry, N. A. M., Leman, M. S., & Ali, C. A. (2016). The gua musang group: A newly proposed stratigraphic unit for the Permo-Triassic sequence of northern Central Belt, Peninsular Malaysia.

Metcalfe, I. (2013). Tectonic evolution of the Malay Peninsula. *Journal of Asian Earth Sciences*, *76*, 195-213.

Erwin, D. H. (2015). *Extinction: How Life on Earth Nearly Ended 250 Million Years Ago-Updated Edition* (Vol. 37). Princeton University Press.

Frisch, W., Meschede, M., & Blakey, R. C. (2010). *Plate tectonics: continental drift and mountain building*. Springer Science & Business Media.

Shuib, M. K. (1994). Structures within the Bentong Suture Zone along the Cameron Highlands-Gua Musang Road.

Pour, A. B., & Hashim, M. (2017). Application of Landsat-8 and ALOS-2 data for structural and landslide hazard mapping in Kelantan, Malaysia. *Natural Hazards and Earth System Sciences*, *17*(7), 1285.

Essink, G. H. O. (2001). Improving fresh groundwater supply—problems and solutions. *Ocean & Coastal Management*, *44*(5-6), 429-449.

Samsudin, A. R., Haryono, A., Hamzah, U., & Rafek, A. G. (2008). Salinity mapping of coastal groundwater aquifers using hydrogeochemical and geophysical methods: a case study from north Kelantan, Malaysia. *Environmental Geology*, *55*(8), 1737-1743.

Kamal, M. Z. A. M., Hashim, N. M., & Zin, M. S. B. M. (2015). Seawater intrusion in the ground water aquifer in the Kota Bharu District, Kelantan. *PEOPLE: International Journal of Social Sciences*, *1*(1).

ARGIALAS, D., LYON, J., & MINTZER, O. (1988). Quantitative description and classification of drainage patterns. *Photogrammetric Engineering and Remote Sensing*, *54*(4), 505-509.