GEOLOGY AND FAULT ANALYSIS OF POS BLAU, GUA MUSANG, KELANTAN

By

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A report submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Geoscience) with Honours

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DECLARATION

I declare that this thesis entitled "GEOLOGY AND FAULT ANALYSIS OF POS BLAU, GUA MUSANG, 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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APPROVAL

"I/We hereby declare that I/We have read this thesis and in our opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Geoscience) with Honors"

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Geology and Fault Analysis of Pos Blau, Gua Musang, Kelantan.

ABSTRACT

Fault analysis is the study on the deformation of the rock with respect to their stress. To determine the deformation especially fault that inherited from Bentong-Raub Suture Zone, a research was conducted at Pos Blau, Gua Musang, Kelantan as there is no comprehensive geology and fault analysis of the study area from previous research. The study area is in a square box shape with 25km^2. The objectives of this research are to produce geological map of the study area with the scale of 1:25,000 and to analyse the faults present in the study area by dynamic and kinematic analysis. The primary goal of the analysis is to use the measurements of present day rock geometries to discover information about the history of the rocks and to understand the stress field that produce the structures observed in the study area in present day. The methodology used to conduct the research include field study, laboratory work which are thin section preparation and petrographic analysis, data processing by using ArcGis 10.2, Stereonet Software and GeoRose. The lithologies that were found in the study area includes schist, tuff, clastic sediment rock; shale, mudstone, sandstone, chert, conglomerate and thick bedded limestone. The oldest lithology identified is schist that aged Pre-Mesozoic while the youngest lithology is thick bedded limestone that was formed during Late Triassic. Two deformations were identified in the study area which are major thrust fault named as Blau Thrust Fault and Brooke Strike-Slip Fault that caused by the ESE-WNW principal stress. The principal stress direction was gained from joint analysis from field study, this corresponds to the major principal stress of the Bentong-Raub Suture Zone formation due to the collision of Sibumasu and Indochina blocks in the Late Palaeozoic and Triassic. Study on faults in Pos Blau area provide better understanding on the rock deformation related to the dynamic and kinematic analysis.

Keywords: Thrust Fault; Strike-Slip Fault; Dynamic Analysis; Kinematic Analysis; Bentong-Raub Suture Zone

Geologi dan Analisis Sesar di Kawasan Pos Blau, Gua Musang, Kelantan

ABSTRAK

Analisis sesar adalah kajian mengenai tekanan yang menghasilkan deformasi batuan. Satu kajian telah dilakukan di kawasan Pos Blau, Gua Musang, Kelantan untuk menentukan deformasi batuan yang menyebabkan terjadinya sesar, kesan dari *Bentong-Raub Suture Zone*. Kajian ini dilakukan kerana tidak ada lagi kajian berkaitan geologi dan analisis sesar di kawasan kejadian dari penyelidikan terdahulu. Kawasan kajian adalah dalam lingkungan 25km^2, di mana setiap sisi mempunyai jarak lima kilometer per segi. Objektif kajian ini adalah untuk menghasilkan peta geologi kawasan Pos Blau dengan skala 1:25,000 dan menganalisis sesar di kawasan kajian dengan analisis dinamik dan kinematik. Matlamat utama analisis ini adalah untuk menggunakan ukuran geometri batuan untuk mengetahui maklumat tentang sejarahnya yang terdahulu dan untuk memahami bidang tekanan yang menghasilkan struktur geologi yang boleh dijumpai di kawasan kajian pada masa kini. Kaedah yang digunakan ketika penyelidikan termasuk kajian awal, kerja lapangan, kerja makmal iaitu penyediaan sayatan nipis dan analisis petrografi, serta pemprosesan data dengan menggunakan ArcGis 10.2, Perisian Stereonet dan GeoRose. Litologi yang terdapat di kawasan kajian termasuk syis, tufa, batuan sedimen klastik; syal, batu lumpur, batu pasir, chert, konglomerat dan juga batu kapur berlapisan tebal. Litologi tertua yang dikenal pasti adalah syis yang berusia Pra-Mesozoik manakala litologi termuda adalah batu kapur berlapisan tebal yang terbentuk semasa Triasik Akhir. Dua bentuk deformasi utama yang dapat dikenal pasti di kawasan kajian adalah sesar naik yang dinamakan "Blau Thrust Fault" dan sesar mendatar iaitu "Brooke Strike-Slip Fault" yang terbentuk hasil dari tekanan utama dari arah TST-BUB. Ini sepadan dengan tekanan utama pembentukan *Bentong-Raub Suture Zone* yang terhasil disebabkan oleh pertembungan antara Sibumasu dan Indochina Blok sewaktu Paleozoik Akhir dan Triasik. Kajian sesar di kawasan Pos Blau akan memberi kefahaman yang lebih baik berkenaan deformasi batuan yang boleh dianalis dengan dinamik dan kinematik.

Kata kunci: Sesar Naik; Sesar Mendatar; Analisis Dinamik; Analisis Kinematik; Bentong-Raub Suture Zone

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CHAPTER 1

INTRODUCTION

1.1 General Background

The research title is Geology and Fault Analysis of Pos Blau, Gua Musang. The research area which is Pos Blau is part of the Gua Musang district located in south west of Kelantan. Gua Musang region is a boundary between Kelantan and Pahang. It is one of Kelantan district in east Peninsular Malaysia and administrated by the Gua Musang District Council. The study area can be access by using Gua Musang-Cameron Highland Highway. The distance of the study area from Gua Musang city is about 30 km. The study area falls under Gua Musang Formation that lies on Indochina terrane plate. This formation occurs resulting from collision of two huge terranes which are Sibumasu and Indochina. The formation is predominantly composed of calcareous and argillaceous rocks with subordinate arenite, pyroclastics and lava flows.

The research focuses on basic geological mapping and fault analysis of Pos Blau, Gua Musang. This research aimed to determine the direction of forces that drive the fault to occur in the study area. Generally the fault movement are caused by three types of stress which are tensional stress, compressional stress and shear stress. The type of fault is classified by the type of stress that acts on the rock. The geological mapping method is the appropriate way to for determining the fault analysis where the data is taken right away and precisely from field. Fault analysis is important to better understand about the Earth movement over time and to reveal the structural or tectonic

history and the changes of the past environment. It is also one of the most important factors that constitute the geological hazards.

1.2 Study Area

The study area is Pos Blau Gua Musang Kelantan which is located in the south west part of Kelantan (Figure1.1). Gua Musang region is a boundary between Kelantan and Pahang while Pos Blau is the west boundary of Bentong-Raub Suture Zone. The study area covers approximately 25km^2 on scale of 1:25,000. The longitude of the study area extend from 101°43’30” E to 101°46’0” E and latitude from 4°42’30” N to 4°45’0 N. The distance of the study area from Gua Musang city is about 30 km. At the upper part of the study area it can be accessed by using Gua Musang-Cameron Highand Highway. The rest of the study area can only be accessed by using the unpaved logging road either by motorcycle, lorry or Hilux.

In the study area, there is a main river named Sungai Berok and numerous small streams. The study area is predominantly covered by some mountain hill area with the highest elevation of 520 meter high and the lowest elevation is 160 meter. At the south-west and north-east of the study area are reserved forests. Some of the study area is occupied by thick forest and karstic area. The other part of the study area composed of agricultural activities which is palm oil plantation.

Figure 1.1: Location map of study area

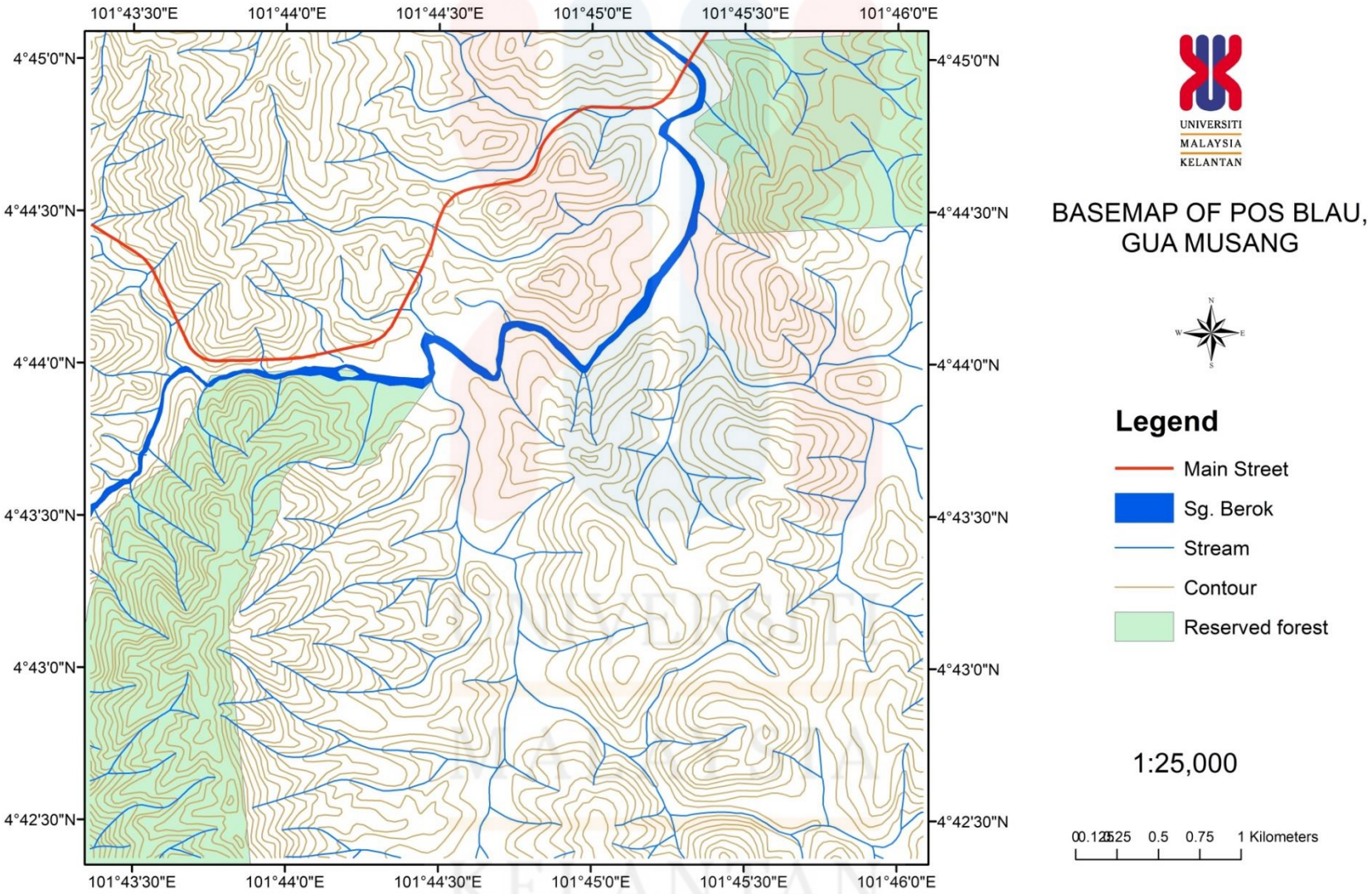


Figure 1.2: Base map of study area (Pos Blau)

1.2.1 Location

Kelantan is one of the states of Peninsular Malaysia. Kota Bharu is the capital state of Kelantan. In Peninsular Malaysia, Kelantan is located at the north-eastern part. South China Sea is positioned in the north-east of Kelantan. To the south-east of Kelantan, it is bordered by Terengganu state, to the north it is bordered by Narathiwat province of Thailand, Perak to the west and lastly bordered by Pahang state at the south part. The study area which is Pos Blau is located in the south-west of Gua Musang District. Gua Musang is the largest district in Kelantan. The total area of Gua Musang covers about 7,980 km^2. Gua Musang district is located at the south of Kelantan which is the border between Kelantan State with Pahang, Terengganu and Perak. It is the gateway to the State of Kelantan from the south via the mainland Kuala Lipis or Kuala Lumpur. Gua Musang is surrounded by limestone hills and caves, which have become popular with cavers and rock climbers. The distance of the study area from Gua Musang city is about 2.5km.

1.2.2 Accessibility

Gua Musang region is a boundary between Kelantan and Pahang while Pos Blau is the west boundary of Bentong-Raub Suture Zone. From Jeli, the road connection to Gua Musang is by Jelawang-Gua Musang highway continues with Gua Musang-Cameron Highland highway. Gua Musang also can be accessed from the other states by using various types of transportations such as train or bus. While for study area, it is a rural area and it can be accessed by unpaved road by using Hilux or motorcycles. There are also some unpaved logging road in the study area due to the active logging activities and can only be passed by Hilux, lorry and motorcycles.

Figure 1.3: Road accessibility to Gua Musang (Source: Google Map)

1.2.3 Demography

People distribution is the pattern or arrangement of how people live in a particular area. It is a measurement of the number of individuals in an area averagely. Gua Musang is located in the southern part of the Kelantan. From the Table 1.1, it can be observed that the population in Gua Musang increased from 63,900 in 1991 up to 90,000 in 2010. The annual growth rate over these 20 years at 29% is believed to be due to the rapid development in the district which brings in the migration of population to the district from another places. A pie chart of the population of Gua Musang based on genders, ethnics and nationality in year 2010 is shown in Figure 1.4, 1.5 and 1.6. From figure 1.4, 54% of the Gua Musang population is female and 46% is male. While figure 1.5 shows that 94.6% of the Gua musang population is Malay, followed by 4.8% Chinese ethnic, 0.4% Indian and the least is other ethnic that come from another country with 0.2% population.

Generally, all the ethnicities in Gua Musang live together. According nationality, there is 94% of the Gua Musang is Malaysian and the rest is other nationality.

Table 1.1: Population by district

District	**Population ('000)**			**Area (Hectare)**
	1991	**2000**	**2010**	
Tumpat	115.9	134.8	154.0	18,000
Kota Bharu	366.8	406.7	491.2	40,326
Pasir Mas	150.4	165.1	189.3	57,238
Bachok	98.6	111.0	133.2	27,951
Tanah Merah	94.3	103.5	121.3	88,414
Machang	71.5	79.0	93.1	52,851
Pasir Putih	96.8	106.1	117.4	42,494
Jeli	32.7	36.5	40.6	133,048
Kuala Krai	90.8	93.6	109.5	22,871
Gua Musang	63.9	76.7	90.1	821,430
KELANTAN	**1181.7**	**1313.0**	**1539.6**	**1,304,713**

(Source: Department of Statistics, Malaysia, 2010)

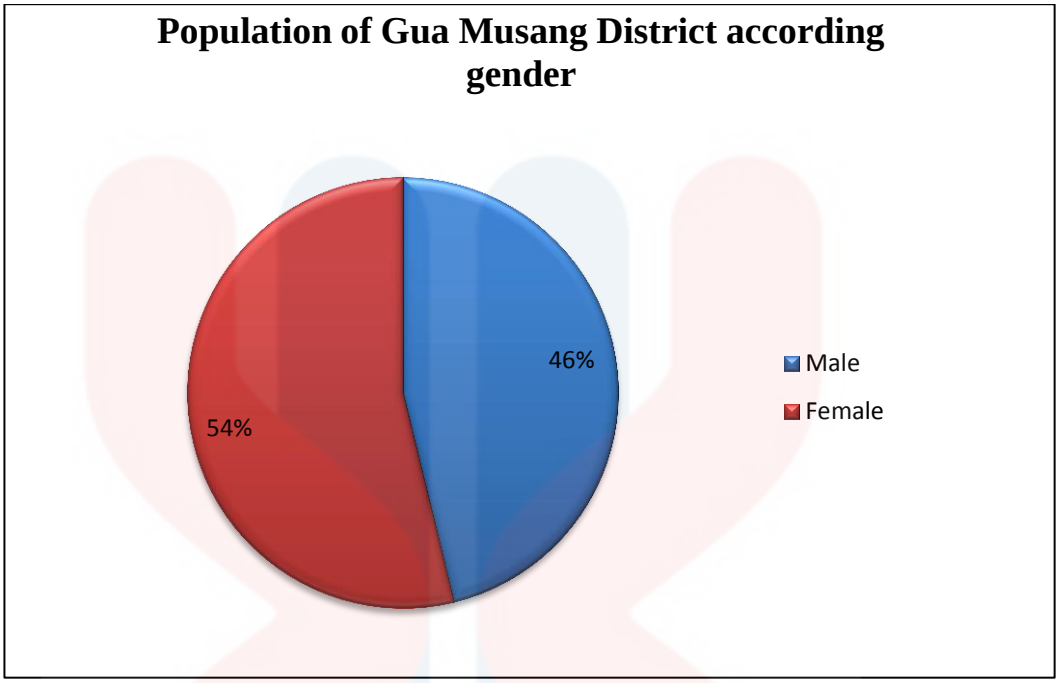


Figure 1.4 : Demographic chart of Gua Musang in year 2010 according gender

(Source: Department of statistics Malaysia)

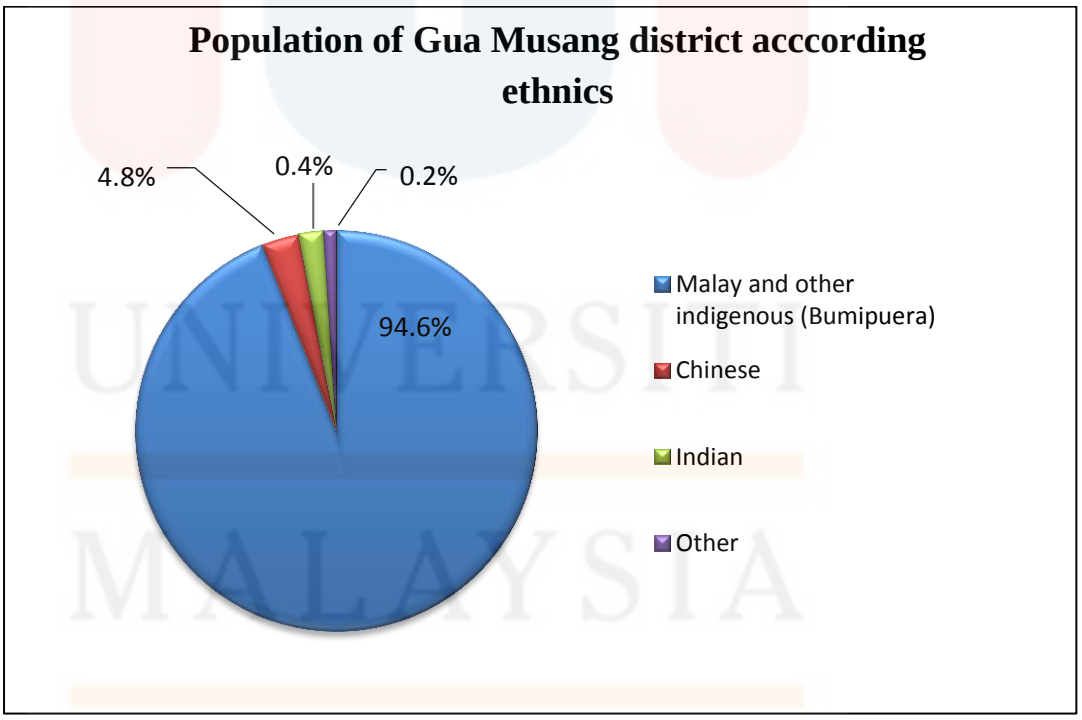


Figure 1.5 : Demographic chart of Gua Musang in year 2010 according ethnics

(Source: Department of statistics Malaysia)

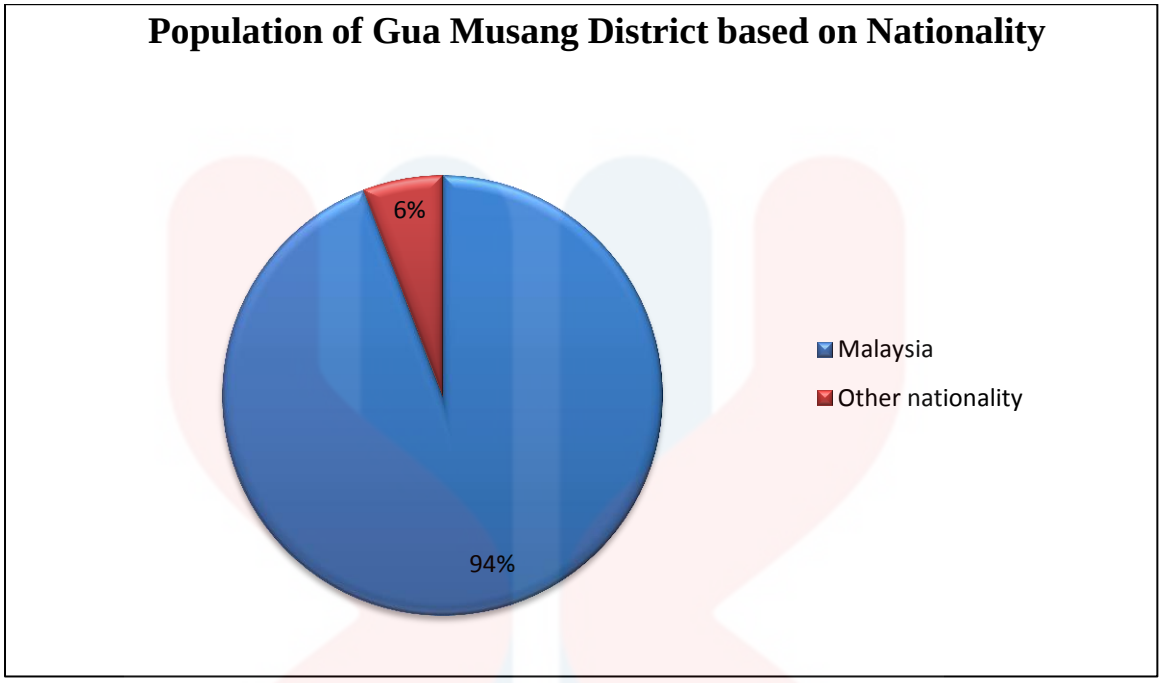


Figure 1.6: Demographic chart of Gua Musang in year 2010 according nationality

(Source: Department of statistics Malaysia)

1.2.4 Landuse

Based on statistics in year 2012, the state of Kelantan Darul Naim has a total land area of 1,502,200 hectares. The diversity of land subsistence with a population of about 1.56 makes the state's natural resources a valuable treasure and is an important legacy of heritage and needs to be preserved sustainably. Of the total area of almost 865,017 hectares is a forested area covering 57.6%. The forested area is comprised of Permanent Reserved Forests covering an area of 623,849 hectares, Government Land Forests of 137,086 hectares, National Park of 103,082 hectares and 69,696 hectares of Forests. (refer Figure 1.7)

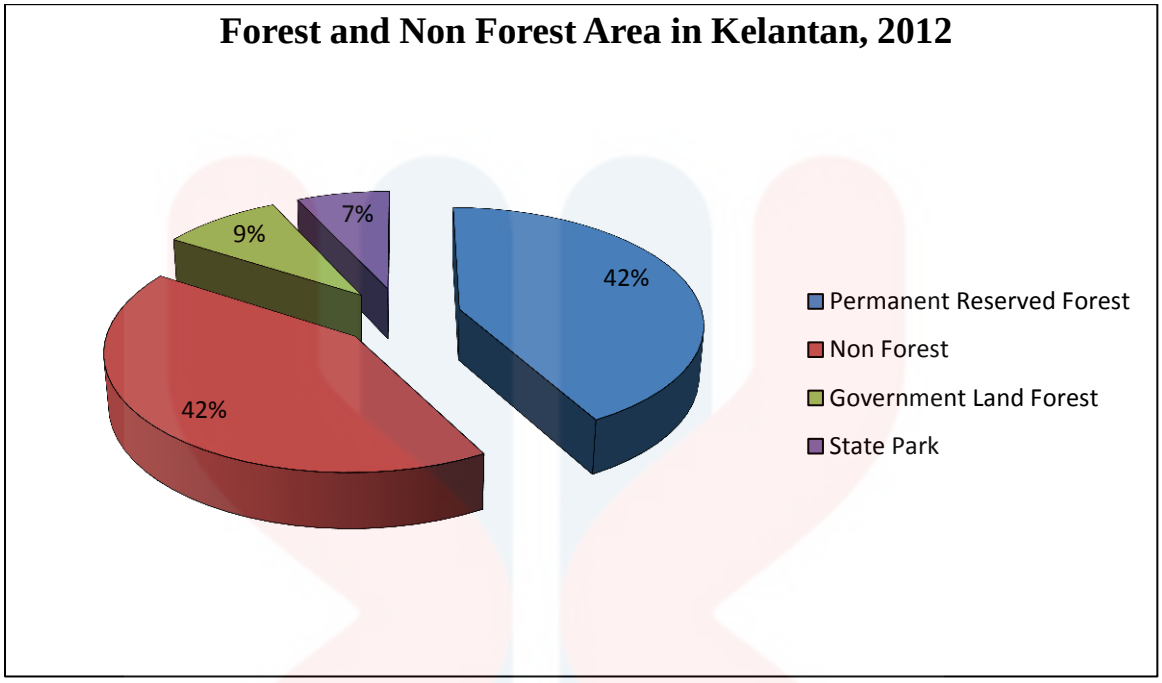


Figure 1.7: Division of Forest and Non Forest area in Kelantan state (KSFD), 2012

Basically the Forest Reserve area in the State of Kelantan is divided into 3 districts or Territories Forest. The division of the Forest Reserves by the Forest Territories is as follows: East Kelantan Forest Zone based on Machang of 167,179 ha, West Kelantan Forest district based in Tanah Merah with a total area of 226,498 ha and Gua Musang Forest district of Kelantan Selatan of 230,172 ha. Table 1.2 shows the list of Permanent Reserved Forests (PRFs) found in each Forest Colony.

The study area which is Pos Blau is located in Gua Musang. From Table 1.2, it shows that about 25,824 hectares of Sg. Brok area is reserved forest. In the study area, the reserved forest located at the South-west and North-east part. Some part of the study area is used for agricultural purposes such as palm oil plantation. The rest of the study area are still not being explored and remain as thick forest.

Table 1.2: List of Permanent Forest Reserves In Kelantan by Forest Area on at 31 December 2010

No.	Reserved Forest	South Colony (ha)	West Colony (ha)	East Colony (ha)	Total (ha)
1.	BATU PAPAN	17,580			17,580
2.	BUKIT HANTU	3,134			3,134
3.	CHIKU	759			759
4.	GUNONG RABONG	16,355			16,355
5.	LIMAU KASTURI	2,107			2,107
6.	LOJING	13,063			13,063
7.	NENGGIRI	21,160			21,160
8.	PERIAS	60,355			60,355
9.	SG.BETIS	52,178			52,178
10.	SG.BROK	25,824			25,824
11.	SG.TERAH	4,442			4,442
12.	ULU GALAS	13,215			13,215
13.	BALAH		56,010		56,010
14.	BERANGKAT		21,409		21,409
15.	BUKIT AKAR		1,072		1,072
16.	G.BASOR		40,613		40,613
17.	GUNONG STONG UTARA		11,044		11,044

18.	GUNONG STONG TENGAH		21,910		21,910
19.	GUNONG STONG SELATAN		28,134		28,134
20.	JEDOK		4,382		4,382
21.	JELI		3,649		3,649
22.	JENTIANG		13,673		13,673
23.	SG.SATOR		2,777		2,777
24.	SOKORTAKU		21,825		21,825
25.	CHABANG TONGKAT			4,863	4,863
26.	LEBIR			47,549	47,549
27.	RELAI			39,432	39,432
28.	SERASA			10,338	10,338
29.	SG.DURIAN			16,481	16,481
30.	SG.REK			15,360	15,360
31.	SG.SAM			3,756	3,756
32.	TEMANGAN			1,590	1,590
33.	ULU SAT			14,432	14,432
34.	ULU TEMIANG			13,374	13,374
35.	SEMERAK			4	4
	JUMLAH BESAR	230,172	226,498	167,179	623,849

(Source: Forest Management Unit of Kelantan State Forestry Department, KSFD)

1.2.5 Social Economic

The factor of socio economic of Pos Blau depends on the geographic nature of the area. The main economical job run by the people in the study area is in agricultural industry which is palm oil plantation. Most of the people in the study area work with palm oil plantations. Some of the villagers work in logging industries such as lorry driver and trees cutter. Some of them are also work someplace else either in government or nongovernment field.

1.2.6 Rain Distribution

The Peninsular of Malaysia is located within the equatorial and surrounded by seas which are South China Sea on the East and Malacca Strait on the West. It is exposed to climate with uniform temperature and high humidity. There are two types of monsoon seasons which are the North-east monsoon that occur between November to March and South-west monsoon occurring between May to September respectively. Kelantan is classified as East Coast of Peninsular Malaysia thus due to the location, the North-east monsoon seasons influences the rainfall distribution of Kelantan state. During monsoon seasons, winds that carry moisture from the seas bring plenty of rainfalls at the East-coast and West-coast of the peninsular. Figure 1.9 shows the monsoon direction of Peninsular Malaysia.

So, during raining season the total amount of rainfall distribution, its frequency and average precipitation increase and get extremely high than normal. The data in Figure 1.8 shows the total rain distribution of Kelantan State in 2016 for each district. Gua Musang has moderate percentage of annual rainfall compare to other districts but during flooding, Gua Musang recorded as the highest percentage of rainfall.

District	Width (km^2)	Rainfall amount during flood episode (mm)	Percentage of rainfall in flood episode (%)	Annual rainfall amount (%)	Percentage of annual rainfall (%)
Tumpat	169.50	1558.70	10.44	3621.28	6.40
Kota Bharu	115.64	3054.00	20.45	1764.10	10.75
Pasir Puteh	433.80	4783.50	32.03	1434.72	13.55
Tanah Merah	884.14	5527.30	37.01	1996.58	15.76
Jeli	1330.48	5132.20	34.37	348.18	9.62
Kuala Krai	2329.00	3091.10	20.70	2023.65	9.64
Gua Musang	8214.30	9584.10	64.19	922.03	24.31
Machnag	546.26	1469.00	9.84	1605.00	2.33
Pasir Mas	139.00	2402.20	16.01	1407.86	9.42

Figure 1.8: Rainfall distribution for each district in Kelantan

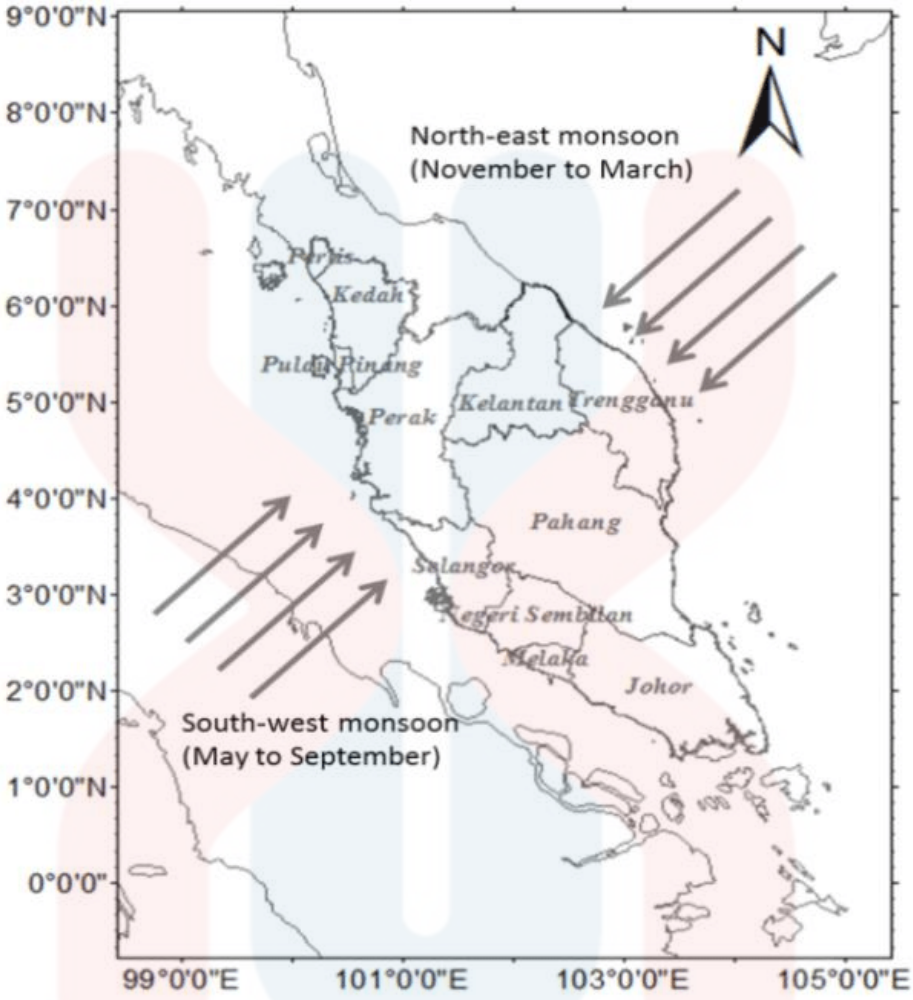


Figure 1.9: Monsoon direction of Peninsular Malaysia

(Source: Deparrment of Irrigation and Drainage Malaysia)

1.3 Problem Statement

Based on the previous research of Pos Blau, Gua Musang Kelantan, there is no comprehensive geology and structural analysis of the study area. Yet, studies have been conducted in this area but they are less related to structural geology aspects especially faults. The previous study of the study area was focussing on sedimentary facies and depositional environment. The primary goal of the analysis is to use the measurements of present day rock geometries to discover information about the history of the rocks

and to understand the stress field that result the structures observed in the study area in present day.

Through previous study, there were several occurrences of landslides along Jalan Lojing Pos Blau-Kampung Kuala Betis. Thus the research as well was conducted to gather the information of the structural pattern of the study area that caused the landslides.

1.4 Research Objectives

i. To produce geological map of the study area with the scale of 1:25,000
ii. To analyse the fault in the study area by kinematic and dynamic analysis

1.5 Scope of Study

The research was conducted at Pos Blau which is located at Gua Musang, Kelantan. Since the study area is in a square box shape with 25km^2, each side would be five kilometres.

This research as well is about three-dimensional distribution of rock units with respect to their deformational histories. Task that has been be conducted is measurements and analysis of the present day rock geometries and their structures to cover the information of deformation history of the rocks thus to understand the stress that resulted in the observed strain and geometries. The data that that has been collected in the fields would be measurement of planar features (bedding planes, fold axial planes, fault planes and joints) and linear fractures (stretching lineation, in which minerals are ductility extended, fold axes and intersection lineation and the trace of a planar failure on another planar surface.

The field reading which are dips, dip direction, strike and joints measurement will be recorded as to use to determine the direction of the principal stress of the deformation. Dip and strike measurement of the bedding attitudes, planes, hinge or any structures of the study area are analysed by using the Stereographic projection. This method is run as to analyse the orientation of lines and planes with respect to each other. While for joints, the data are analysed by using Rose Diagram software. The result of the rose diagram shows the direction of principal force of the study area that contributes to the deformation and geological structures that present in the study area.

1.6 Significance of the Study

Aim to produce a geological map of Pos Blau, Gua Musang Kelantan with scale 1:25,000 by using ArcGIS software. The existing map can be modified and updated with more detailed features. This study provide the geological structural data of the study area such as folds, fault zones and fractures, foliations and lineations and the geomorphologic features of the study area and how it affects the lithology of the surrounding area. Thus the understanding of the dynamics and mechanisms of the structures can be linked to important events in the geologic past of the study area with respect to regionally widespread patterns of rock deformation due to plate tectonics. As fault is a weak zone, it is the weakness to any engineering projects. Thus, the research provides more useful and important information about the weak zone towards future engineering project as a guideline and precaution to the side effects and hazards of any development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This part comprise about all the previous study and research that had been conducted by other researcher near or at the study area. Among all the detail, it provides general information about study area such as Gua Musang Formation, regional geology and tectonic setting, stratigraphy, structural geology especially fault, historical geology, petrography, and sedimentology.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia was formed by the collision of two different blocks which are Sibumasu block and Indochina/East Malaya block at late Permian (Dzulkafli, Jasin, & Shafeea Leman, 2012). Based on distinct differences in stratigraphy, structure, magmatism, geophysical signatures and geological evolution, there are three belts of Malay Peninsula known as the Western, Central, and Eastern belt (Metcalfe, 2013).

In Peninsula Malaysia, Kelantan state is located at the northern part. The eastern part of this state is Terengganu, southern part is Pahang, western part is Perak and Kedah while Thailand is the boundary of Kelantan to the north ("Structural Geology of Gua Musang Formation in Kelantan," 2010) .The study area which is is located in Lojing, Gua Musang Kelantan. According to Mohamad, Dan, & Rafek (1994), Kelantan was lies at the central belt of Peninsular Malaysia.

The Central Belt of Malaysia consists Permo-Triassic sediments and most of them located in area of Gua Musang with a low-grade metasediments, deep to shallow marine clastic sediments and limestone with abundant intermediate to acid volcanics and volcaniclastics, deposited in paleo-arc basin (Metcalfe, 2002).

According to Ahmad Rosli (2008), he stated that the oldest rock that exposed in the central belt of Malaysia are Silurian-Devonian rocks which is known as Bentong Group. Gua Musang Formation consists of sedimentary and metasedimentary rock. The oldest facies or facials found in the Gua Musang Formation consists of conglomerate and sandstone forming Gunung Ayam (Mohamad et al., 1994).

2.3 Stratigraphy

Four types of rock can be found in Kelantan, they are sedimentary/metasedimentary rocks, extrusive rocks (volcanic rocks) , unconsolidated sediments and granitic rocks (Pour & Hashim, 2016). According to Mohd Shafeea Leman (1993), Gua Musang formation are from Middle Permian to Upper Triassic age. The age of the formation is dated by the finding of fossil of ammonoid and pelecypods (Khoo, H. P. 1983). Peng, Leman and Karim (2004), stated that the argilicious and calcacerous rocks with subcoordinate arenite, pyroclastic and lava flows is mostly found in this formation. The Gua Musang formation started from North of Gua Musang to the North of Pahang.

The upper boundary of Gua Musang formation it is overlain by Koh formation (Kamal Roslan Mohamed, Nelisa Ameera Mohamed Joeharry, Mohd Shafeea Leman, 2016). Khoo and Tan (1983) discovered that the upper part of this formation is interfingering with the Semantan Formation, Telong Formation and Rabong Formation.

Gua Musang formation covered a surface area by approximately 250 square miles (Yin, E. H. 1965). Telong Formation is said to be identical with Gua Musang Formation as the Nilam Marble and the Telong Formation sediments are similar to the Gua Musang Formation (Yee, F. K. 1983).

2.4 Structural Geology

Structural geology is about folds, faults, joints and other structures in the lithosphere and also on how they how appear, and why they formed. Peninsular Malaysia is divided into two terranes which form Sunda shelf (Eurasian plate-Indochina) and Sibumasu (Shan Thai) terranes. The Bentong-Raub Suture Zone is result from northwards subductions of Paleo-Tethys Ocean beneath Indochina in the Late Paleozoic and the Triassic collision of the Sibumasu terrain with and under thrusting of Indochina.

The occurrence of Middle Permian oceanic sediments (radiolarian bearing siliceous sediments) indicates that the Palaeo- Tethys was divided into two depositional basins named the Semanggol basin in the Western Belt and Semantan/ Gua Musang/Aring basin in Central Belt (Sashida, Adachi, Igo, Koike, Ibrahim Amnan, 1995). These basins were separated by Bentong Raub Suture Zone. However, the extension of Bentong-Raub suture to the north and south is speculative since the exposure is limited only to Bentong-Raub and Kuala Lipis area.

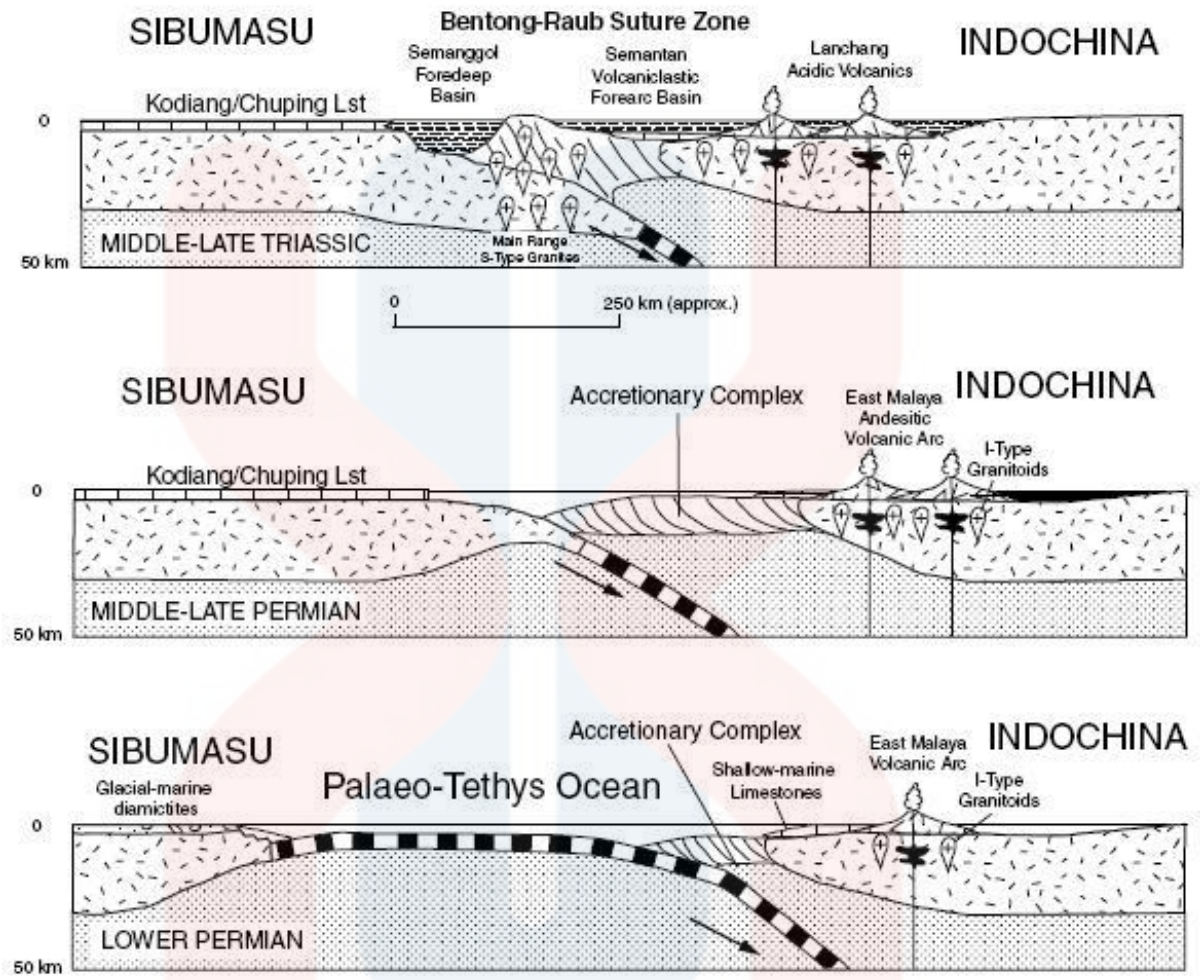


Figure 2.1: Subduction of Sibumasu plate into Indochina plate

(Source: Hutchinson, C. S. 2007)

2.5 Historical Geology

Historical Geology is the study that uses the principles and techniques of geology to reconstruct and understand the changes to Earth and life in time and space. The geological timescale is known as the calendar of Earth history that divides the geologic history into units. It is created by using relative dates on samples to know the relative age and arrange in sequence of history in proper order. The structure of geological time scale consists of the largest time unit which is Eons, followed by Era,

Periods and the smallest unit which is Epochs (U.S. Geological Survey Geologic Names Committee, 2010).

In the past, Peninsular Malaysia and the regional South-East Asia countries such as Thailand and Vietnam were originally located deep down in the Paleo-Tethys Ocean. This ocean were uplifted to the surface due to the collision between Sibumasu plate and Indochina plate and represented by Bentong-Raub Suture line. The process began in Devonian, just about the same time of Tarim, Indochina, North and South China continent separated from Gondwana continent (Metcalfe, 2000).

2.6 Sedimentology

Gua Musang Formation consists of tuff, crystalline limestone, interbedded with thin beds of shale, chert nodules and subordinate sandstone and volcanic which it is estimated to be 650m thick (Hutchison & Tan, 2009). Yin, E. H. (1965) found that the Gua Musang Formation comprised of a thick succession of limestone and shale with subordinate pyroclastic and quartzites.

The main successions of the Gua Musang Formation were found on the western portion of the region which is overlain by the younger sediments on the central part (Yin, E. H. 1965). The argillaceous outcrops are much more extensive than the limestone thus it form the large quantity of the sequence of the south of the Gua Musang to Merapoh area (Hutchison, C. S. 2004). The top of the Gua Musang Formation was made up of thick sequence of limestone which aged of late Scythian (Aw, 1990). The limestone of the Gua Musang Formation appeared to deposit on top of accreationary complex (Metcalfe, 2000).

2.7 Fault Analysis

There are main fold and main fault in Gua Musang Formation. The main fold of Gua Musang formation is located in the middle part towards north-south up to north-northwest – south-southeast. The northern part of this main fold was intruded by granite and diorite pophire towards NE-SW. The main fault of Gua Musang Formation are dextral and sinistral fault ("Structural Geology of Gua Musang Formation in Kelantan," 2010).

The result of structural analysis shows the deformation recorded over Mesozoic carbonatic sequence by the present of dip-slip, oblique-slip and strike skip kinematics are indicators on the fault plane. Fault kinematic studies on the mylonites at Bukit Tinggi show that the early ductile movement had a dextral sense of shear (Shub, 2009). The geological structure that is commonly found in the study area is joints, where they divide the rock body into large, roughly angular blocks, which is called as brecciation (Department of Minerals and Geoscience Malaysia, 2003).

During late Triassic, the Taku Schists and the nearest area has been uplifted, suffered regional metamorphism and recumbent style folding. The marine sedimentation has been terminated by the orogenic uplift of late Triassic in the rest of the Central Belt (Khoo & Tan, 1983).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

In this chapter, all the methodology and materials involved to complete this research is discussed. Methodology is the most important stages in conducting a research. It describes all the steps of the research in detail. Several methods have been used to make sure all the data needed for this research can be obtained and analysed in an orderly and systematic way.

3.2 Materials

In order to fulfil the task, there are a few materials and tools that have been used in order to help in obtaining data and information during geological mapping and laboratory analysis.

i. Base map

Base map of the study area and all the existing data about the study area is created such as main road, main river, small stream and contour elevation. It is important because it is used as reference during the geological fielddwork. This map is be produced by using the ArcGIS software with the scale of 1:25,000.

Components in base map:

a. Title
b. Specific study area
c. North arrow
d. Scale bar
e. Legend
f. All basic information in the study area
g. Magnetic direction

ii. Geological hammer

Geological hammer is the tool used to take out the fresh sample from an outcrop as to determine its composition and mineralogy. The hammer is made from hard steel for the chisel head and a rubber coated shock reduction for the handle. Compass (Suunto)

iii. Handlens

Hand lens is used to take a closer look at rocks as first analysis of rock samples during fieldwork before the samples sent for laboratory analysis. It will help in identifying the minerals and microfossils that present in the rock as well as to take a closer look at the rock textures.

iv. Global Positioning System (GPS)

The Global Positioning System (GPS) is a space-based navigation system that told very accurately the latitude, longitude, altitude, velocity and time. It is used to identify the position and coordinate of the outcrop and rock samples or any

important geological features during fieldwork. The GPS as well record the traverse track while in the box and measure the elevation.

The compass is used for navigation and orientation that shows the direction relative to the geographic cardinal directions. It also functions as for measuring the strike and dip of the geological features such as faults and sedimentary strata.

v. Digital camera

For photographing the outcrops and the geomorphology of the research area. The photos are further used in the research writing.

vi. Measuring tape

To measure the thickness of the beds that are large in size to obtain the accurate measurement.

vii. Hydrochloric acid (HCL) solution

The hydrochloric acid is used to observe the presence of carbonate minerals such as calcite or dolomite. It is tested on a rock or any mineral while observing the bubbles of carbon dioxide released. The presence of the bubbles shows the presence of the carbonate minerals.

viii. Notebook and stationery

The stationery such as clipboards, notebook, pencil, ruler, protractor, marker will be used to note down all the information needed while in the study area.

ix. ArGIS 10.2 software

ArcGIS 10.2 is used to make the base map of study area. The entire traverse done has been transferred into ArcGIS and any observable features in the field were documented into this software for further interpretation.

x. Stereonet software

Stereonet is a plotting program that displaying a variety of geological data on a hemisphere graph. This software enables to display those geological data for further structural analysis.

xi. Georose software

GeoRose is a rose diagram plotting program that usually used for plotting the structural geology such as joints. It enables to shows the force direction that created the joints of the research area.

Figure 3.1: Materials and equipment

3.3 Methodology

In this section, the steps to start conducting the research are discussed. Generally, preliminary study is done followed by field studies, laboratory work, data processing, data analysis and interpretation and finally research write up. Therefore, some components of research methodology had been list down and the flow chart has been shown in Figure 3.3. Basically, there are six components of research methodologies have been conducted:

a. Preliminary study

b. Field study

c. Sampling

d. Laboratory work

e. Data processing

f. Research write up

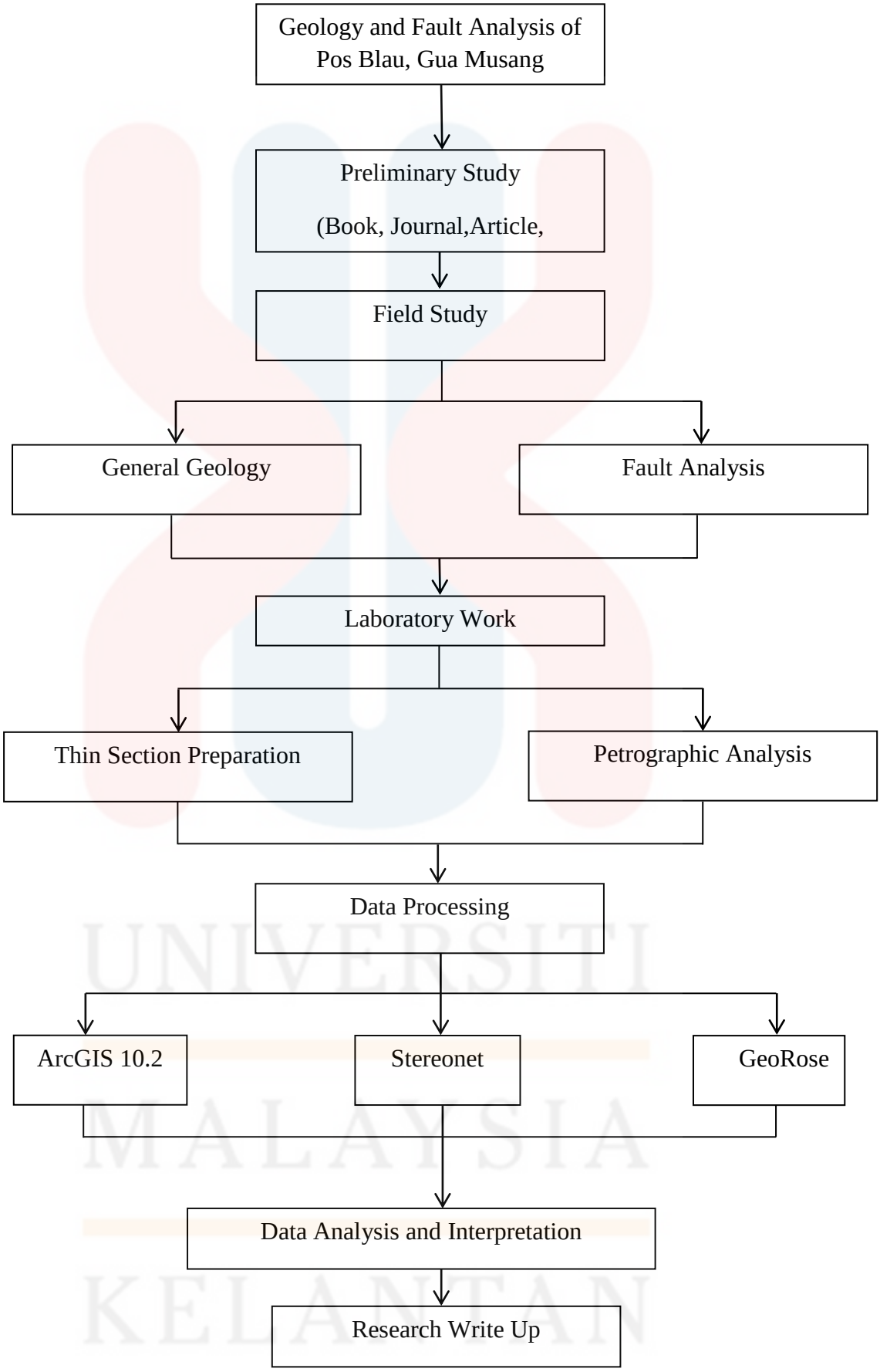


Figure 3.2: Research flowchart

3.3.1 Preliminary studies

The primary study is conducted before getting a research started. It is done in order to have a better understanding on the basic concept and geology of the study area. The information gathered is based on the location of the study area and research specification. They are obtained from the published journals, articles, books and other publications served as the references as conducting the research. From preliminary researched, the knowledge about the geologic setting, geomorphology and the geological structures are obtained. This process gives a clear view on concept of structural analysis research.

3.3.2 Field studies

This research focused on the geology and fault analysis of Pos Blau, Gua Musang. From field studies, the general information of geologic data such as lithology, geomorphology, topography, geological structures are obtained. It also included the activity of taking all the geologic data within the study area and collecting the rock and soil samples.

a) Lineament Analysis

Lineaments are often apparent in geological or topographic maps and can appear obvious on aerial or satellite photographs. Usually, lineament comprises a fault-aligned valley, a series of fault or fold-aligned hills, a straight coastline, sudden offset of river or hill, or a combination of these features.

b) Traverse

It is a process of reconnaissance of the study area. The basic geological mapping is needed to fulfil the first objective of the research. The observation of geomorphology, stratigraphy and structural geology were done.

c) Rock Sampling

It is the steps of taking the rock samples from the particular outcrops as to be used for further analysis in laboratory work. It is very important to collect the rock samples from the geological mapping activities because all the information that are needed for further analysis are depending on the rock samples such as thin section and petrographic analysis. The rocks sampling are done by using the geological hammer which is chisel hammer.

d) Strike-Dip Data Measurement

Strike and dip data are collected throughout the geological mapping. The strike and dip are measured on the geological features such as faults and sedimentary strata. For joints, to obtain the accurate results the number of measurements taken must be more than 100 data. The strike and dip data are very important for future analysis of magnitude and force direction of the rock deformation which are depending on fault, fold and lineament analysis. The data taken are processed by using GeoRose software for joints data and stereonet projection for the strike-dip data of faults and other sedimentary strata.

3.3.3 Laboratory Work

The samples that were collected from the fieldwork are proceed with the thin section preparation and petrographic analysis.

a) Thin Section

The processed involved in thin section preparation are cutting the rock samples into smaller size and thinning the rock into glass slide size using the cut-off saw and trim saw. Next, the glass is frost and the samples are cemented to the slide. The slide is then grinded in order to get the suitable thickness and lastly the cover slip is put at the end of the process.

b) Petrographic Analysis

After the thin section is cut and polished, it is observed by using the petrographic microscope. There are two types of polarizing filters set at right angles to each other as a result. The main purpose of the petrographic study is to establish a baseline of information about the petrography variability that can be observed in samples that has been taken in comparison with the previous research. This can be accomplished by characterizing the minerals, rock fragments and other components identified rock in a standard sized petrographic section of rocks.

3.3.4 Data Processing

All of the data obtained from the research are processed by using ArcGis 10.2 software, Georose software and Stereographic Projection software.

a) ArcGIS 10.2 Software

A geological map of study area is produced by using the ArcGIS software. The data from the geological mapping and from the GPS are used. The components of the geological map are title, scale (bar scale), stratigraphy unit, legends, cross section and other explanations if needed.

b) GeoRose Software

Rose diagram a circular histogram plot which displays directional data and the frequency of each class. Rose diagrams are used for displaying such feature such as strike of vertical joints. All the joints data that are measured from the study area are added to the GeoRose software. The intervals of angle are plotted as pie-shaped segments of a circle in their true orientation, and the length of the radius is proportional to the frequency of that orientation. The use of the true angle conveys an intuitive sense of the orientation distribution.

i. Dynamic Analysis

Dynamic analysis is the energy, force, stress and strength that produce the motion of particles (rocks). Joints that were measured in field study are processed using GeoRose Software. Thus, from the rose diagram produced, the principal stresses which are sigma one, sigma two and sigma three that result the geological structures in study area are determined.

c) Stereographic Projection Software

The stereographic projection is a methodology used in structural geology to analyse orientation of lines and planes with respect to each other. They are used for analysis of various field data such as bedding attitudes, planes, hinge lines and numerous other structures. The data related to faults, folds and other structures are added into stereographic projection software.The equal angle stereonets are suitable for kinematic analysis. They provide the best projection for analysing the direction and the vectors of structural forces. This is because the equal angle stereonets preserves the true relationships between stratigraphic and structural features. Two types of features are generated on the stereonet, a

line which is plotted by trend and plunge and a plane that plotted by strike and dip reading. A line is plotted as a point and a plane a great circle.

i. Kinematic Analysis

Kinemtic analysis involves investigating the motion that cause the geometries within the rock. The data such as strike and dip of the beding, fault plane or fold are further processed by using stereographic projection software. The planes are plotted on the stereonet based on their orientations that gained from field assessment in terms of dip direction and dip. The orientations of the discontinuities are represented on the stereonet in form of great circles, poles or dip vectors.

3.3.5 Data Analysis and Interpretation

In this method, the results obtained from the data processing are analysed and interpreted. The direction of the forces that acted on the particular area can be determined. Thus, the history of the deformation and the reasons of the structural geology formed in the study area mainly the fault as well can be interpreted.

3.3.6 Research Write Up

All data collected together with the result are recorded in this report. The complete data and result are compiled and written into this report and finished as the final year project assessment.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

In this chapter, the geomorphology, lithostratigraphy, structural geology and historical geology of the study area were discussed. The data were obtained through field observations and geological mapping in order to have a better understanding on the study area. The study area is located in palm oil plantation area where the accessibility to reach the target location is by using the unpaved logging and plantation road. Transportations such us plantation trucks, lorries and motorcycles can pass through these unpaved roads. However, about 25% of the study area was covered by reserved forest therefore it could not be accessed by any vehicles.

4.1.1 Accessibility

The study area is covered by palm oil plantation which is known as Ladang Pandan Intan. It can be accessed by the unpaved road which is usually used by the palm oil plantation workers. The unpaved road is connected to the Gua Musang –Lojing highway. Figure 4.1 showes the Lojing-Gua Musag Highway while Figure 4.2 and Figure 4.3 show the unpaved road in the palm oil plantation area where usually accessed by pickup trucks such as Hilux, Ford Ranger, lorry and also motorcycles.

Figure 4.1 : Lojing-Gua Musang Highway

(Coordinate : 4º 45' 05", E 101º 45' 22")

Figure 4.2 : Unpaved road into Ladang Pandan Intan

(Coordinate : N 04º 45' 20.7", E 101º 45' 34")

Figure 4.3 : Unpaved road in palm oil plantation area

(Coordinate : N 04º 43' 39.3", E 101º 45' 54.7")

Figure 4.4 : Pickup trucks used to access the study area

(Coordinate : N 04º 43' 39.3", E 101º 45' 54.7")

4.1.2 Settlement

There is no village in the study area, but a few settlements were recognised which are workers' accommodation that came from another countries such as Bangladesh, Vietnam and Indonesia. There are also offices found in the study area which is located at N 04º 43' 46.0", E 101º 46' 4.4" and N 04º 42' 49.0", E 101º 45' 33.3". Figure 4.5 showed the workers' accommodation and office respectively.

Figure 4.5 : Workers accommodation

(Coordinate : N 04º 43' 46.0", E 101º 46' 4.4")

Figure 4.6 : Office of palm oil plantation's manager

(Coordinate : N 04º 42' 49.0", E 101º 45' 33.3")

4.1.3 Forestry

About75% of the study area is palm oil plantation and the rest of it is reserved forest. Figure 4.7 shows the palm oil trees in the study area. The palm oil plantations in the study area are mostly owned by Chinese. Palm oil also has been a major job of the Lojing area's immiggrants.

Figure 4.7 : Agricultural of palm oil terraces in the highlands of the study area

Figure 4.8: Young oil palms taken to be planted in the main field

The oil palms are transplanted into the main field when seedlings reach about 12-14 months old with 1-1.3 meter height. Transplanting of the oil palms to the main field has to be done during the onset of rainy season to avoid the seedlings from destroyed due to highly impermeable soils.

4.1.4 Traverses and Observations

Traverse is the method done in field surveying in order to keep track of the path travelled and to collect geological filed data. Traverse was done around the study area and geological data were collected and recorded. Figure 4.9 shows the traverse map that represent the path travelled and all the observation points during geological mapping activities. The observation points include the data of rock sample collections, geomorphological observation, structural measurement and bedding reading.

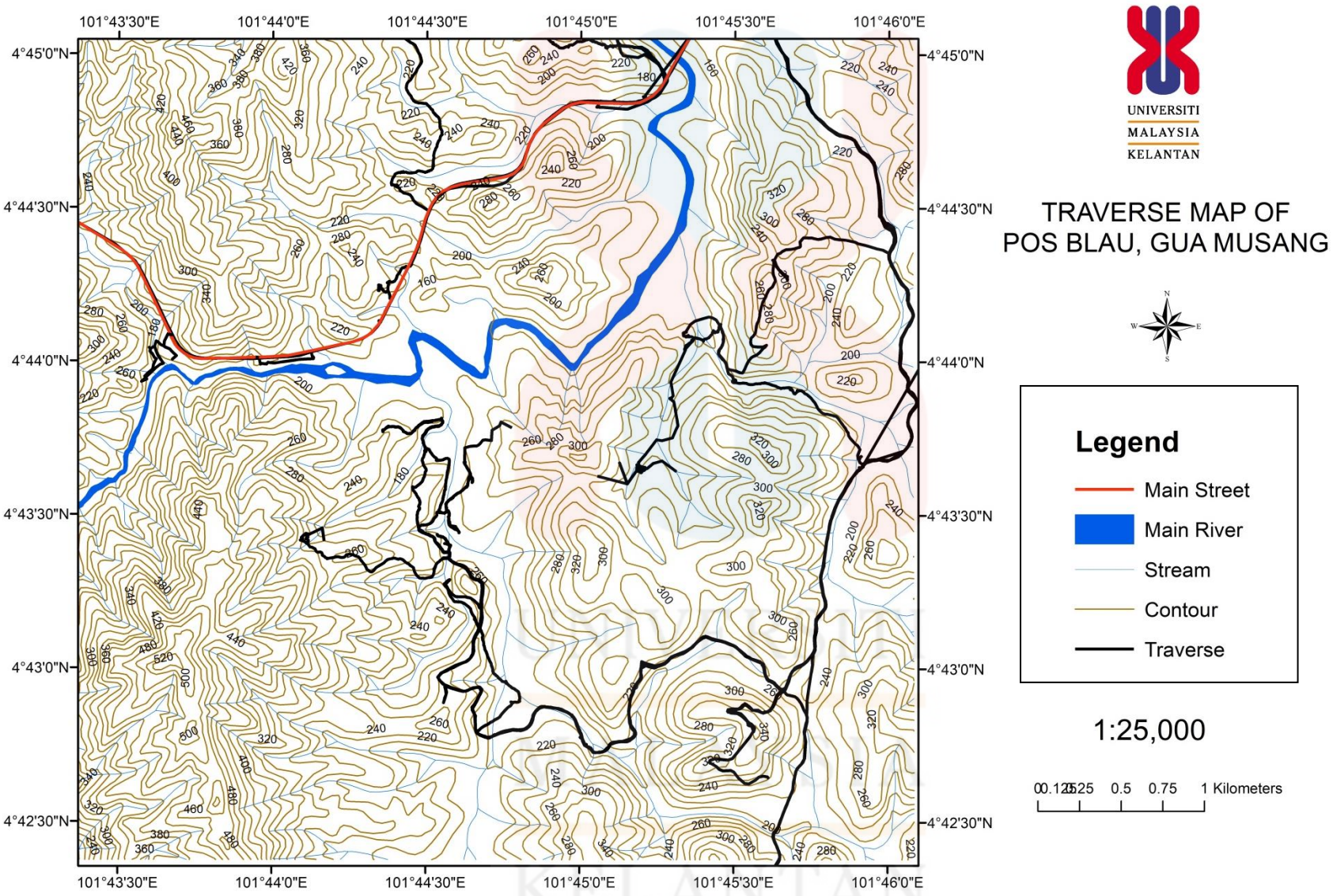


Figure 4.9 : Taverse map

4.2 Geomorphology

Geomorphology refers to the physical features of the Earth's surface which are the landform and its origin and evolutions that is related to its geological structure. The landform of the Earth's surface can be created either by physical, biological and chemical processes that occurred near the Earth's surface. By studying the geomorphology, we can understand the origin and the evolutions of the study area that have been occurred in the past. Geomorphology as well revealed the Earth's history and the reasons of the different morphology formations that present in the study area.

4.2.1 Geomorphological Classification

Geomorphology is the study of the shape of the earth's surface and the various processes that triggered the formation of the landforms and landscapes. It is resulted from geology and structural setting of the region. For example, a region of rock can be bent thus forming mountain and hills when it exerted by the huge compressional forces due tectonic plate movement beneath the Earth's surface. Geomorphology encompasses the topics of each genesis in general such as the formation of the ocean basin and continental platform and the minor structures like plains, plateaus, mountains, and others. All these physical features are known as landforms on the Earth surface that control the ecosystem, climate, weather and the essence of life on Earth. These landforms are then come into existence due to the natural processes such as erosion and weathering by wind, rain, ice and moving water. The geomorphology includes the study of the drainage pattern, topographical aspects and geomorphic landforms such as mountains, hills, valleys, plateaus, and plains.

Figure 4.10 shows the landforms present in the study area. The landforms present in the study area are mountain, hill, karst and alluvium and river. In the study area, mountains cover about 45% and located at the North-West and South-West of the study area. It composed of mudstone and schist lithology.

The mountains are referred to the highest landform on the Earth surface. It usually shown a point tip as the peak and the mountain is found to be conical in shape with steep sides. It involve plate tectonics, where compressional forces, isostatic uplift and intrusion of igneous matter forces surface rock upward, creating a landform higher than the surrounding features. It is a large landform that rises abruptly from the surrounding level and attains a high elevation that able to separate from the surrounding lower elevations and adjacent peaks. The final way in which mountains are formed is through erosion. This occurs during and after an uplift, where a newly formed mountainous region is subjected to the effects of wind, water, ice, and gravity. These forces actively shape the surface of mountain ranges, wearing down the exposed surfaces, depositing sediment in alluvial flows, and leading to the formation of characteristic landforms.

While hill landform also present in the study area and it cover approximately 45% at North extended South at the center of study area. It composed of mudstone, tuff and also chert. This landform is used for palm oil plantation purposes. Hill landform is also higher than it surrounding land area but it much lower compared to mountain with elevation less than 300 meter.

Hills may have once been mountains that were worn down by erosion over many thousands of years. This area is used for palm oil plantations. As for karst landform, it is situated at the East part of the study area and covered approximately 10%. It comprised of limestone and carbonaceous limestone. Alluvial plain is a flat landform and low lying areas created by the deposition process where the rivers flow down from the mountainsides and hillsides over a long period of time. There is 2% of alluvial plain in the study area located along the main river known as Sungai Brooke.

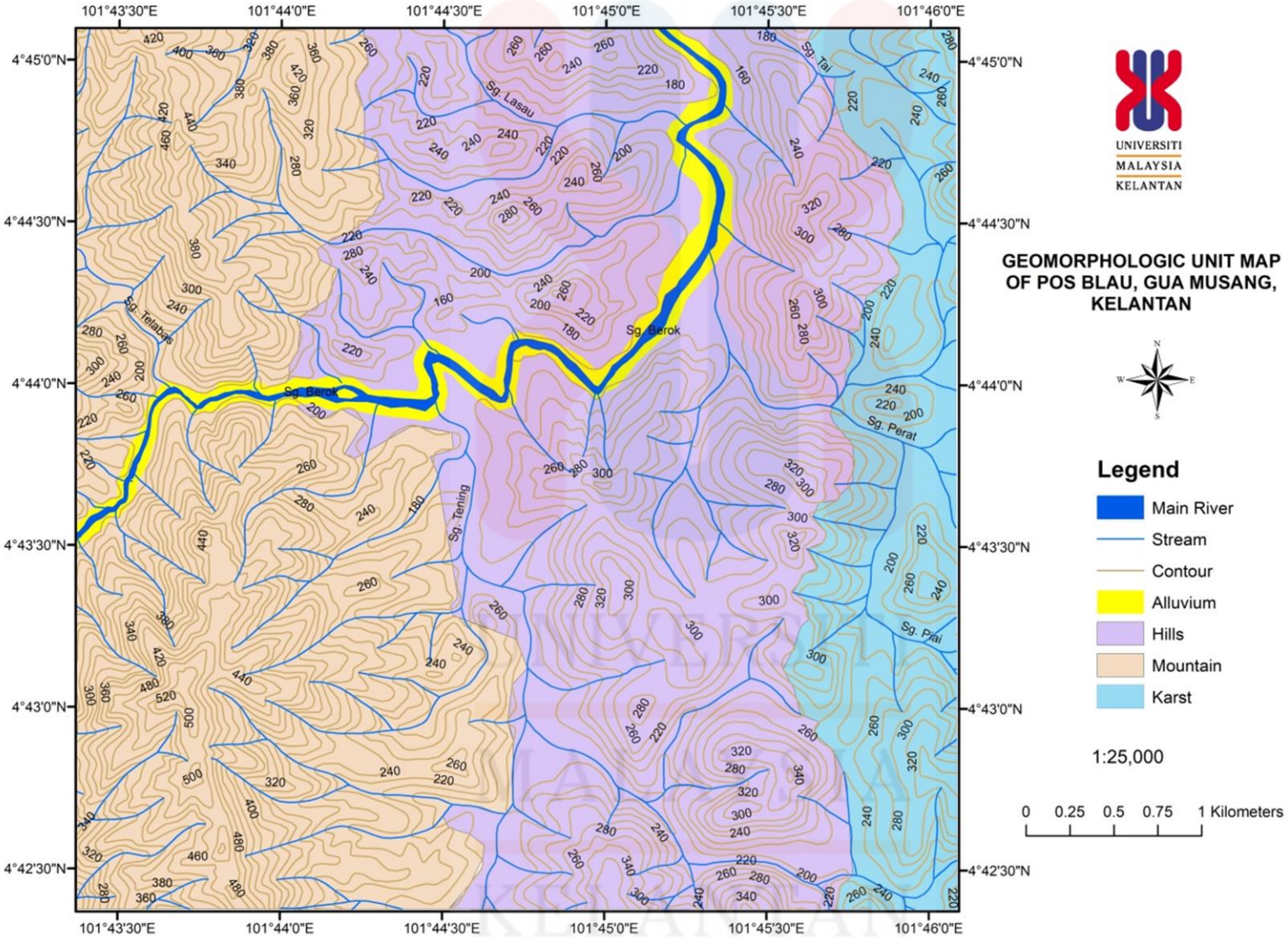


Figure 4.10 : Geomorphology Map

4.2.2 Hilly Morphology

From the geomorphology map, the study area showed that most of the area is covered by hilly morphology. A mountain or hill can be defined as an area of land that rises abruptly from its surrounding region. The highest elevation of the hilly morphology is 520m with mudstone and quartz composition at the South-West of the study area. They formed due to the tectonic plate's movement in the Earth's crust that elevate, fold and fault rock materials where compressional forces, isostatic uplift and intrusion of igneous matter forces surface rock upward, creating a landform higher than the surrounding features. It took a very long time up to million or millions of years to form a hill or mountain because the plates themselves move very slowly beneath the Earth's surface. Tectonic mountains can occur as a single range or as a belt of several mountain ranges. There are three stages involved in mountain building which are accumulation of sediments, an orogenic period of rock deformation and crustal uplift and crustal uplift caused by isostatic rebound and block faulting.

Mountain belts usually contain numerous layers of sedimentary and volcanic igneous rock. In the orogenic stage of the mountain building, deformation of accumulated sediments occur caused by the compressional from the collision of tectonic plates. The compression squeezes the flat sedimentary beds to be folded causing the crust to over thicken and uplifted. Reverse and overthrust fault normally formed due to this compressional stress. Lastly, the mountain was uplifted by the isostatic rebound. It is the state where continental crust rise vertically as erosion occurred and removed the weight of surface materials from the mountains. Isostacy occurs as the buoyancy force pushed the lithosphere upward equals to the gravitational forces pulling it down (floats on the mantle) depending on its thickness and density.

Over the course of many million years, these uplifted sections are eroded and shaped by the elements which are wind, rain, ice and gravity. These gradually wear the surface of the mountains down, cause the surface to be younger than the rocks that form them, and lead to the types of formations and distributions we are familiar with today.

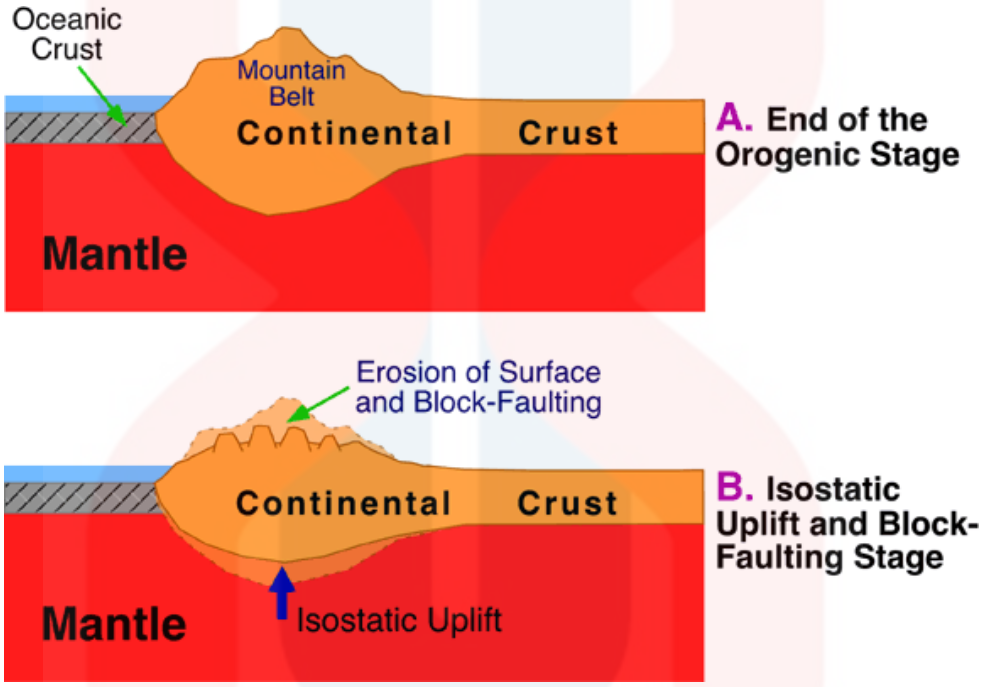


Figure 4.11: Illustration of mountain building

Figure 4.12 : Hilly morphology

4.2.3 Karst Morphology

The study area as well composed of karst morphology. The dissolution of limestone unit formed the karst topography which characterized by the presence of caves or holes within the limestone. Karst predominantly composed of limestone rock that contains more than 60% of calcium carbonate. Karst formed by chemical weathering where carbonation and solution process take place towards the underlying bedrocks. Carbonation process occur as the carbon dioxide and water chemically react to produce carbonic acid, a weak acid, that reacts with carbonate minerals in the rock. Typically, carbonation takes place in wet, moist climates and affects rocks both on and beneath the surface.

The development of karst occurs due to the reaction of acidic water started to dissolve the surface of bedrock near its crack. This process simultaneously weakens the rock and removes the chemically weathered materials. Limestone itself either worn away from the surface or eroded from its inside. As the cracks enlarged through time, these fractures became wider and eventually start to form some sort of drainage system. The presence of these drainage system speeds up the development of karst topography as it allows more water to flow through over time.

In the study area, there are two tower karsts present which are located at the South–East. These tower karsts have vertical steep sides, resembling towers. It is developed mainly in low latitude that is characterized by the residual limestone hills rise from a flat plain.

Figure 4.13 : Tower karst 1

Figure 4.14 : Tower karst 2

4.2.4 Weathering

Weathering is the disintegration or alteration of rock and its mineral content at the Earth's surface due to particular environment factors such as the action of rainwater, extremes of temperature, and biological activity. Weathering breaks down the rocks into smaller pieces via physical, chemical and biological mechanism. It wears away the rock materials, changes the texture and rock's appearance through the exposure with the Earth's atmosphere, water and biological organisms.

Weathering process altered the physical and chemical properties of the rocks which eventually will weathered to become soils. It is a slow process where it takes a very long time to give a significant change to the Earth's landscape. Generally, there are five main factors that influenced the rate of weathering such as material's properties, climate, total surface area, chemical reaction and time. Malaysia is well known by its tropical climate where heavy rainfall and warm climate presents most of the time. This has increased the rate of weathering on the surface as weathering favours in hot, warm and damp weather.

i) Physical Weathering

Physical weathering is the geological process of breaking apart of the rocks without changing their chemical composition. physical weathering occurs when the rocks directly contact with atmospheric conditions, such as changing temperature, water, ice, wind and pressure. Temperature fluctuations contribute to thermal stress where it involves contraction and expansion of the rocks. Rocks expand when the temperature increases and contract when the temperature decreases. Over time, this process weakens the rocks thus break down the rocks into smaller pieces by the uneven expansion and contraction.

Water is the weathering agent and it causes rock to break apart through a process called freeze thaw cycle. In this cycle, water gets into the rocks through the small cracks and become freeze. When the water freeze, it expands cause the rock to weaken and enlarge the crack in the rock. As the ice melts, the water carries away tiny pieces of the rock causes the rock to disintegrate into smaller fragments. Winds, water and waves pound on rocks and wears them up. Prolonged action causes larger rocks with rugged surfaces to smoothen. During runoff, water carries sand and smaller debris and smashes them against larger rocks in their path resulting abrasion causes wearing away of the rocks.

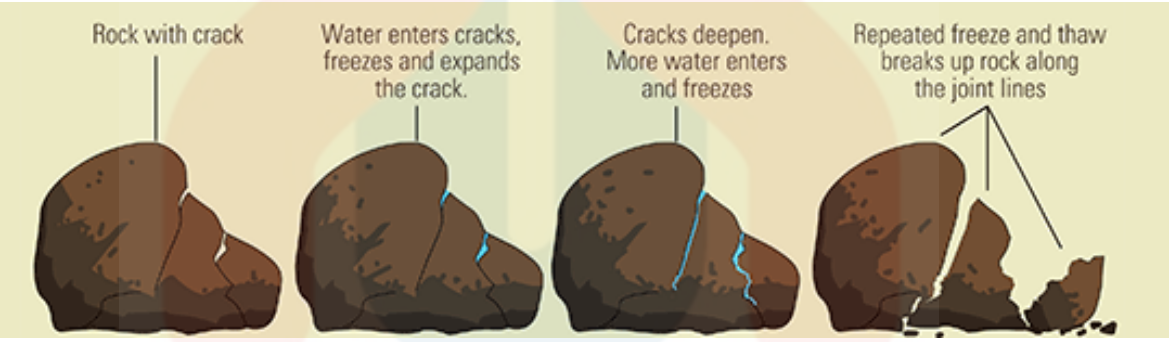


Figure 4.15 : Process of physical weathering

Figure 4.16 : Physical weathering of schist outcrop

ii) Chemical Weathering

Chemical weathering is the breakdown of rock via chemical mechanism that changes the chemical composition of the rock. The decomposition of the rocks is commonly through carbonation, hydration, hydrolysis or oxidation. Chemical weathering greatly influence by the presence of water, oxygen and carbon dioxide.

The mudstone unit and tuff unit at coordinate N 04° 44’40.7” E 101° 44’49.5” of the study area possessed oxidation chemical weathering. Oxidation occurs when mineral iron in rocks reacts with the oxygen forming iron oxides which lead to the changes of mineral composition of the rock. When minerals in rock oxidize, they become less resistant to weathering. The oxidation chemical weathering causes rust and red coloured on the surface and inside of the rock thus weakened the rock due to its reaction with oxygen. Oxidation is more effective in the presence of moisture. Based on field

observation, oxidation weathering is the most weathering occurred in the study area. Figure 4.17 shows the oxidation chemical weathering on tuff outcrop.

Figure 4.17: Chemical weathering on tuff

(Coordinate: N 04° 44’40.7” E 101° 44’49.5”)

The dissolution chemical weathering occurs on carbonaceous limestone at the East part of the study area. Naturally, the solubility of calcite in pure water is very low, but the reaction will vastly increase in the presence of carbon dioxide where the gas dissolved in the water to produce carbonic acid and thus permits dissociation of calcium carbonate. Carbonic acid will then remove the soluble material and the limestone no longer remain solid and form holes, rills or rough surfaces and eventually falls into pieces or decomposes. This process will act faster when the water is been acidified.

Figure 4.18 shows the dissolution chemical weathering on limestone in the study area. Dissolution is an easily observed kind of chemical weathering on limestone. The small pits and holes on limestone are due the action of slightly acidic solutions on the

rock. Over time, it can slowly enlarge and widen pre-existing fractures. In a dissolution reaction, the mineral is broken into its constituent ions in solution:

$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$

(calcite) + (carbonic acid) → (calcium ion) + (bicarbonate ion)

Figure 4.18 : Chemical weathering on limestone outcrop

(Coordinate: N 04° 43’41.5” E 101° 45’54.6”)

iii) Biological Weathering

Biological weathering is the weakening and disintegration of rock by the action of living organisms such as plants, animals and microbes. The most common biological weathering occurred is when tree roots grow through the cracks or joints in order to find

moisture, eventually the roots gradually separate the rock apart. This is because when the plant grows in the cracks or fractures, their roots become bigger thus it will exert pressure on the rocks and make the cracks become wider, and deeper that weaken and eventually disintegrate the rocks.

Figure 4.19 shows the outcrop of sandstone that undergoes the biological weathering by the action of plant roots that exerts pressure to the cracks and fractures of the rock. This disintegration of rocks into smaller pieces exposed a larger amount of total surface area to the atmosphere which then increases the rate of weathering. At the end, parts of the rocks weathered into soil.

Figure 4.19 : Biological weathering on sandstone outcrop

4.2.5 Drainage Pattern

Drainage pattern is also known as the river systems in geomorphology. It is formed by the streams, rivers, and lakes in a particular drainage basin. Drainage patterns are determined by regional geology and governed by structures, gradient of the land, bedrock erosional characteristics whether by hard or soft rocks that dominated the particular region. The different drainage patterns are formed due to combinations of the geologic control. The drainage patterns are help in determining the regional geologic history that occurs in past time. Basically, there are several categories of drainage pattern which is dendritic, parallel, trellis, rectangular, angular, and contorted.

Sungai Berok is the main river that present in the study area which connected to other smaller streams such as Sungai Lasai, Sungai Perat, Sungai Piai, Sungai Tai, Sungai Telabas and Sungai Tening. From the observation, it can be clearly noticed that the water current of the Sungai Brook is high and it may experience a high erosion rate on its river basin which eventually deepen the river depth and widen its width.

In the study area, the drainage patterns that have been recognized are dendritic and rectangular pattern. The dendritic pattern is a treelike pattern and it composed of many irregular branching that contributes to a main stream. It is usually develop when the stream channel follows the slope of the terrain in a variety of structural and lithological environments such as in the mountainous and hilly areas and finally joined together into the tributaries of the main river. Dendritic pattern is associated with the areas of homogeneous lithologies, horizontal or very gently dipping strata, flat and rolling extensive topographic surface having extremely low reliefs. These assumptions can be proved by the presence of similar lithologies in the study area which are interbedded of tuff and chert.

Meanwhile, the rectangular drainage develops when the small streams join the main streams at right-angles, and exhibit sections of approximately the same length which form rectangular shapes. The shape of the river channel exhibit sections of approximately rectangular shapes and same length. This drainage system often develops on area where the rocks are with uniform resistance to erosion. From Figure 4.22 it showed that the stream system is consist mainly of straight line segments with right angles bends with the tributaries joined at right angles too. This rectangular drainage pattern is present at the east part and northwest of the study area where the lithology is clastic sediment and schist respectively.

Figure 4.20 : Sungai Berok

Figure 4.21: Sungai Parat (small stream)

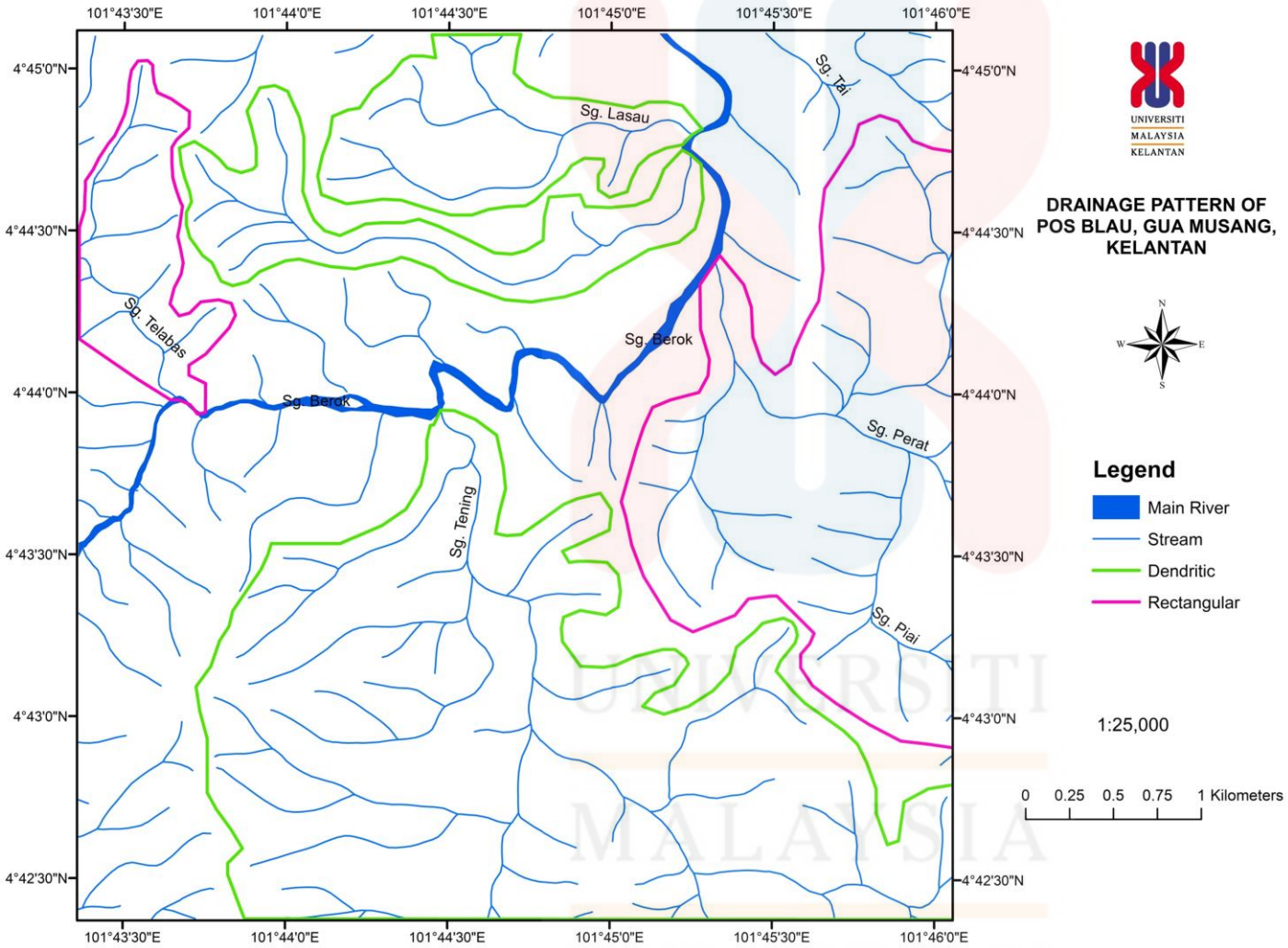


Figure 4.22 : Drainage pattern map of study area

4.3 Lithostratigraphy

Lithostratigraphy is the study of strata or rock layers based on physical and their petrographic features. Basically, a lithostratigraphic unit may consist of sedimentary, or igneous, or metamorphic rocks. These sequences of different rocks are important in determining the changing of geological conditions or geological history of the area through time. The different lithostratigraphic units are identified and recognized by their observable physical features and also based on their petrography, mineralogy, lateral variation and the relationship with adjacent units either horizontally or vertically.

4.3.1 Stratigraphic position

In undisturbed conditions, the beds in higher stratigraphic sequence of deposits will be younger than the lower beds and the layers of sediment were originally deposited horizontally under the action of gravity. In the study area, due to the tectonic tilting it caused the older rock uplifted to the surface.

Several outcrops were found during mapping. Different types of rocks were identified in the study area, they are limestone, clastic sediment rocks (shale, sandstone, mudstone, conglomerate), tuff, chert and metamorphic rock schist and quartzite. Petrography analysis is done to the rock samples collected from field mapping for further rock classification and to determine their nomenclature. The stratigraphy positions of the lithology in the study area are arranged from oldest followed by the younger age the rock units (from lower to upper part column). In the study area, schist unit is the oldest lithology while limestone is the youngest unit. Figure 4.23 shows geological map of study area and Figure 4.24 shows stratigraphic column of the study area.

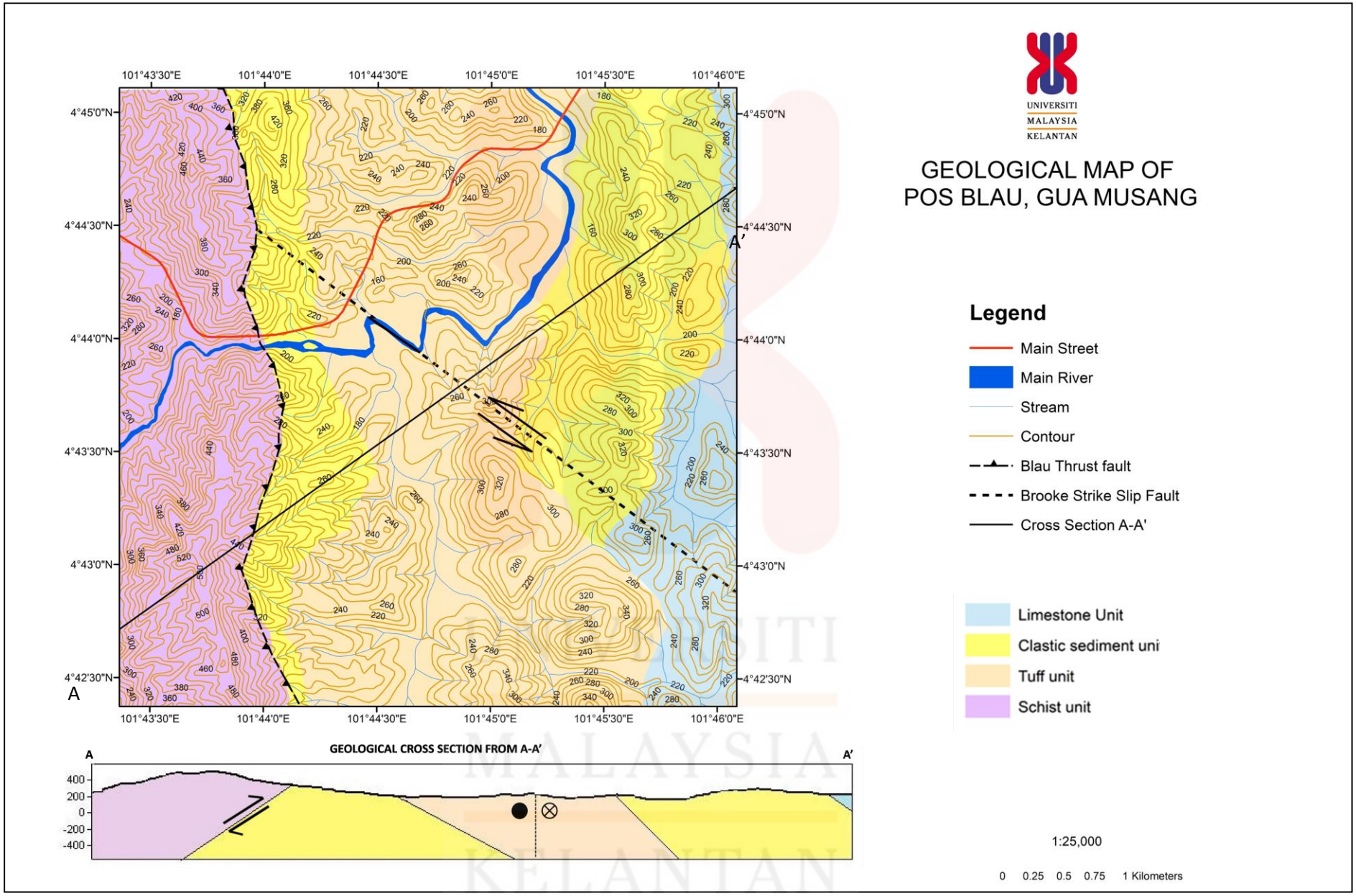


Figure 4.23 : Geological Map of Pos Blau, Gua Musang

Lithology	Period	Description
	Late Triassic	**Limestone** ➢ Consists thick bedded limestone
	Middle Triassic	**Clastic Sediment** ➢ Composed of sandstone, mudstone and shale
	Early Triassic	**Tuff subordinate Chert** ➢ Dominantly tufft with subordinate chert
	Pre-Mesozoic	**Schist** ➢ Schist and mica schist

Figure 4.24 : Stratigraphic column

4.3.2 Unit Explanation

The study area composed of four main lithological units which are schist unit, clastic sediment, tuffaceous unit and limestone unit. Clastic sediment unit consists of mudstone and sandstone. While the tuffaceous unit consists of tuff and chert. The limestone of the study area is carbonaceous limestone. The quartzite as well has been identified present in the study area.

i) Schist

Schist unit covered approximately 20% of the total extent of study area. Figure 4.25 showed one of the schist outcrops in the study area with coordinate of N 04° 43’59.38” E 101°43’49.9”. The schist outcrop is found at the west region of study area along a small stream and in the reserved forest area. It is medium grade of metamorphic rock and mostly appeared in dark, black colour. The hardness is moderate and it has medium grain size.

This type of rock is form by the metamorphosis of sedimentary rock such as mudstone or shale, or some types of igneous rock that have been subjected to compressive forces, heat, and chemical activity. The clay minerals of mudstone or shale are converted into platy mica minerals such as muscovite, biotite, or chlorite by the intense metamorphic environment. Under the moderate metamorphic environment, the sedimentary rock of shale becomes the low-grade metamorphic rock known as slate when the directed pressure pushes the transforming clay minerals from their random orientations into a common parallel alignment where the long axes of the platy minerals are oriented perpendicular to the direction of the compressive force. Further metamorphism of slate causes the mica grains in the rock to grow and it is elongate perpendicular to its compressive force, thus transform it to become phyllite. Schist is form when the phyllite is exposed to additional metamorphism, with the properties of mica grain that it large enough to be seen with the unaided eyes.

Figure 4.25 : Schist outcrop

Figure 4.26 : Schist hand specimen

From the microscopic observation in Figure 4.27, it shows that schist contains mica minerals which is muscovite (47%), quartz minerals (38%) and chlorite minerals (15%). In plane polarized light (PPL), muscovite minerals are colourless while in cross polarization light (XPL), muscovite shows second and third order interference colours. Quartz has low relief and is colourless in PPL. In XPL, quartz shows black colour and first order yellow colour. Chlorite is colourless in PPL and present as pale green colour under XPL. It has low to moderate relief.

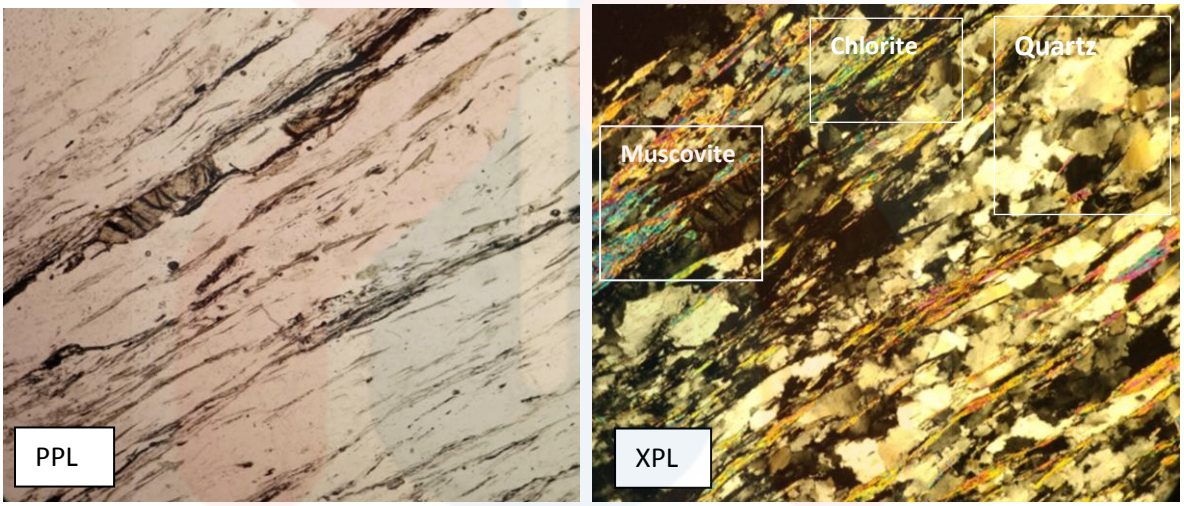


Figure 4.27 : Microscopic analysis of schist

ii) Tuff

Tuff unit approximately covered 40% of the total extent of study area. Figure 4.28 shows the tuff outcrop with coordinate of 04° 42’49.1” E 101° 45’40.0”. The outcrop is found along the hillside that had been cut to make way for the vehicles to pass through. From the Figure 4.28, it can be see that the outcrop has undergoes excavation, thus the geological structure of fold is well exposed. Therefore, information related to the geological structures such as fold can be observed and identified in this area.

Tuff is a type of volcanic explosive igneous rock made of volcanic ash that was ejected from a vent during a volcanic eruption onto the Earth surface. It is relatively

soft, porous rock that is usually formed when ejection of ash from volcanic eruption deposited and compacted into a solid rock in a process called consolidation. It contains the fragments of dust-size particles and sand-size particles. Tuff can occur in chalky white and pinkish, pale grey or yellow in colour. Tuff can be classified in various ways and often shows well defined layers recording the sequence falls of the ash. It can be classified as vitric, lithic or crystal. Vitric tuffs consist mostly of glassy particles, lithic tuffs of rocky particles, and crystal tuffs of visible crystals. Tuff may also be characterized as lapilli tuff or tuff-breccia: lapilli tuff consists of ash mixed with lapilli (volcanic fragments 2–64 mm in diameter); tuff-breccia consists of ash mixed with block-sized (volcanic fragments >64 mm in diameter) fragments.

The tuff outcrop in Figure 4.28 located at south-east part of study area with coordinate N 04° 42’49.1” E 101° 45’40.0”. Tuff is the dominant rock in the strata with subordinate of chert, thus it is called as tuffaceous unit. The tuff unit in this location exhibit a pale grey colour and is very fine-grained where the crystals are not visible to the naked eye. Its hardness is quite soft and most of them are exposed to oxidation chemical weathering. Figure 4.28 and 4.29 shows the tuff outcrop and hand specimen found in study area respectively.

Figure 4.28 : Tuff outcrop

Figure 4.29 : Hand specimen of tuff

From the microscopic observation in Figure 4.30, it shows that the tuff contains fine-grained volcanic ash which mineral of quartz and plagioclase. In plane polarized light (PPL), the plagioclase shows no colour .In cross polarization light (XPL), plagioclase shows twinning characteristic where the white grains stripping with the black colour. The extinction angle of the plagioclase is between 45° to 50º. For quartz mineral, in plane polarized light it is colourless while in cross polarized light it shows grey to black colour. The extinction angle for quartz mineral is 58°.

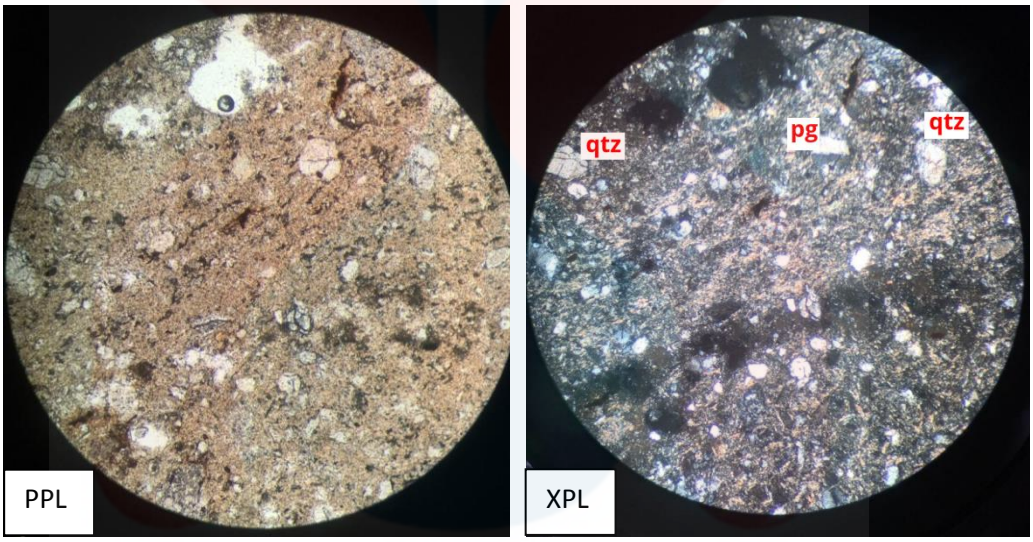


Figure 4.30 : Microscopic analysis of tuff

In tuff unit as well, a few fossils of bivalve were found at location N 04° 44’44.6” E 101° 44’32.7”. Bivalves are the marine organisms that live in shallow water environment. As they were found in tuffaceous unit area and not origin from the outcrop, they are assumed as transported fossils. Figure 4.31 shows the hand specimen of bivalve fossil.

Figure 4.31 : Bivalve fossils

iii) Shale

Shale unit covered approximately 5% of the total extent of study area. Figure 4.32 shows shale outcrop in the study area with coordinate of N 04° 43’41.1” E 101°45’59.5”. The outcrop is found nearby the small stream channel. From the Figure 4.32, it can be seen that the shale outcrop is in contact with tuff outcrop. However, shale is more dominant compare to tuff unit in this area.

Shale is a laminated clastic sedimentary rock composed of fine grained mud that is a mix of flakes of clay minerals and tiny fragments of other minerals. Shale occurs in a wide range of colours. The colour is determined primarily by its composition. In general, the higher the organic content of a shale, the darker its colour. The colour of shale can be significantly altered by the presence of a few percent of organic materials or iron. Just a few percent of hematite or limonite (hydrated ferric oxide) can gives rise to reddish and purple colouring, while mineral components rich in ferrous iron impart blue, green, and black hues.

In the study area, the shale is found at the east region and it mostly appeared in dark gray colour. The dark gray colour of the shale is may due to dominant composition of organic matters in it. It composed of very fine grained mineral fractions. Shale can be recognized by its thin laminated structure or parallel layering and its fissility. Due to its fissility characteristics, they have high tendency to easily split into thin layers that are usually parallel to the bedding plane surface. From the hand specimen of Figure 4.33, it can be clearly seen that the shale has fissile characteristics as the rock was split and break into thin pieces along the laminations with the sharp edges. For hardness, shale is categorized as soft to moderate.

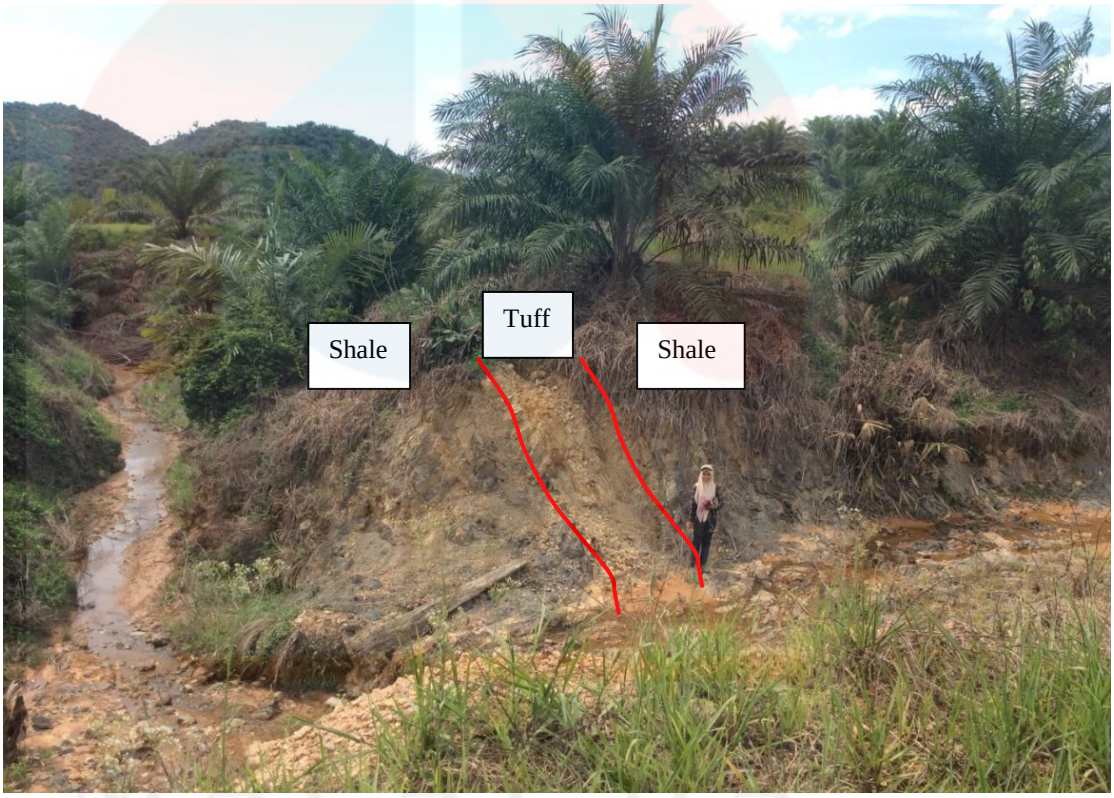


Figure 4.32 : Shale outcrop

Figure 4.33 : Shale hand specimen

Majority of the grain particles in shale sample are too fine to be observed. From petrographic analysis in Figure 4.34, it shows that shale contains clay mineral particles and opaque minerals. Clay mineral is relatively small grain size, colourless in PPL and has medium relief. It is the major mineral presence in shale. Opaque minerals show black colour in both PPL and XPL. There is also iron staining mineral with red-brown colour identified in shale.

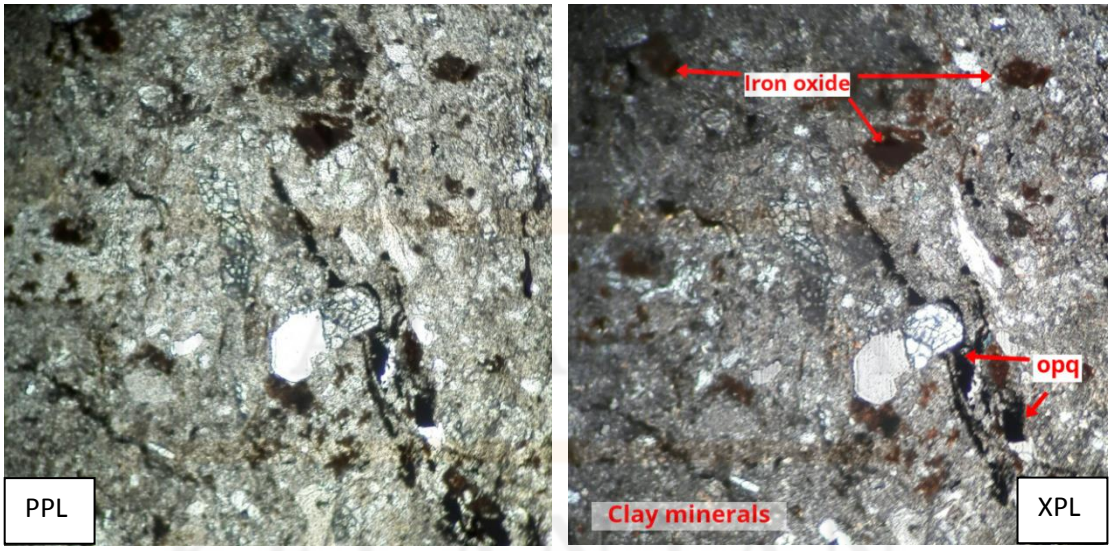


Figure 4.34 : Microscopic analysis of shale

i) Chert

Chert unit approximately covered 10% of the total extent of study area. Figure 4.35 shows the chert outcrop with coordinate of N 04°45’3.4” E 101°45’20”. The chert outcrop has undergoes excavation due to the construction for Gua Musang-Cameron Highland Highway. Therefore, the outcrop has exposed to weathering processes. A few geological structures of folds such as syncline, anticline and chevron fold were found in chert unit.

Chert is a hard, fine-grained sedimentary rock composed of microcrystalline or cryptocrystalline quartz, the mineral form of silicon dioxide (SiO_2). Chert is often of biological origin but may also occur inorganically as a chemical precipitate or a diagenetic replacement. It can be in the form of nodules, concretionary masses, and as layered deposits. Chert occurs in a wide variety of colors include white and black or between cream and brown, green, yellow, orange, and red cherts. The darker colors often result from inclusions of mineral matter and organic matter.

In the study area, chert is found at the roadside of Gua Musang-Cameron Highland Highway. It mostly appeared in brown to reddish colour. It may due to the chert contains abundant of iron oxides. This rock has a very fine-grained size particles that cannot be seen with naked and its hardness is very hard (number 7 on the Mohs hardness scale) and it has well bedded bedding. Chert is biological organism origin with a glassy silica skeleton. When these organisms die, their silica skeletons fall to the bottom, dissolve, recrystallize, and might become part of a chert nodule. In some areas the sedimentation rate of these materials is high enough to produce rock layers that are thick and laterally extensive.

Figure 4.35 : Chert outcrop

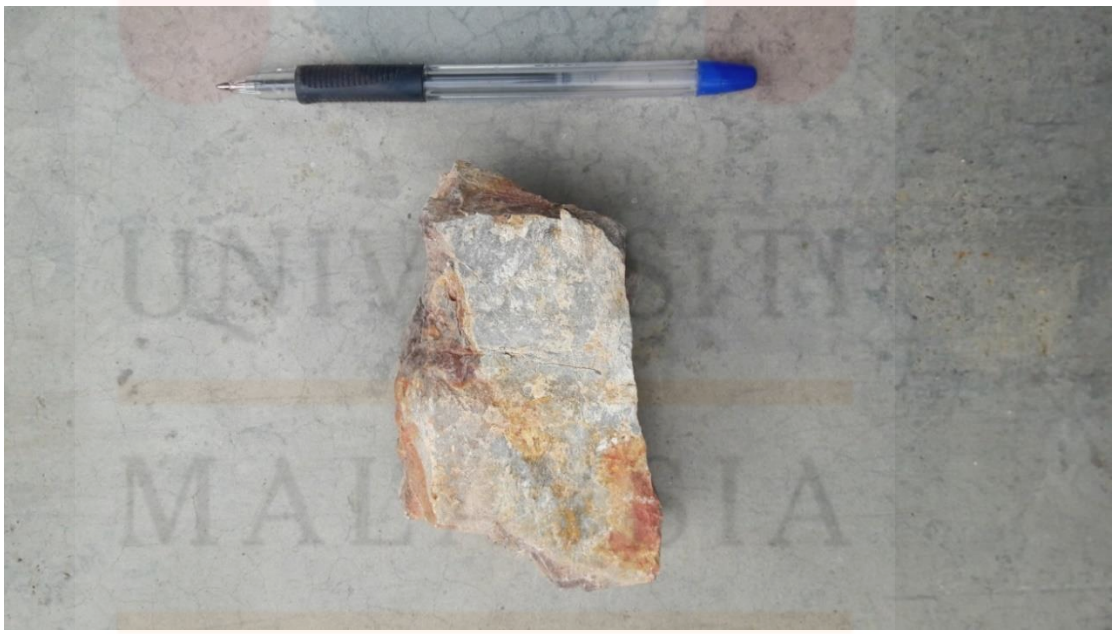


Figure 4.36 : Hand specimen of chert

Based on microscopic observation, the individual minerals are too fine to resolve with the optical microscope. In plane polarized light and cross polarized light, they show a distinctive 'salt & pepper' texture.

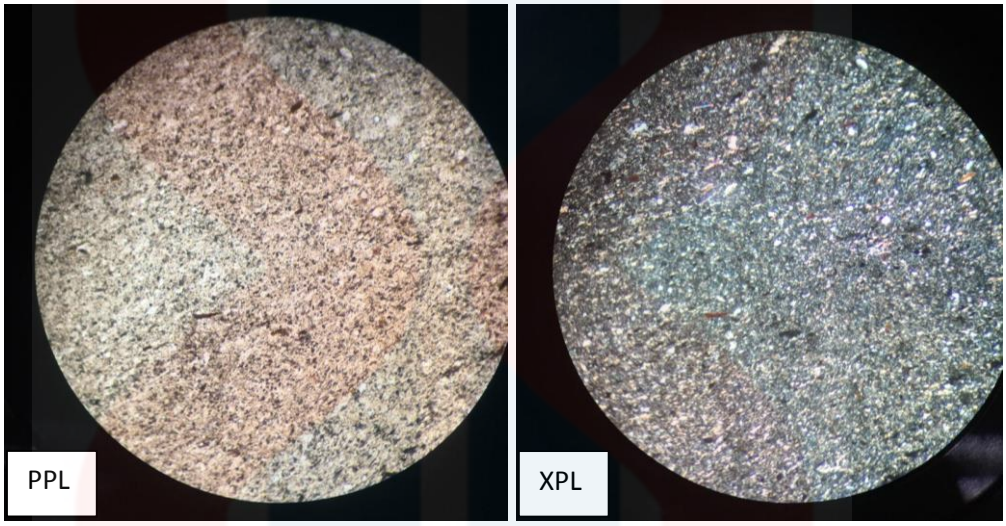


Figure 4.37 : Microscopic analysis of chert

ii) Sandstone

Clastic sediment of the study area is dominantly composed of sandstone with subordinate of mudstone, conglomerate and shale. Clastic sediment unit covered approximately 40% of the total extent of the study area.

The sandstone outcrop in Figure 4.38 is located at N 04° 44’0” E 101° 45’40”. The sandstone unit is located next to a small stream, Sungai Perat. From the figure, it can be seen that the outcrop undergoes physical and biological weathering as part of the rocks are disintegrated due to the plants grow in the cracks and fractures of the rock.

Sandstone is composed primarily of sand-sized grains of minerals, rock, or organic material and may contain a matrix of silt- or clay-size particles that occupy the spaces between the sand grains. It is a clastic sedimentary rock that forms where the cementing material binds the sand grains together. Sandstone occurs in a wide range of colours depending on the impurities within the minerals and composition of cement that binds the mineral particles together. However, the most common colours of sandstone are tan, brown, yellow, red, grey, pink, white, and black.

Figure 4.39 shows the hand speciment of sandstone unit. It shows yellowish colour. Hardness of the sandstone found in the study area is moderate as it is exposed to the atmosphere and thus is weathered. Due to the weathering process as well, the outcrop bedding cannot be clearly identified and the surface show none sedimentary structures present. The upper part of the sandstone outcrop has turned to soil due to action of physical weathering. The sandstone is rarely consists of sufficient thickness or lateral bedding.

Figure 4.38 : Sandstone outcrop

Figure 4.39 : Hand specimen of sandstone

i) Limestone

The limestone unit in study area approximately covered 10% of the total extent of study area. The limestone outcrop in Figure 4.40 is located at N 04° 43’41.5” E 101° 45’54.6”.

Limestone is a chemical sedimentary rock composed of calcium carbonate mineral ($CaCO_3$) in the form of the mineral calcite. It most commonly forms in clear, warm, shallow marine waters. This environment is suitable for the organisms to form the calcium carbonate shells and skeletons can easily extract the needed ingredients from ocean water. When these marine organisms die, their shell and skeletal debris will accumulate as sediment which then undergoes lithification and turns into limestone. Limestone that forms by this process is categorized as organic or biological sedimentary rock. This type of limestone may contain macroscopic fossils of marine organisms. However, some limestones are formed by direct precipitation of calcium carbonate from ocean water. They are called as chemical sedimentary rocks. As there is various ways of limestone formation, therefore limestone can be either crystalline, clastic, granular or massive deposits.

Figure 4.41 shows the carbonaceous limestone hand specimen found in study area. It appears in a dark gray colour and the texture is fine grained. It has a vigorous fizz effect when tested with drops of hydrochloric acid (HCL) to release bubbles of carbon dioxide gas. The reaction of limestone towards HCL indicates the presence of calcium carbonate minerals.

Figure 4.40 : Limestone outcrop

Figure 4.41 : Hand specimen of limestone

4.4 Structural Geology

Structural geology is a scientific discipline that is concerned with the deformation of surface and subsurface of the Earth. Structural geology focuses on the three dimensional distribution of large rock bodies, their surfaces, and the composition of their inside with respect to their deformation. Deformation is an alteration of the size or shape of rocks and it is caused by stress or force applied to a certain area. Rocks and their forming minerals accommodate the stresses acting upon them and keep a record thereof by developing at times truly spectacular geological structures, such as fractures, faults or folds. Geological structures found in the study area includes vein, joint, fold and fault.

4.4.1 Vein

Vein is a distinct sheet-like body of crystallized minerals within a rock. Vein is form when a pre-existing fracture or fissure within a host rock is filled with new mineral material. It occurs when the aqueous solutions carrying various mineral constituents migrate through fissures or fractures in rock and deposit their burden onto the fissure walls by the process of precipitation. The boundary between host rock wall and deposited vein minerals are clearly delineated because the mineral deposits that fill the crack or fissure in the host rock do not extend into the host rock. This is because most vein deposits are formed as new mineral species are precipitated onto rock walls which themselves remain unaltered. Usually the hydraulic flow involved in vein formation is due to hydrothermal circulation.

In study area, the type of vein found is calcite vein in limestone at coordinate N 04° 43’41.5” E 101° 45’54.6” and quartz vein in sandstone at N 04° 44’00” E 101° 45’30”. Figure 4.42 showed the calcite vein found in the study area. The calcite vein is white in colour and its hardness is quite soft (number 3 in Mohs Hardness Scale) that it is easily scratched by any metal material. This calcite vein may form when the hot mineral-rich fluids force their way through the limestone. As the fluids cooled, they left salts or minerals behind at the wall of the host rock and they are deposited as veins. Figure 4.43 showed the quartz vein found in sandstone in the study area. The quartz vein may formed due to the filling of an already present cracks in rocks. The quartz vein is hard and has milky colour.

Figure 4.42 : Calcite vein in limestone

Figure 4.43 : Quartz vein in sandstone

4.4.2 Joint

Joint is planar discontinuities that involve no displacement of adjacent blocks. Joints are formed during the exposure of rocks due to the erosion of overburden. It results from the contraction and expansion due to cooling and decompression respectively.

In study area, joint analysis was conducted at N 04° 42’51.7” E 101° 45’34.7” where strikes are measured on rock surface using compass. 100 readings were taken for the location and the data was recorded and plotted in rose diagram in order to determine the major direction of force for all the joints.

The joints in the study area are found on tuff outcrop at the elevation of 270 meter. Joints that form on the outcrop is shear joint. From the Rose Diagram shown in Figure 4.44, the major direction of joints are trending in ENE-WSW.

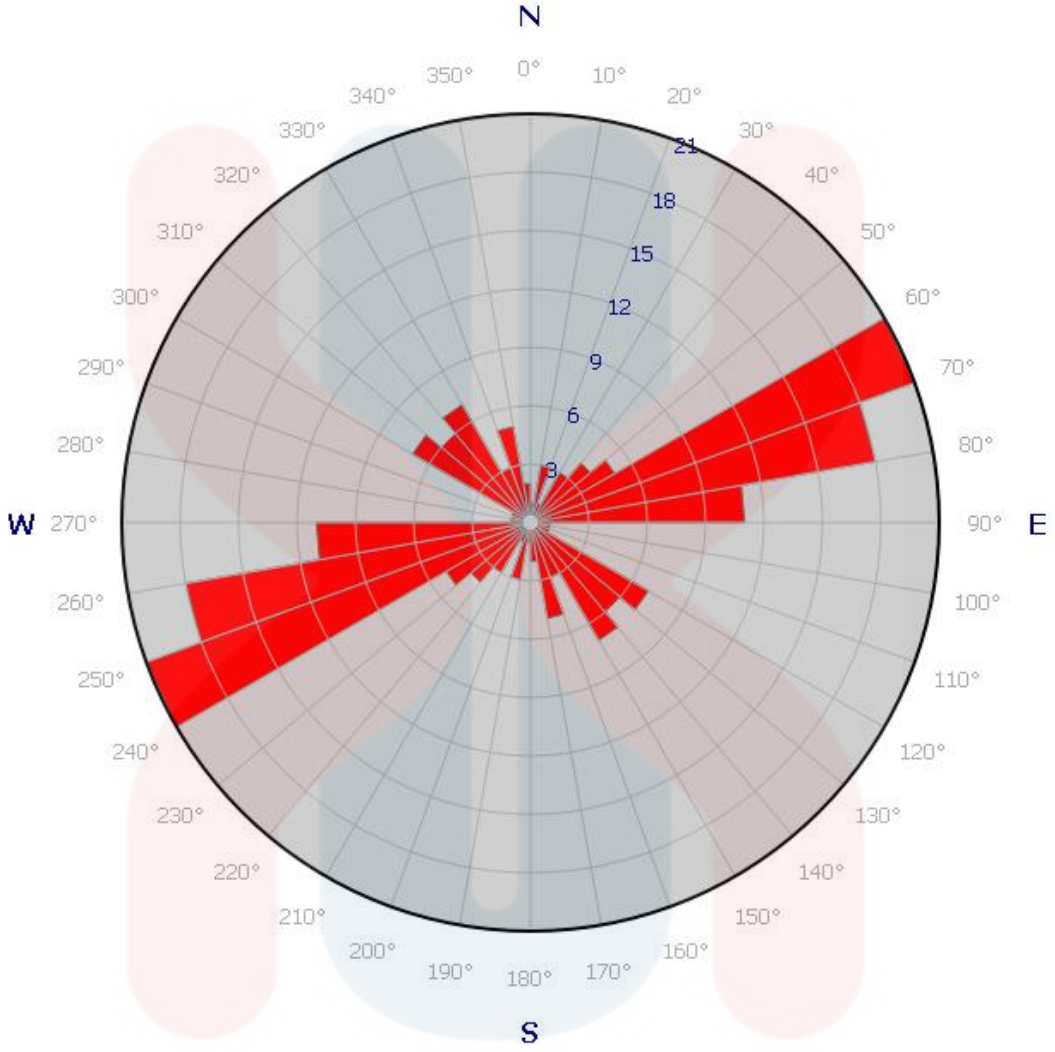


Figure 4.44 : Rose diagram

(Coordinate: N 04° 42’51.7” E 101° 45’34.7”)

Table 4.1 : Joint reading for location N 04° 42’51.7” E 101° 45’34.7”

No.	Strike	No.	Strike	No.	Strike	No.	Strike	No.	Strike
1.	105	**21.**	278	**41.**	093	**61.**	234	**81.**	115
2.	235	**22.**	300	**42.**	048	**62.**	232	**82.**	144
3.	142	**23.**	028	**43.**	253	**63.**	062	**83.**	152
4.	033	**24.**	043	**44.**	045	**64.**	228	**84.**	134
5.	047	**25.**	273	**45.**	035	**65.**	214	**85.**	058
5.	020	**26.**	280	**46.**	028	**66.**	274	**86.**	054
7.	220	**27.**	229	**47.**	235	**67.**	200	**87.**	110
8.	230	**28.**	068	**48.**	240	**68.**	106	**88.**	067
9.	295	**29.**	071	**49.**	094	**69.**	102	**89.**	070
10.	050	**30.**	220	**50.**	243	**70.**	113	**90.**	096
11.	050	**31.**	027	**51.**	241	**71.**	110	**91.**	123
12.	046	**32.**	215	**52.**	237	**72.**	311	**92.**	151
13.	250	**33.**	222	**53.**	290	**73.**	029	**93.**	127
14.	027	**34.**	244	**54.**	073	**74.**	060	**94.**	052
15.	013	**35.**	045	**55.**	241	**75.**	127	**95.**	075
16.	284	**36.**	066	**56.**	230	**76.**	064	**96.**	034
17.	096	**37.**	035	**57.**	081	**77.**	128	**97.**	171
18.	252	**38.**	250	**58.**	262	**78.**	067	**98.**	049
19.	014	**39.**	108	**59.**	281	**79.**	144	**99.**	124
20.	312	**40.**	039	**60.**	225	**80.**	052	**100**	249

4.4.3 Fault

Further details will be discussed in Chapter 5

4.4.4 Fold

Fold is the formation of bending and curving of originally flat or planar surfaces due to shortening that altered the competent and less competent layer of rocks. The formation of folds in sediments indicates various condition of stress, pressure and temperature that the body of rock encounters.

There are several types of folds such as anticline, syncline, chevron, recumbent, etc. In the study area, at coordinate N 04° 45’3.4” E 101° 45’20” a chevron fold was found. Chevron fold can be characterised by the angular fold with straight limb and small hinges. This fold form on chert unit. Figure 4.45 shows the chevron folding in the study area.

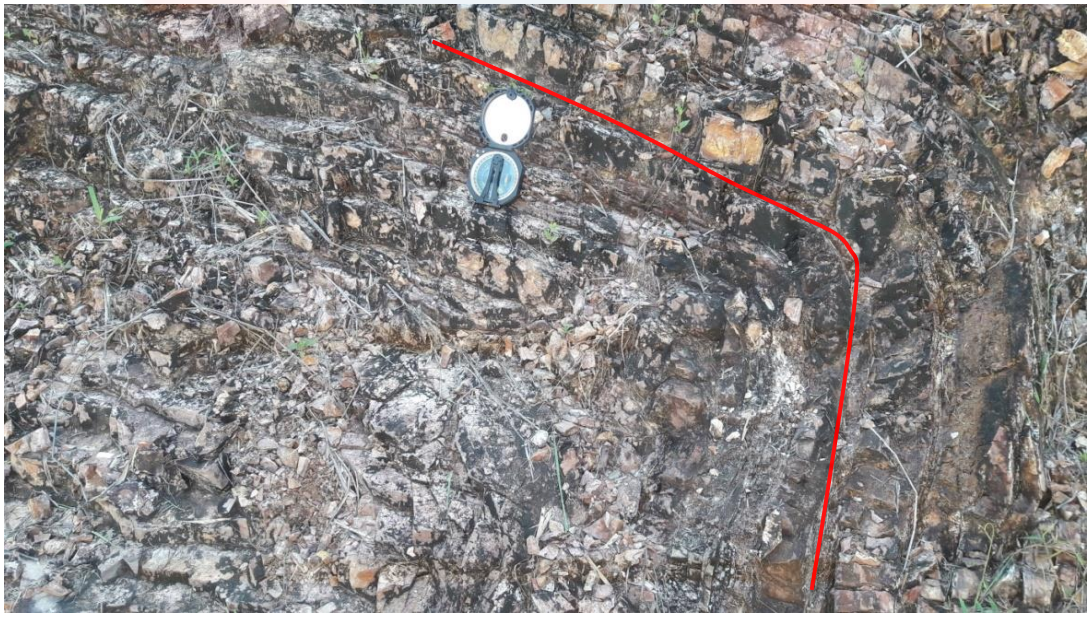


Figure 4.45 : Chevron fold

Besides, a synclinal fold was also found in study area at coordinate N 04° 45’3.4” E 101° 45’20”. It is formed on chert unit as well. Syncline is a concave structure in which the dipping is downward towards the centre of the structure. Formation of syncline structure is caused by compressional stress. The syncline fold in the study area is an asymmetrical folding. It has a characteristic in which its bed in one limb dip more steeply than those in the others as shown in Figure 4.46.

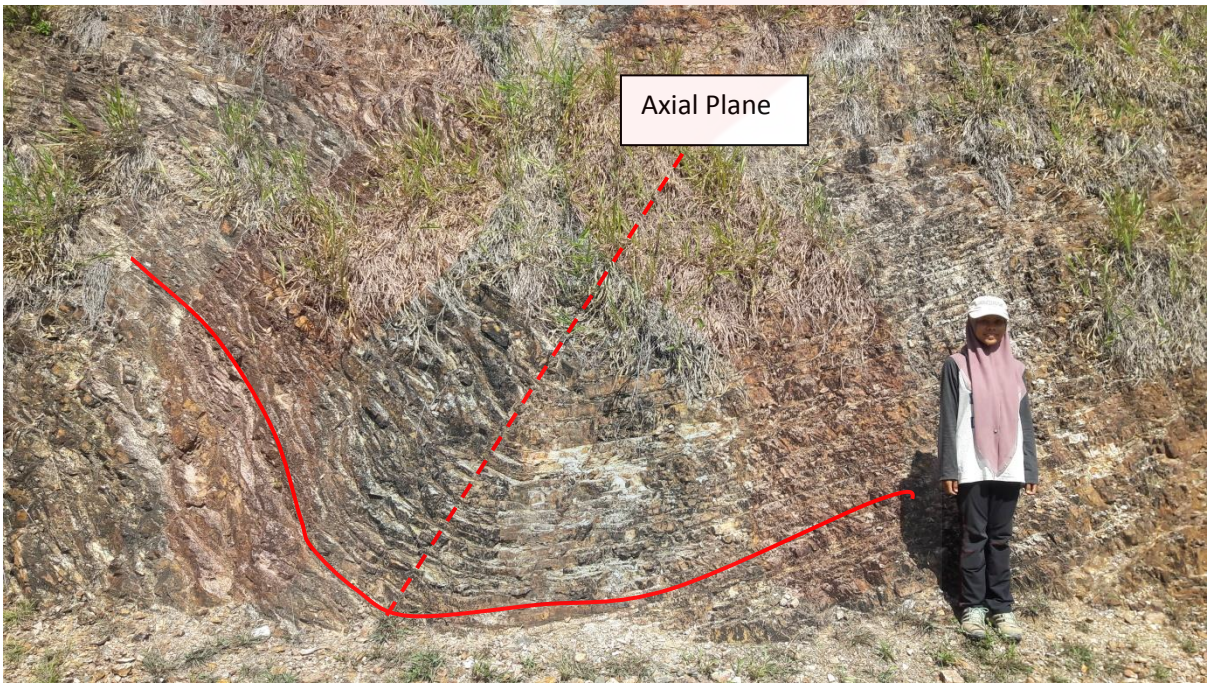


Figure 4.46 : Asymmetrical fold (syncline)

Other than that, at N 04° 42’51.7” E 101° 45’34.7” an anticline fold was observed. This fold formed on tuff unit at the South East of the study area. Anticlines are folds in which each half of the fold dips away from the crest. Anticline has an “A” shape form and its formation is by the compressional stress. This type of fold also caused by the compressional stress.

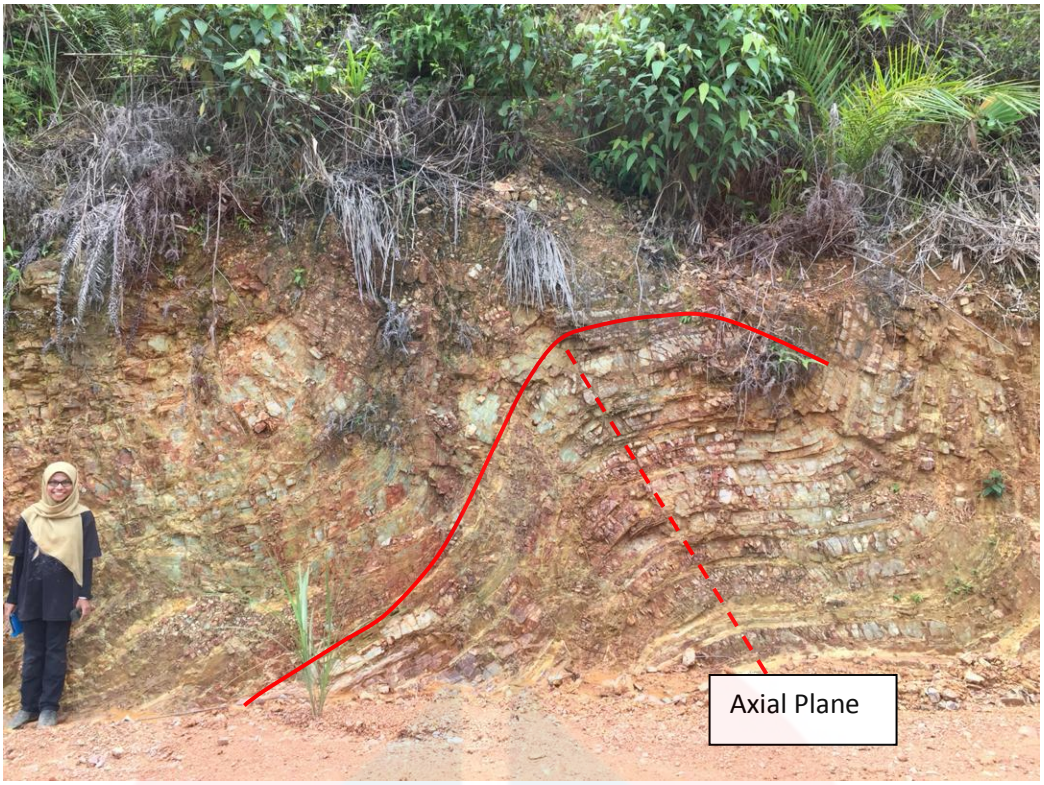


Figure 4.47 : Asymmetrical fold (anticline)

4.5 Historical Geology

Generally, the study area located at the Bentong-Raub suture zone within the collision zone between Sibumasu plate and Indochina plate during Upper Permian and was completed by Upper Triassic. In the past, Peninsular Malaysia and the regional South-East Asia countries such as Thailand and Vietnam were originally located deep down in the Paleo-Tethys Ocean. Due to the collision, the major part of the history of the Palaeo-Tethys was destroyed and only a small portion is still preserved in blocks of oceanic sedimentary rocks such as cherts which range in age from Middle Devonian to Middle Permian, and me´lange includes chert and limestone clasts that range in age from Lower Carboniferous to Lower Permian. In study area, sedrimentary rocks such as chert and limestone were found with age Pre-Mesozoic and Middle Triassic respectively.

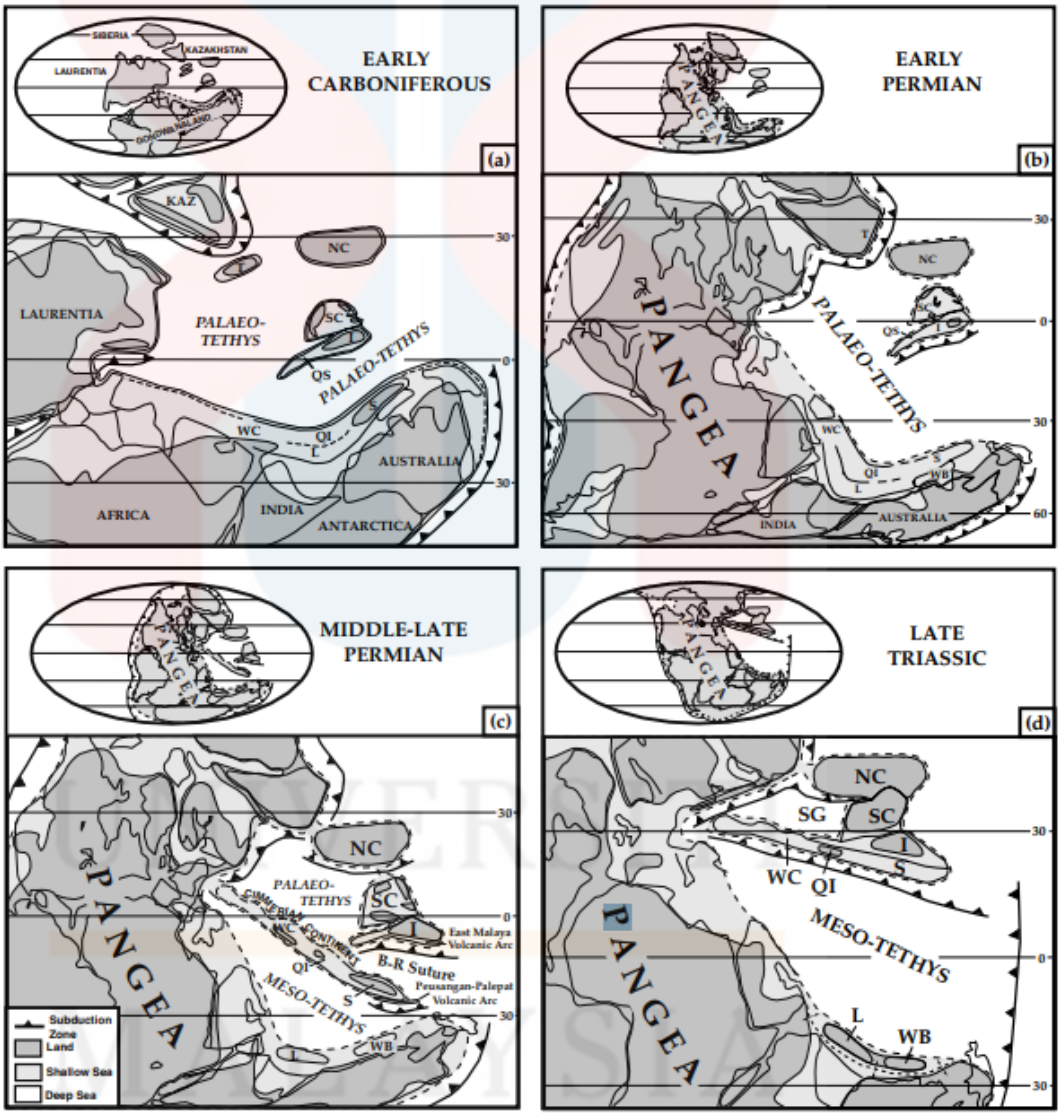
The geological formation of the study area composed of Gua Musang formation with the age ranging Middle Permian to Late Triassic. The lithology unit in Gua Musang Formation includes argillaceous and calcareous rocks interbedded with volcanic, minor presence of arenaceous rocks. The geological setting of Gua Musang Formation is shallow marine shelf deposit, with active volcanic activity.

The deformation of rocks that occur in the study area which are especially major thrust fault and strike slip fault are inherited from the Bentong Raub Suture Zone formation where its formation is due to the collision between Sibumasu and Indochina block. Subduction of the Palaeo-Tethys, represented by the Bentong–Raub Suture Zone, may have begun in the Carboniferous, with evidence for this being abundant volcanics in continental margin Carboniferous sediments in eastern Peninsular Malaysia, and the presence of a Carboniferous volcanic arc through Thailand and Western Yunnan.

Northwards subduction of the Palaeo-Tethys beneath Indochina during the Permian and Triassic is recorded by I-type granitoids and intermediate to acidic volcanics of the East Malaya Volcanic Arc. The Sibumasu Terrane, as part of the elongate Cimmerian Continental strip, separated from the margin of Gondwana in late Lower Permian times. During the remainder of the Permian and Triassic Sibumasu drifted rapidly northwards, as documented by changes in biogeography and palaeolatitudinal position (Figure 4.48).

During Permo-Triassic times, subduction beneath Indochina constructed an accretionary complex of offscraped oceanic sediments and me´lange, and also produced the East Malaya Volcanic Arc and I-type granitoids. With time, the accretionary complex built up into an outer arc on which shallow-marine limestones formed, some of which were incorporated as clasts into me´lange, and the volcanic arc migrated

westwards. In the Triassic, thick volcaniclastic sediments filled the forearc/ intra-arc "Semantan" basin which corresponds to the Central "Belt" or basin of Peninsular Malaysia and turbiditic rhythmites and conglomerates of the Semanggol Formation were deposited in the Semanggol foredeep basin, on top of Permian and Triassic cherts and pelagic limestones.



Figur 4.48 : Palaeographic reconstructions for (A) Carboniferous; (B) Early Permian; (C) Middle–Late Permian; and (D) Late Triassic, showing relative positions of the East and Southeast Asian terranes and distribution of land and sea.

In Figure (a), it represent Early Permian age where thick argillite and volcanic were deposited adjacent to Indochina volcanic arc, as the current Aring and Telong formations. In the west, pebbly mudstone of Singa formation and argillite of Kubang Pasu formation were deposited. Accretionary complex builds up as Paleo-Tethys Ocean were subducted. While in Figure (b), in Middle-Late Permian, the hick argillites and volcanics created shallow marine Gua Musang platform favorable for carbonate development and benthic fauna. The current Gua Musang formation started to develop in the east. Volcanism peaks while forearc basin started to subside. In the west, Kodiang-Chuping limestones were developed in a shallow setting while chert was deposited within Semanggol foredeep basin.

Figure (c) is Early Triassic, during this time forearc subsidence intensified in Gua Musang platform, creating more accomodation space for carbonate-argillite-volcanis deposition. PaleoTethys Ocean had been completely subducted as Sibumasu docked into Indochina. In (d) Middle-Late Triassic, the oblique subduction of Sibumasu aided process of basin segmentation on the subsiding Gua Musang platform, thus creating the deep marine Semantan-Gemas basin. This basin was bounded by shallow marine platform as portrayed by the geometry of Central Belt as we observe today. Basin faulting and segmentation caused the presence of slump deposits and intraclasts in Pos Blau, Krau, Raub, and Kota Gelanggi. In the west, rudite-arenite were deposited in submarine fans of Semanggol foredeep basin.

CHAPTER 5

FAULT ANALYSIS

5.1 Introduction

Fault is a planar fracture or discontinuity in a volume of rock where compressional or tensional forces cause relative displacement of the rocks as a result of rock-mass movement. Some faults are tiny which may range in length from a few millimeters, but others are part of great fault systems along which rocks have slid past each other for thousands of kilometres. Faults allow the blocks of the rocks to move relative on either side. This movement may occur rapidly, in the form of an earthquake or may occur slowly, in the form of creep. When the sudden and rapid movement occurred, the released energy causes an earthquake. Large faults within the Earth's crust result from the action of plate tectonic forces, with the largest forming the boundaries between the plates, such as subduction zones or transform faults.

This chapter explains the fault analysis in the study area that includes lineament analysis, and interpretation of fault by means of geometry, kinematics and dynamic of faults in Pos Blau, Gua Musang. As to determine the types and direction of fault that present in the study area, the fault analysis has been done. In this chapter, the results and interpretations of fault analysis are discussed.

5.2 Lineaments

Lineaments are extractable linear features from aerial photographs, remotely sensed imagery or topographic map but not identified on the ground. Lineaments are reliable indicators of geological structures especially faults and folds. Lineaments are also used for identifying different information about geological settings, for example type of drainage network (pattern) can indicate general geological setting. Besides, the lineaments can be used to identify the landslide but the interpretations are depends on the resolution and quality of the image.

For the analysis of linear features, a lineament map was made on terrain map and topography around the study area. The lineament analysis also has been done on topography map of the study area with scale of 1:25,000. In Figure 5.1 and 5.2 the lineaments are drawn and the lineament directions are obtained. All lineaments are represented as straight-line segments that approximately follow the linear features drawn on the images. The measured lineaments' direction were then plotted in rose diagram to determine the major direction of force.

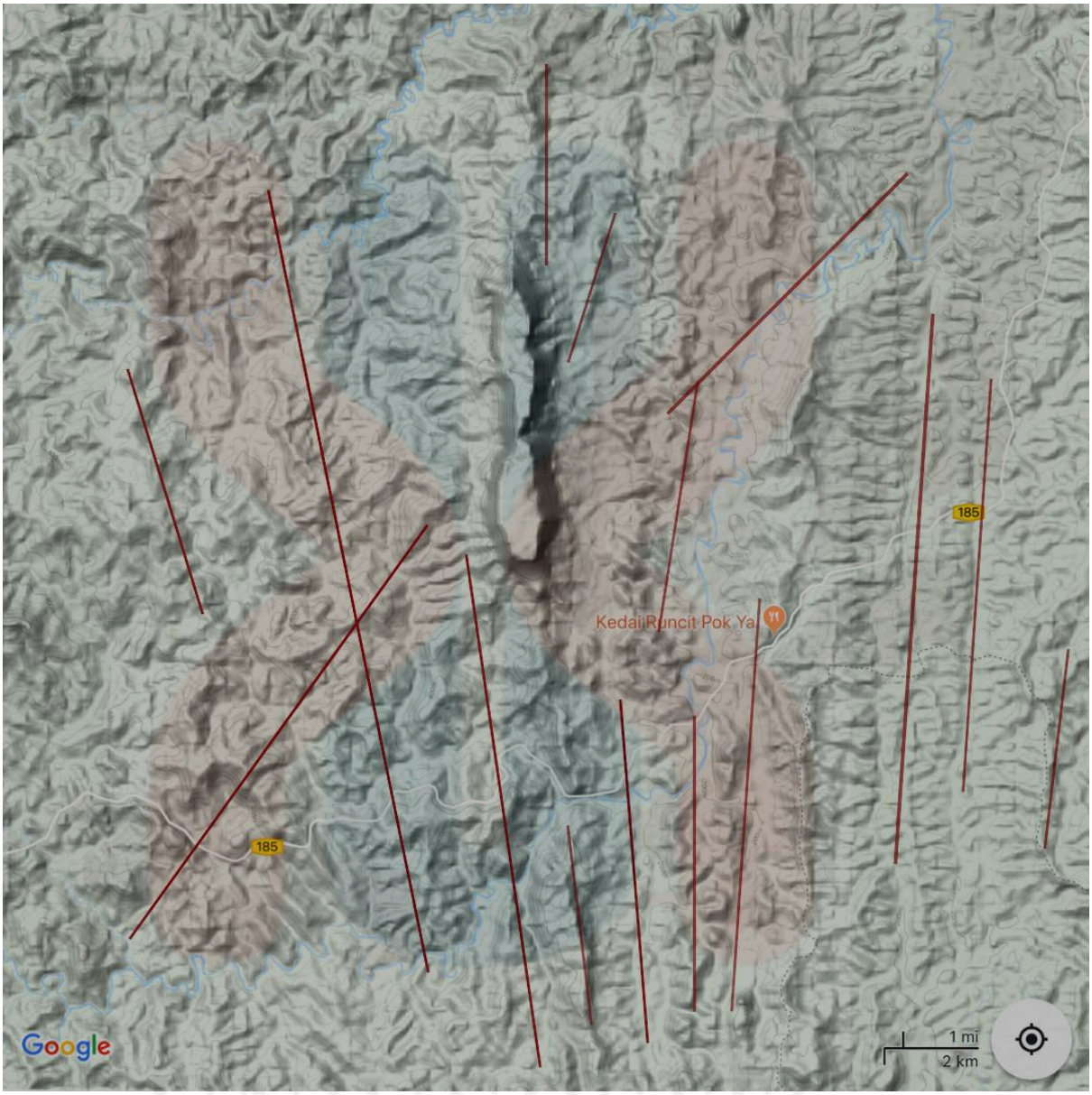


Figure 5.1 : Lineament analysis using Terrain Google Map

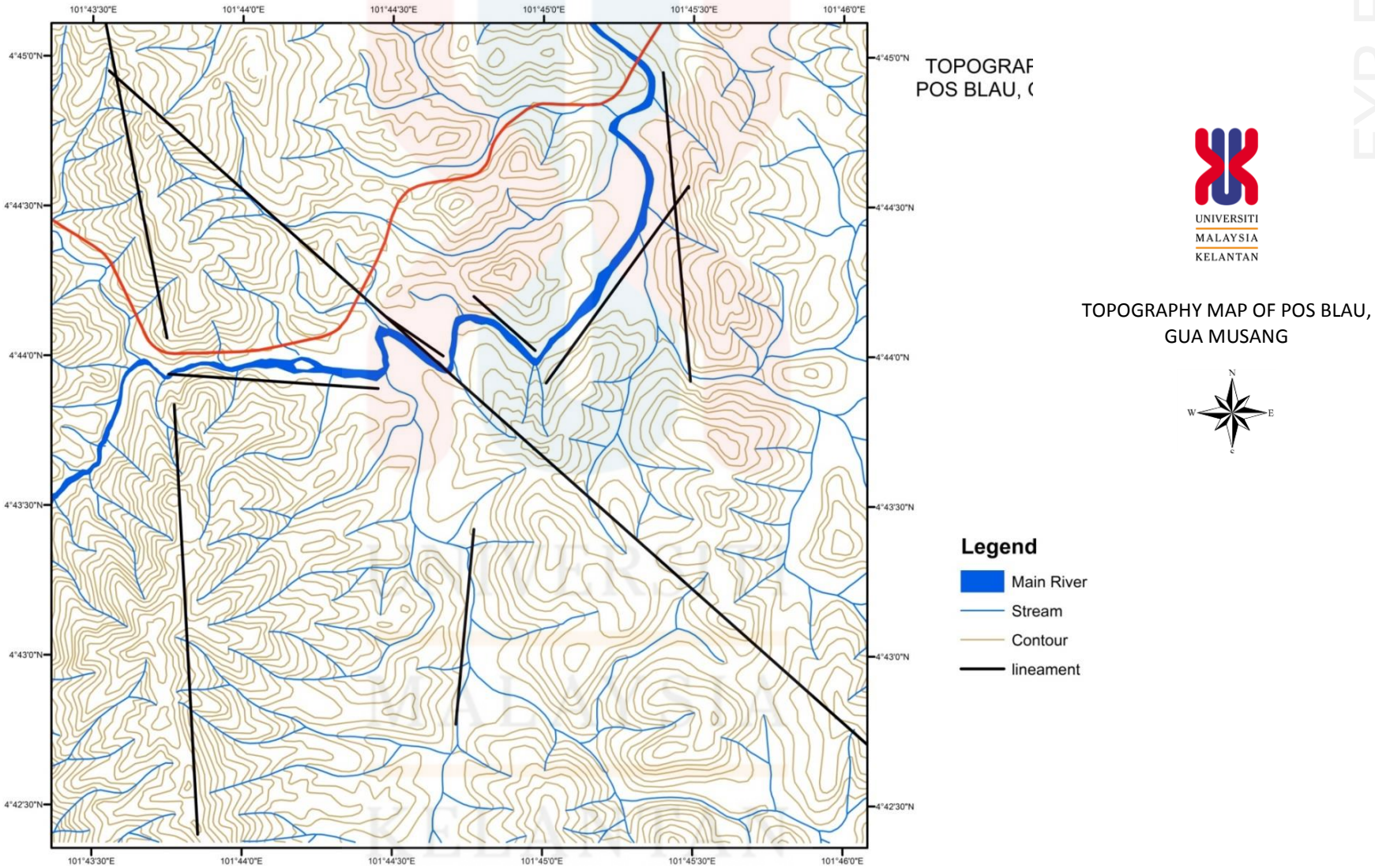


Figure 5.2 : Lineament map of Pos Blau

Figure 5.3 shows the local lineament rose diagram in study area while table 5.1 shows the reading of lineament analysis from terrain map and topography map of Pos Blau, Gua Musang.

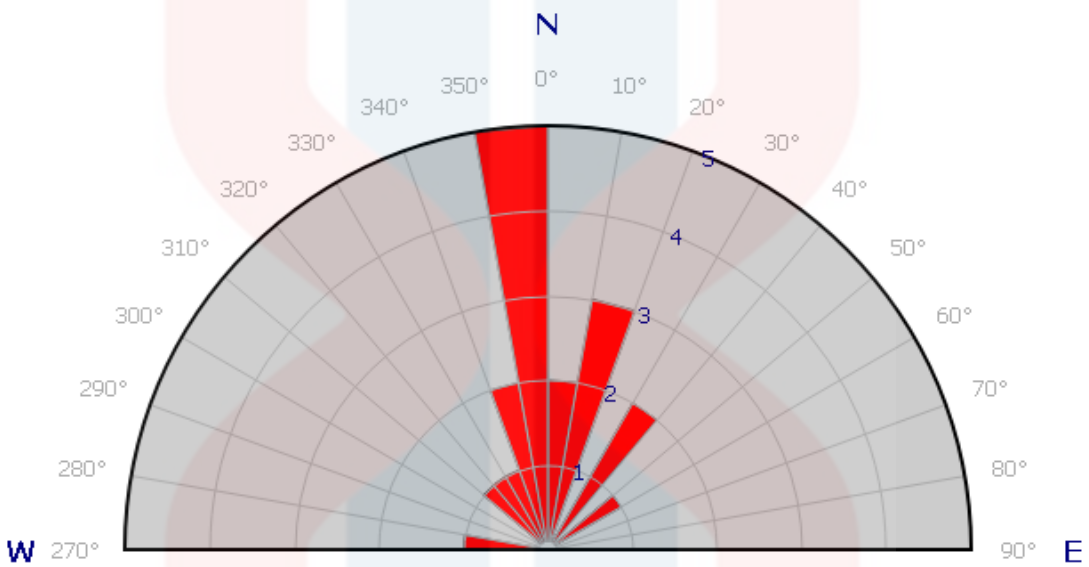


Figure 5.3 : Lineaments rose diagram

Table 5.1 : Joint readings for lineament of terrain and topography map

No.	Strike	No.	Strike
1	10	11	275
2	5	12	348
3	3	13	355
4	50	14	310
5	10	15	352
6	353	16	38
7	351	17	320
8	339	18	347
9	37	19	10
10	10	20	350

5.3 Field Observation

In the study area at coordinate N 04° 44’02” E 101° 45’18.0”, a reverse fault is found on tuff outcrop. Reverse fault is a dip slip fault where the rock walls shifted vertically. It is characterised by a hanging wall that moves up relative to the footwall. It has a steep slope or dip which is greater than 45º. This fault has a reading of 220/68 (strike/dip). The reverse fault is the result of compression stress. Figure 5.4 shows the reverse fault found in the study area.

Figure 5.4 : Reverse fault

5.4 Fault Analysis

Based on lineament analysis that was done previously in terrain map and topography map, the major structure that can be interpreted is fault. The faults are recognized as thrust fault and strike slip fault.

5.4.1 Blau Thrust Fault

Blau thrust fault is a type of dip slip fault that has a dip of 45 degress or less. In the study area, the thrust fault is analysed to occur along the lithology of schist and clastic sediment. In thrust fault, the hanging wall moves up relative to the footwall. Thrust fault causes the older rocks are pushed above the younger rock due to the horizontal compressive stress by plate tectonic mechanism. From the lithostratigraphic unit, schist unit is the oldest unit of rock in the study area. The evidence that show the occurrence of Blau Thrust Fault in the study area is due to the hanging wall which consist of metamorphic rock of the schist unit is found over the younger clastic sedimentary rock units.

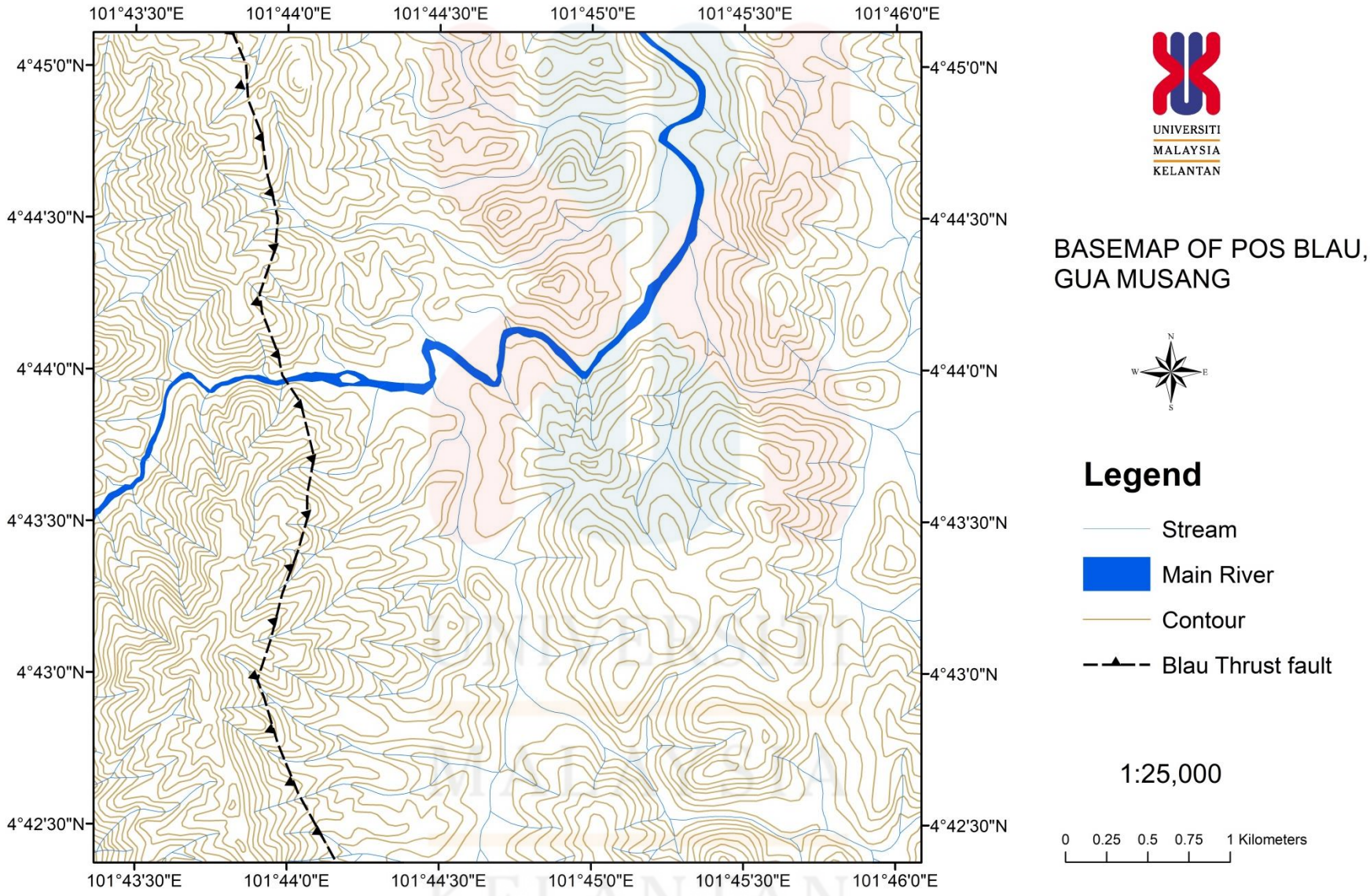


Figure 5.5 : Blau Thrust Fault

a) Descriptive Analysis

i) Structure

The geological structures such as joint, slickenside, slickenline, lineations, dragfold are the indicators of the fault existence. In the study area, joints were found at coordinate N 04° 42’51.7” E 101° 45’34.7”. The types of joints found in the study area is shear joint and they are found on the tuff outcrop. The shear joints may occur due to shearing stresses involved in folding and faulting of rocks. These joints are rather clear-cut and tightly closed. Shear joints occur in two sets and intersect at a high angle to form a “conjugate joint system”.

Joint

Figure 5.6 shows the outcrop where the joint readings are taken. Figure 5.7 showed the rose diagram of joint analysis at N 04° 42’51.7” E 101° 45’34.7” while table 5.2 showed the measuring taken from the joints. From the orientation of joint observed in the field, it enables to indicate on each occasion of most dominant fracture direction. From the rose diagram, it can be clearly seen that the major compressional force, σ_1 is trending ESE-WNW direction because it is acute angle (30°) from major joints distribution.

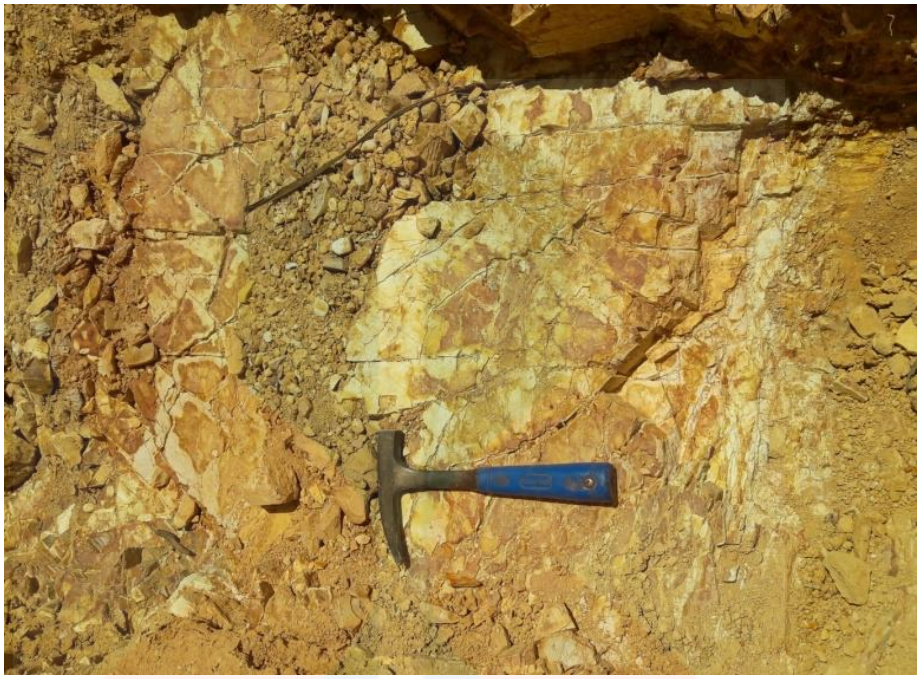


Figure 5.6 : Shear joint in tuff outcrop

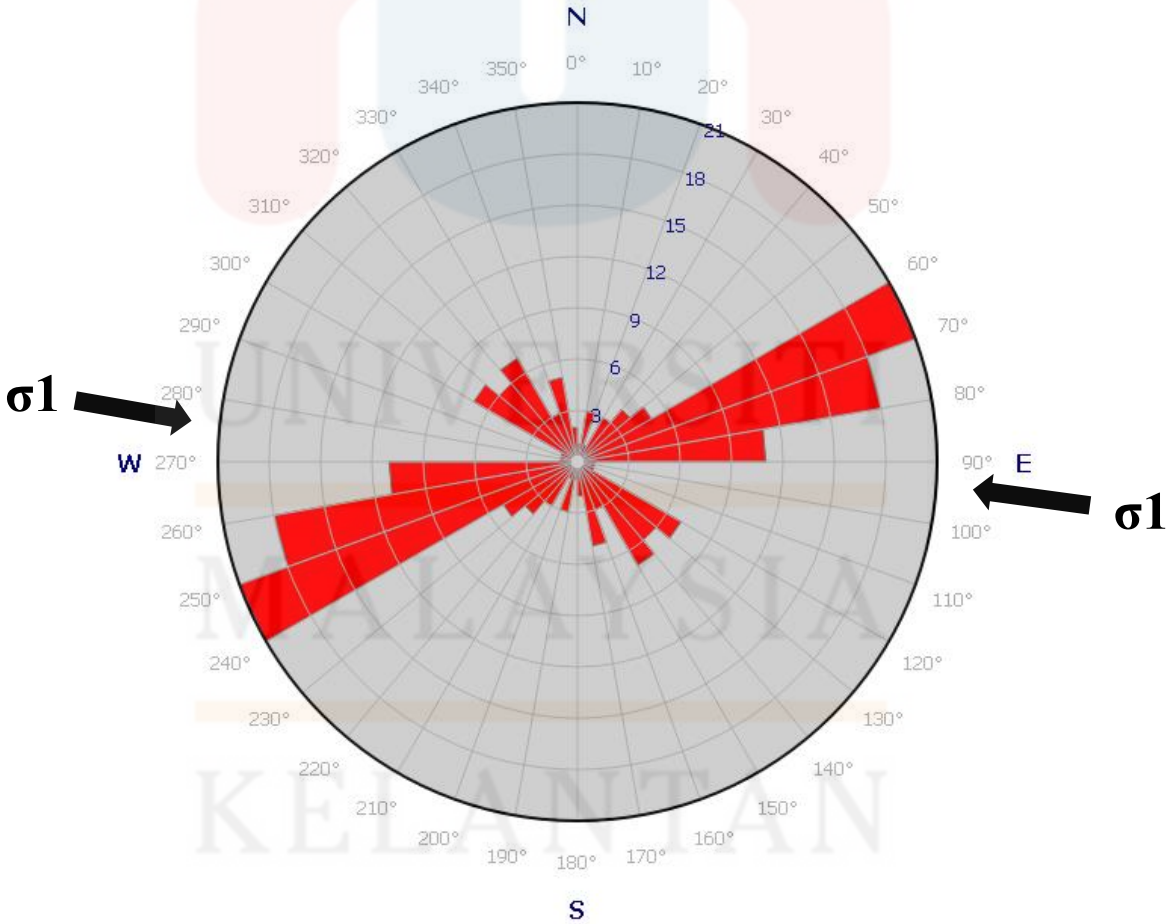


Figure 5.7 : Rose diagram at N 04° 42’51.7” E 101° 45’34.7”

Table 5.2 : Joint reading for location N 04° 42’51.7” E 101° 45’34.7”

No.	Strike	No.	Strike	No.	Strike	No.	Strike	No.	Strike
1.	105	**21.**	278	**41.**	093	**61.**	234	**81.**	115
2.	235	**22.**	300	**42.**	048	**62.**	232	**82.**	144
3.	142	**23.**	028	**43.**	253	**63.**	062	**83.**	152
4.	033	**24.**	043	**44.**	045	**64.**	228	**84.**	134
5.	047	**25.**	273	**45.**	035	**65.**	214	**85.**	058
5.	020	**26.**	280	**46.**	028	**66.**	274	**86.**	054
7.	220	**27.**	229	**47.**	235	**67.**	200	**87.**	110
8.	230	**28.**	068	**48.**	240	**68.**	106	**88.**	067
9.	295	**29.**	071	**49.**	094	**69.**	102	**89.**	070
10.	050	**30.**	220	**50.**	243	**70.**	113	**90.**	096
11.	050	**31.**	027	**51.**	241	**71.**	110	**91.**	123
12.	046	**32.**	215	**52.**	237	**72.**	311	**92.**	151
13.	250	**33.**	222	**53.**	290	**73.**	029	**93.**	127
14.	027	**34.**	244	**54.**	073	**74.**	060	**94.**	052
15.	013	**35.**	045	**55.**	241	**75.**	127	**95.**	075
16.	284	**36.**	066	**56.**	230	**76.**	064	**96.**	034
17.	096	**37.**	035	**57.**	081	**77.**	128	**97.**	171
18.	252	**38.**	250	**58.**	262	**78.**	067	**98.**	049
19.	014	**39.**	108	**59.**	281	**79.**	144	**99.**	124
20.	312	**40.**	039	**60.**	225	**80.**	052	**100**	249

Drag Fold

Drag fold is a minor geological fold produced in soft thinly laminated beds lying between harder or massive beds in the limbs of a major fold. It can be a centimetre to a few meters in size. In study area, drag fold has been found on tuff outcrop at coordinate N 04° 42’51.7” E 101° 45’30.4”. This type of fold develop due to the shearing/dragging effect. The hanging wall moves upward relative to the footwall. It can be seen from Figure 5.8 that the bedding of the tuff unit on the hanging wall was dragged upward. The reading of this fault is 280/68 (strike/dip). Figure 5.6 show the drag fold structure.

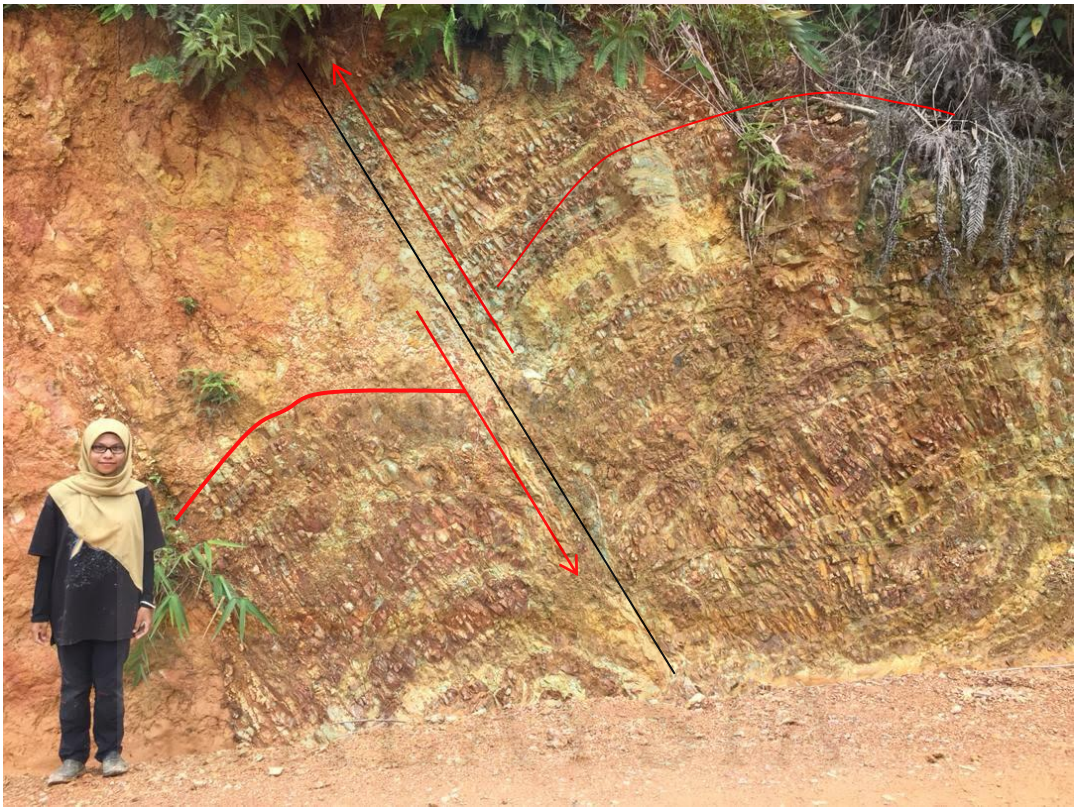


Figure 5.8 : Drag fold

(Coordinate : N 04° 42’51.7” E 101° 45’30.4”)

ii) Geomorphology

From the map of the study area, it shows that the contour lines of the western part are close together to each other. This shows that the magnitude of the gradient is large and the variation is steep. Along schist lithology unit, it can be seen that the elevation of the hill is high and has steep terrain compare to the other parts. This is because the schist has high resistency towards weathering make it higher compared to other hills with sedimentary lithology unit which is low resistant toward weathering. Figure 5.9 shows the differential elevation of rock units by the contour lines.

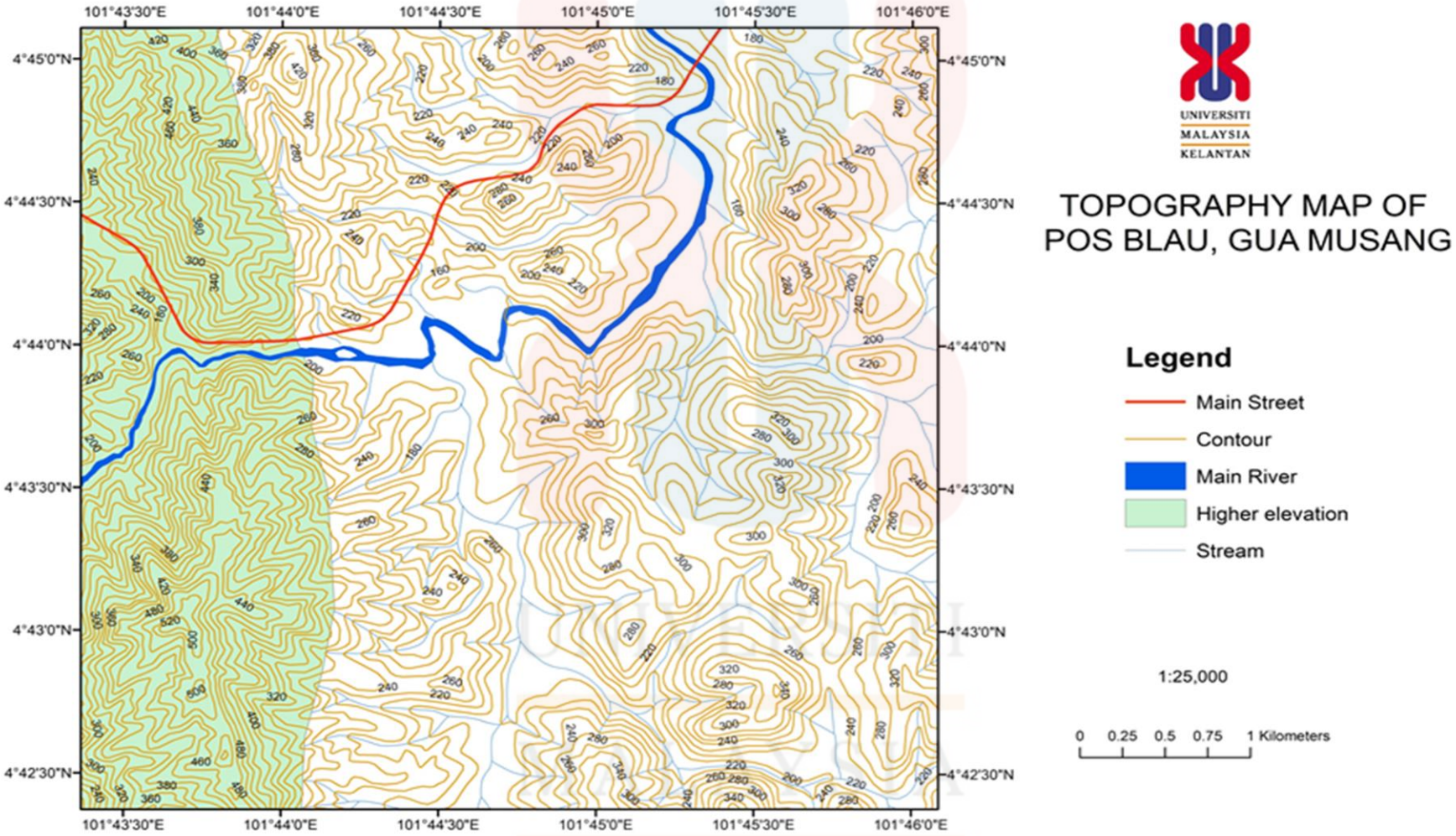


Figure 5.9 : Topography map of Pos Blau

iii) Lithology

The different lithology which is between schist and clastic sedimentary rock gives the indication of thrust fault occurrence. This is due to the uplifting of the older rocks, which in this case is schist that was move up over the younger rock. The thrust fault is interpreted to occur along schist and clastic sedimentary rock and it separate them into two different regions.

b) Kinematic Analysis

Generally, kinematic analysis is done to determine the movement of the rock during deformation. In kinematic analysis, the fault data is analysed by means of graphical method. The data collected during field observation was analysed by using the stereonet, and the data is correlated with strain analysis.

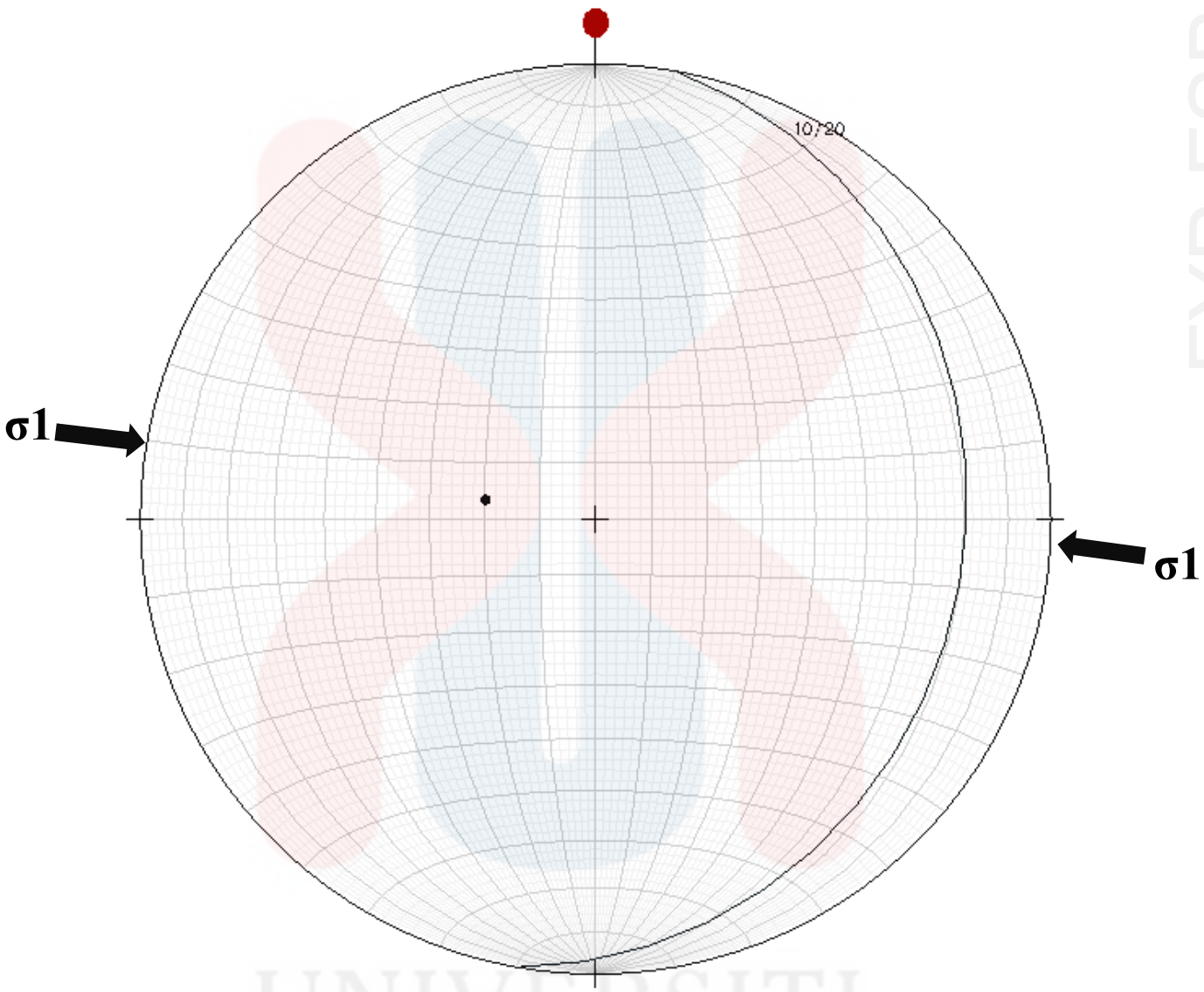


Figure 5.10 : Stereonet for location 1

The strike and dip data was collected on schist outcrop at the Blau Thrust Fault zone at the western part of the study area. The dipping is quite gentle which is 20°. This is due to thrust fault occurs at low angle which is at 45° or less. Blau Thrust Fault occur by the compressional force of ESE-WSW direction which is principal stress of sigma one gain from joint analysis that was done previously. Thus, as refer to stereonet in Figure 5.10, the position of strong force (σ1) is at about 85°SE.

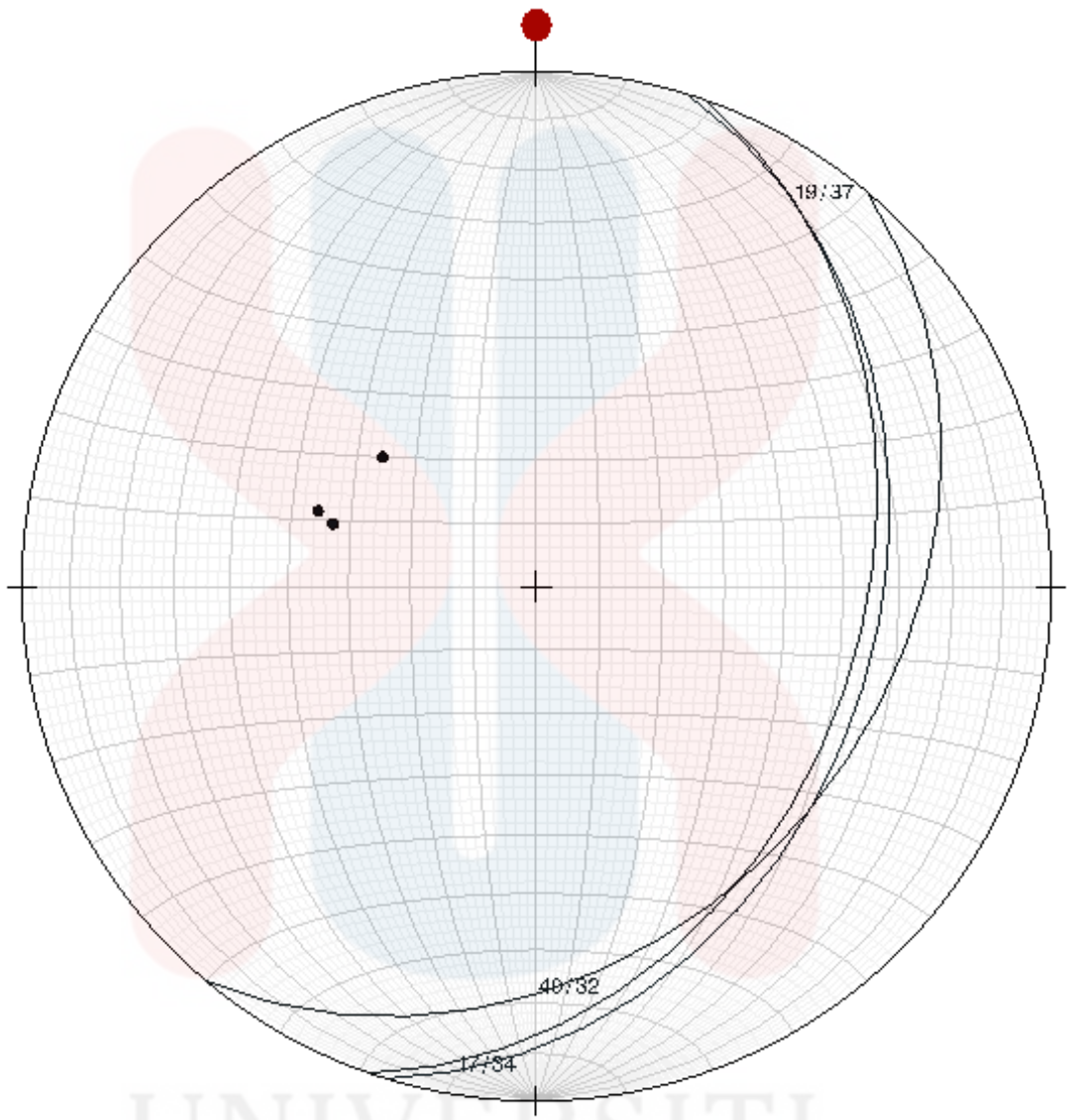


Figure 5.11 : Stereonet for location 2

The strike and dip data were collected on mud outcrop nearby the Blau Thrust Fault zone. Based on the stereonet in Figure 5.11, it shows that the dip angles are less than 45° as well. This is due to the vertical dragging effect of major Blau Thrust Fault formation on the hanging wall causing the other side of the rock to also have the dip angles resemble the thrust fault which are less in steepness.

5.4.2 Brooke Strike Slip Fault

Strike slip fault involve shear stress between two fault blocks. The strike slip fault in the study area is Brooke strike slip fault. This fault occurs across the schist unit, clastic sediment unit, tuffaceous unit and limestone unit. In strike slip fault, the rock strata are displaced mainly in a horizontal direction which is parallel to the line of the fault. Straight line in Figure 5.12 shows the Brooke Strike Slip Fault.

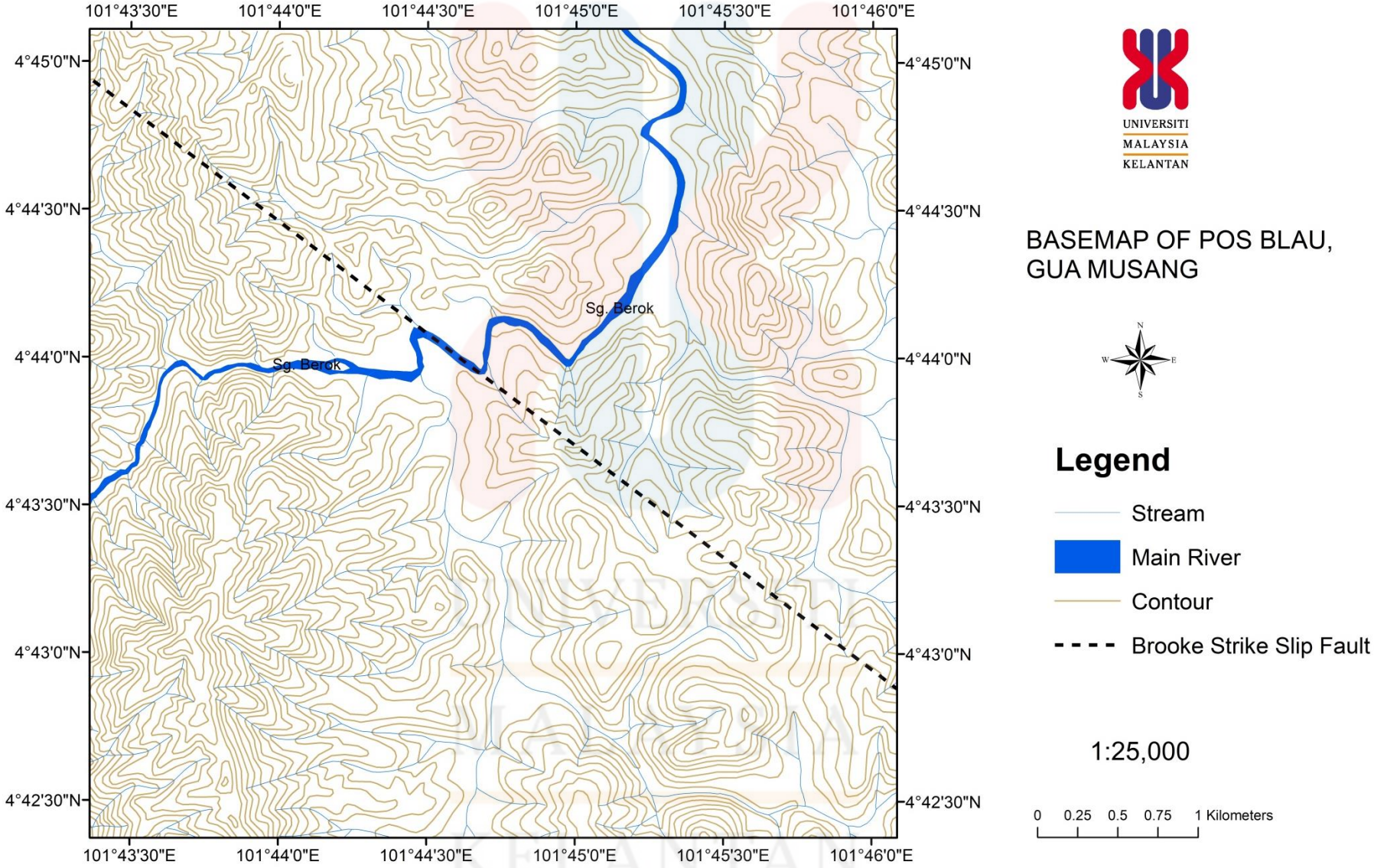


Figure 5.12 : Brooke Strike-slip Fault

a) Descriptive Analysis

i) Structure

Joint analysis was done as previously shown in Figure 5.5 and 5.6.

ii) Geomorphology

River Offset

Based on Figure 5.13, an offset occurs on the main river which is Sg. Brooke. The river offset shown in Figure 5.13 shows early Brooke river (green line), current Brooke river (purple line) and the Brooke Strike Slip Fault (black line). Due to the sinistral strike slip fault, the Brooke river has changed to meandering type of river compare to its origin pattern.

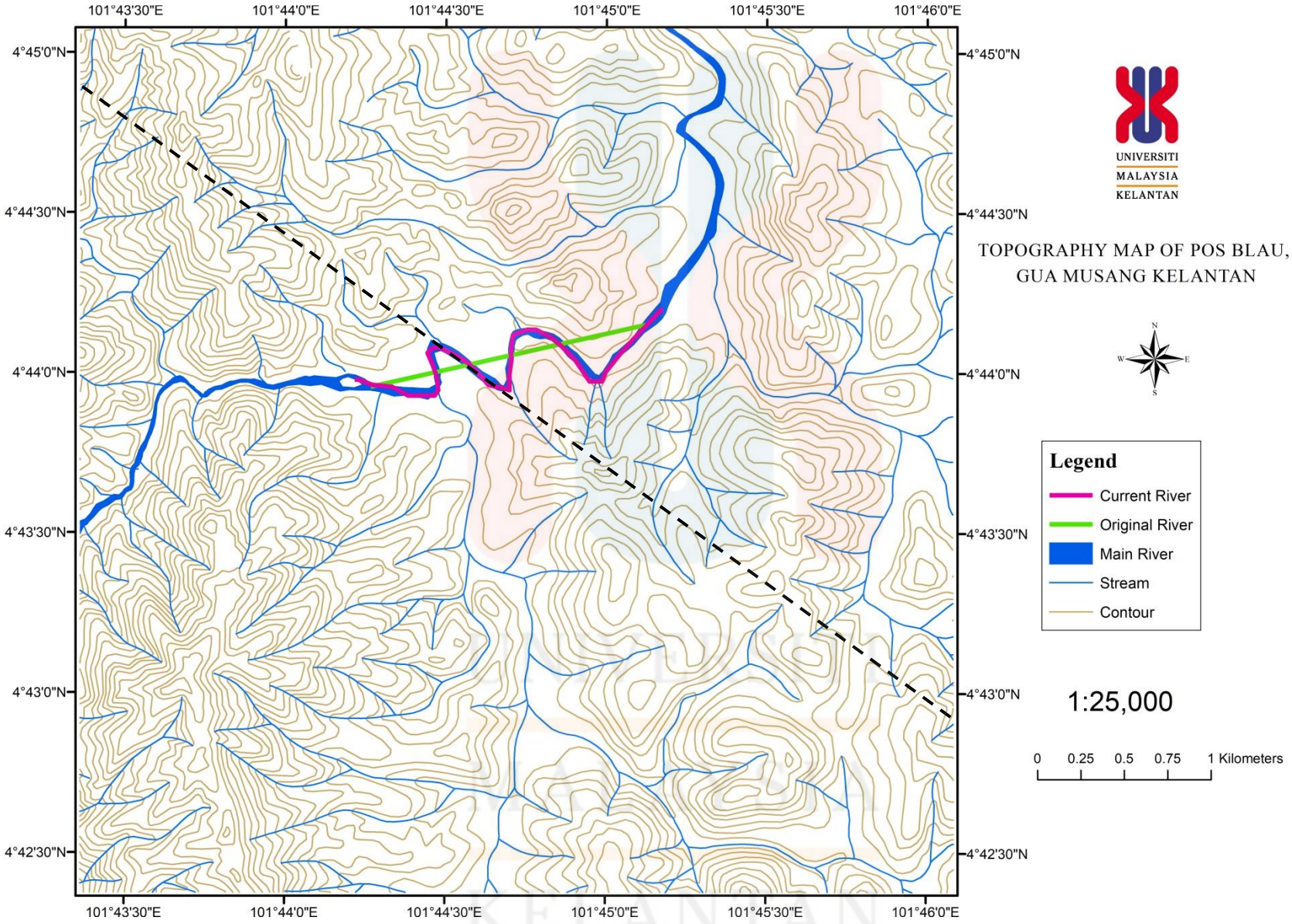


Figure 5.13 : River Offset

b) Kinematic Analysis

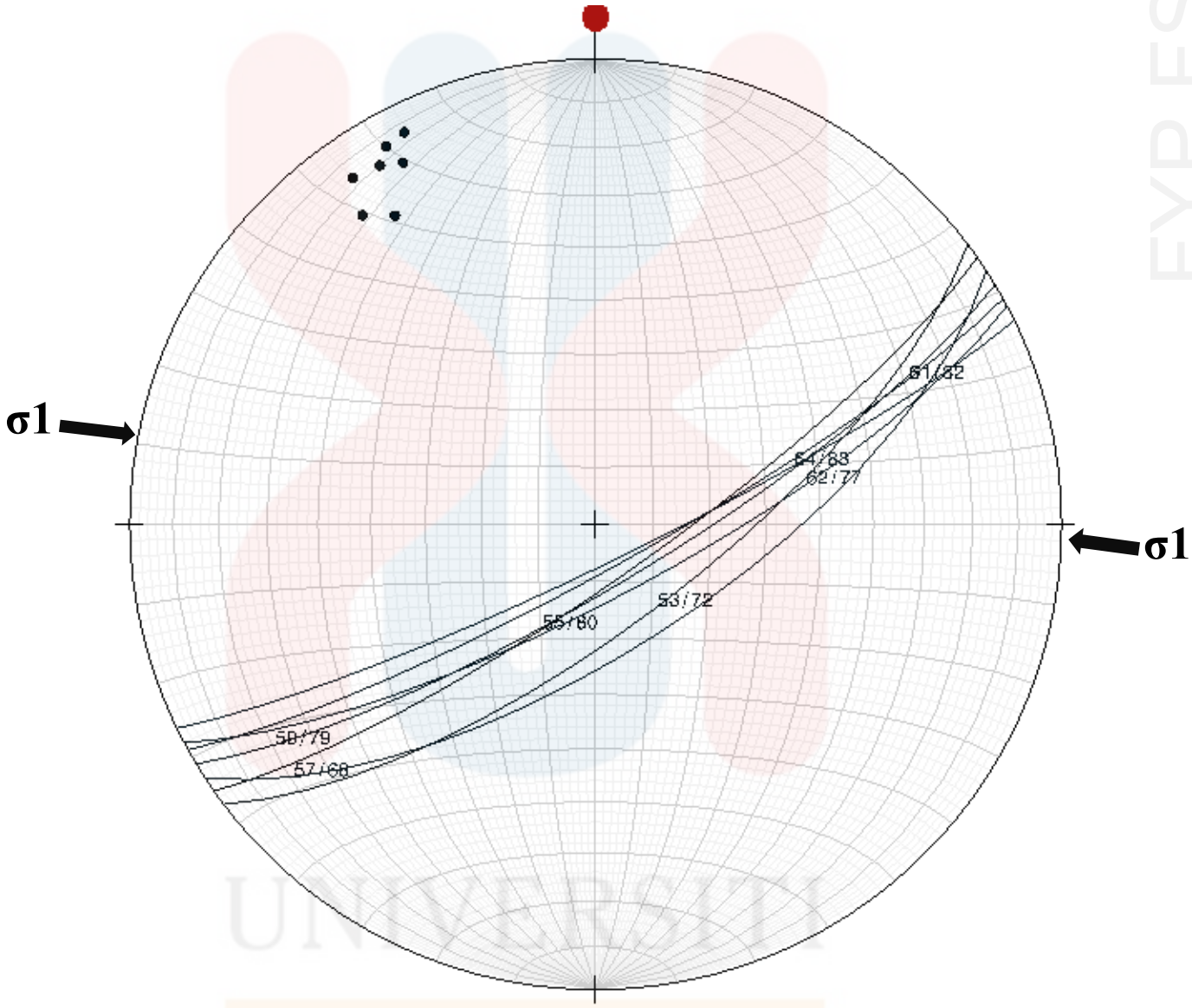


Figure 5.14 : Stereonet of station 1

The strike and dip data were collected on sandstone outcrop at the Brooke Strike-slip Fault zone of the study area. The type of the strike slip fault is sinistral strike slip fault where the block across the fault moves to the left. Strike slip fault occurs about an angle of

30° from principal stress. Thus, as refer to stereonet in Figure 5.14, the position of principal stress (σ1) is about 88° SE.

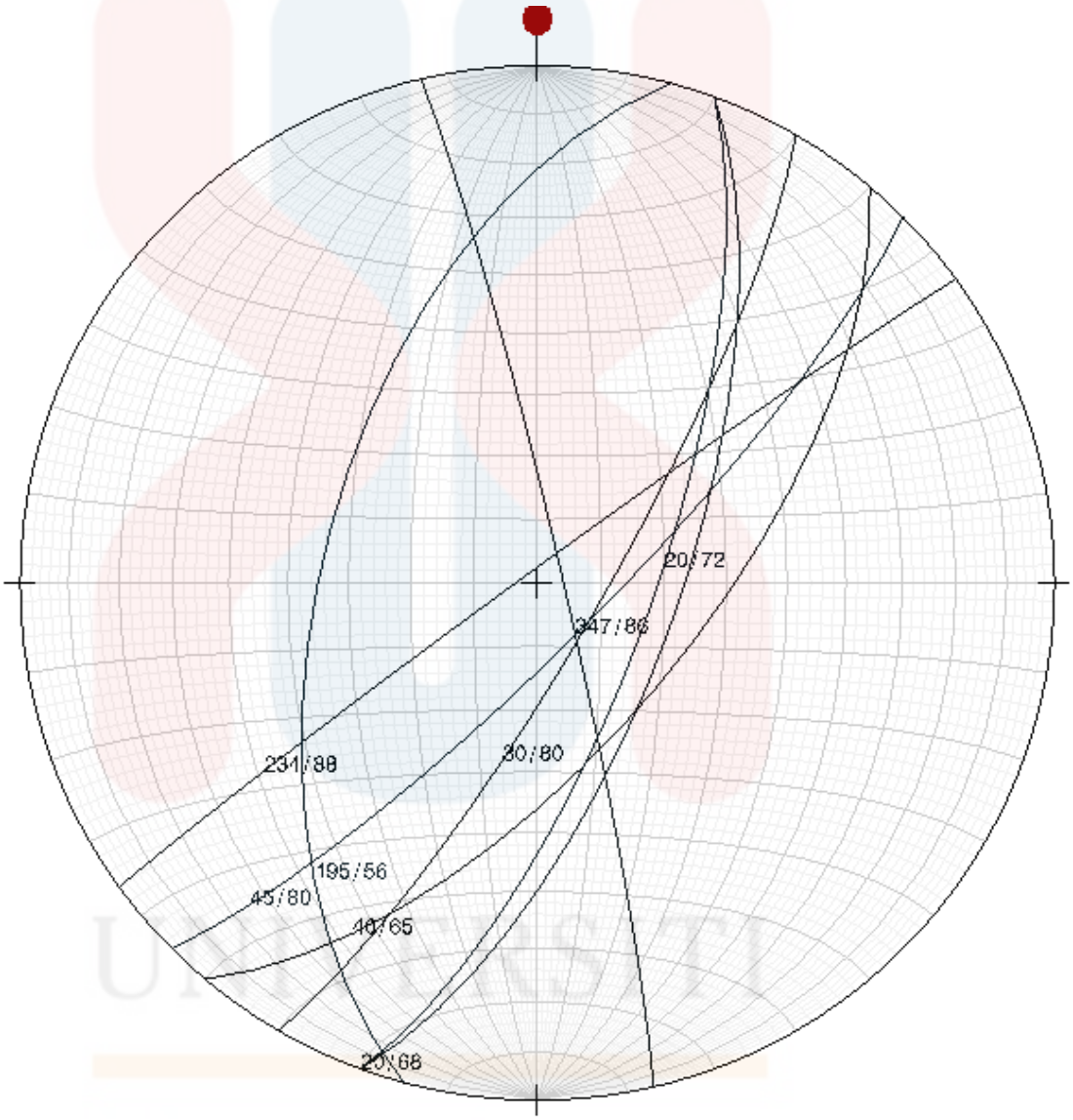


Figure 5.15 : Stereonet of station 2

The strike and dip data were collected on tuff outcrop nearby the major strike slip zone. Based on the stereonet in Figure 5.15, it can be seen that strike and dip pattern were in various direction. It shows that the rocks nearby the strike slip fault zone were disturbed by

the occurrence of the sinistral strike slip that was dragged together along the deformation. Thus, the strike and dip of the rock change from its original form and not in uniform direction.

5.4.3 Dynamic Analysis

Dynamic analysis is the part of structural geology that involves energy, force, stress, and strength that cause motion of particles (kinematics). Dynamic analysis involves measurement or estimation of the force or stress that has affected rocks. Forces acting on a body generate stress, and if the level of stress becomes high enough, rocks start to move. Dynamic analysis is done in the field as to determine the orientation and magnitude of the stress field that caused the deformation in the study area, which in this case is the fault. The deformation of the rock caused by the stress developed in the rocks due to the external force resulted from either tectonic plate movement, subduction or volcanic activity. Generally, dynamic analysis involved three principal stresses which are sigma one (σ_1), sigma two (σ_2), and sigma three (σ_3).

i) Principal Stress

In a plane, when a force is applied on its surface, the stress that acts upon the plane can be differentiate into two, which is normal stress that acts perpendicular to the plane (σ_n), and shear stress that acts parallel to the plane surface (σ_s). When a body of rock is under stress from all direction, three planes of zero shear stress will exist and are called as principal plane of stress.

Principal stress includes three mutually perpendicular normal stresses which are referred to as sigma 1, sigma 2 and sigma 3. The principal stress of σ_1 is the maximum stress, σ_3 is the minimum stress. In dynamic analysis, joint analysis must be done in order to determine the principal stress direction from the joints found in the study area.

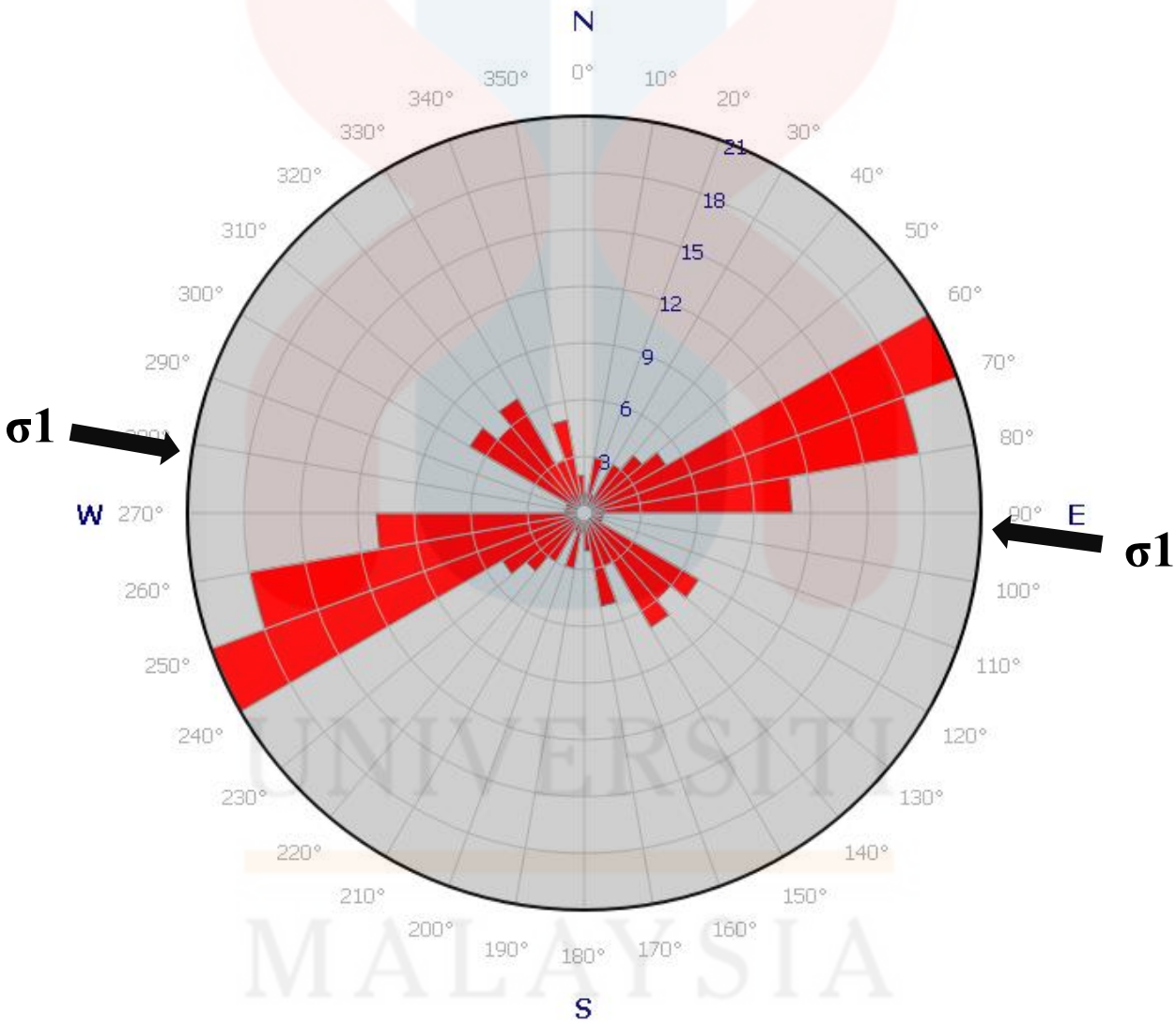


Figure 5.16 : Rose diagram

(Coordinate: N 04° 42’51.7” E 101° 45’34.7”)

From the joint measurements in the study area at location N 04° 42’51.7” E 101° 45’34.7” the major joint distributions show the direction NE-SW. As the major principal stress (σ_1) is define about 30° from the major distributions of the joints, it is interpreted that major principal stress (σ_1) is trending ESE-WNW.

5.4.3 Strain Analysis

The deformation in rocks is described in term of change in shape or size of an imagery sphere. This imagery sphere within the rock becomes an ellipsoid during homogeneous deformation. This ellipse is called as strain ellipsoid, in which the orientation and dimension describes the deformation of the plane in which it lies. Figure 5.17 shows strain ellipse that represent the deformed circle.

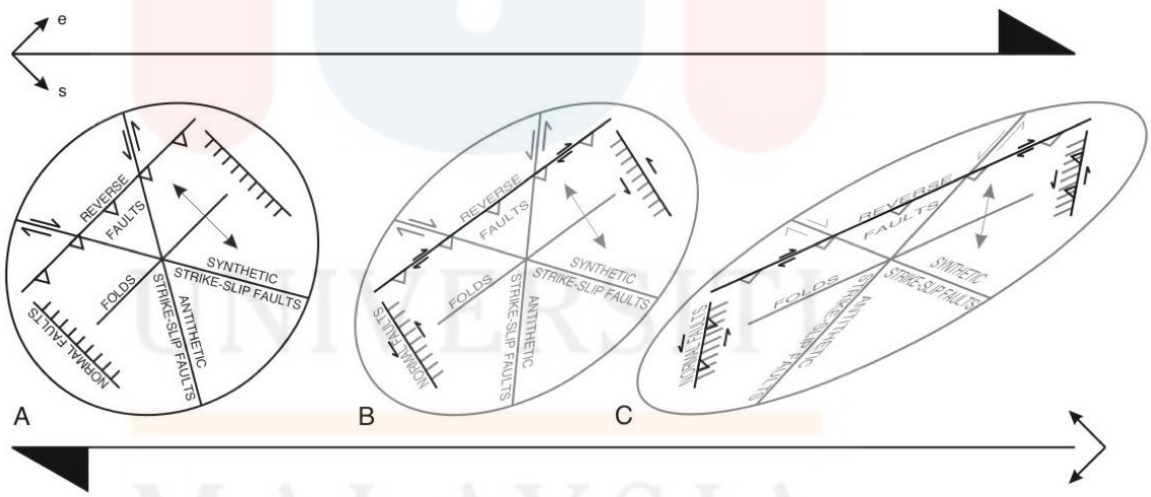


Figure 5.17 : Strain ellipsoid

This strain ellipsoid can be correlated with major fault in the study area which are the thrust fault and strike slip fault. When principal stress (σ_1) comes from direction of ESE-WNW, the circle will be pressed and deformed as ellipse, thus the rock bodies will experience deformation. The deformation of rock includes thrust or reverse fault which is perpendicular to the principal stress, strike slip fault, normal fault parallel to the principal stress and other deformation such as joints or folding.

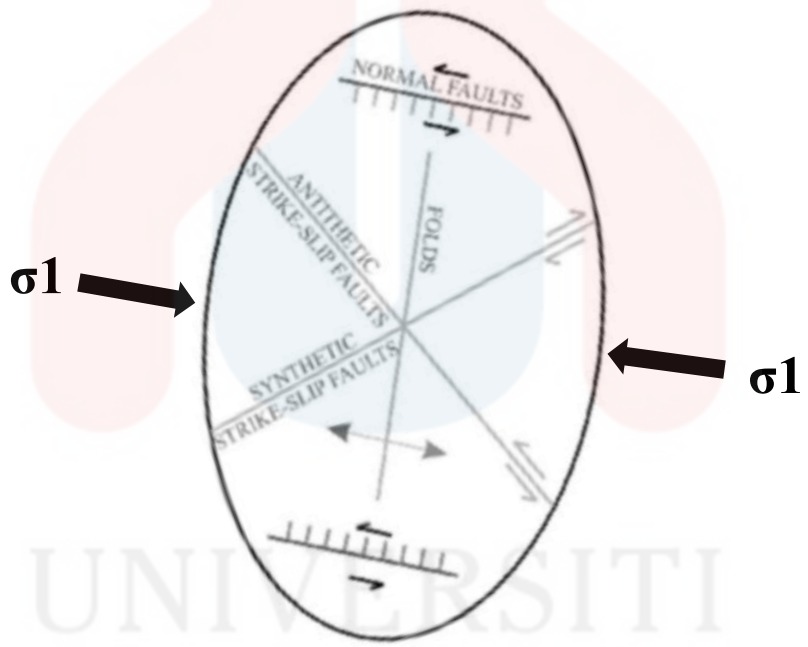


Figure 5.18 : Strain analysis in study area

The strike slip fault in the study area is represented by anthetic strike slip fault as shown in Figure 5.18. While the thrust fault in the study area is perpendicular to the principal stress. Based on the joint analysis that was done earlier, the principal stress is trending ESE-WNW which respectively 30° to the Brooke Strike Slip Fault and

perpendicular to the Blau Thrust Fault analysed in the study area. Thus, the theory of the presence of strike slip fault and thrust fault in the study area is accepted.

5.5 Mechanism of Fault

Tectonically, the study area can be related to the major fault zones which is Bentong-Raub Suture Zone. Main lineaments orientation of Bentong-Raub Suture Zone generally strikes N-S, NNE-SSW, NE-SW and NW-SE. N–S striking lineaments are often cut by younger NE–SW and NW–SE trending lineaments. Figure 5.19 shows the map of Peninsular Malaysia with the major fault zone.

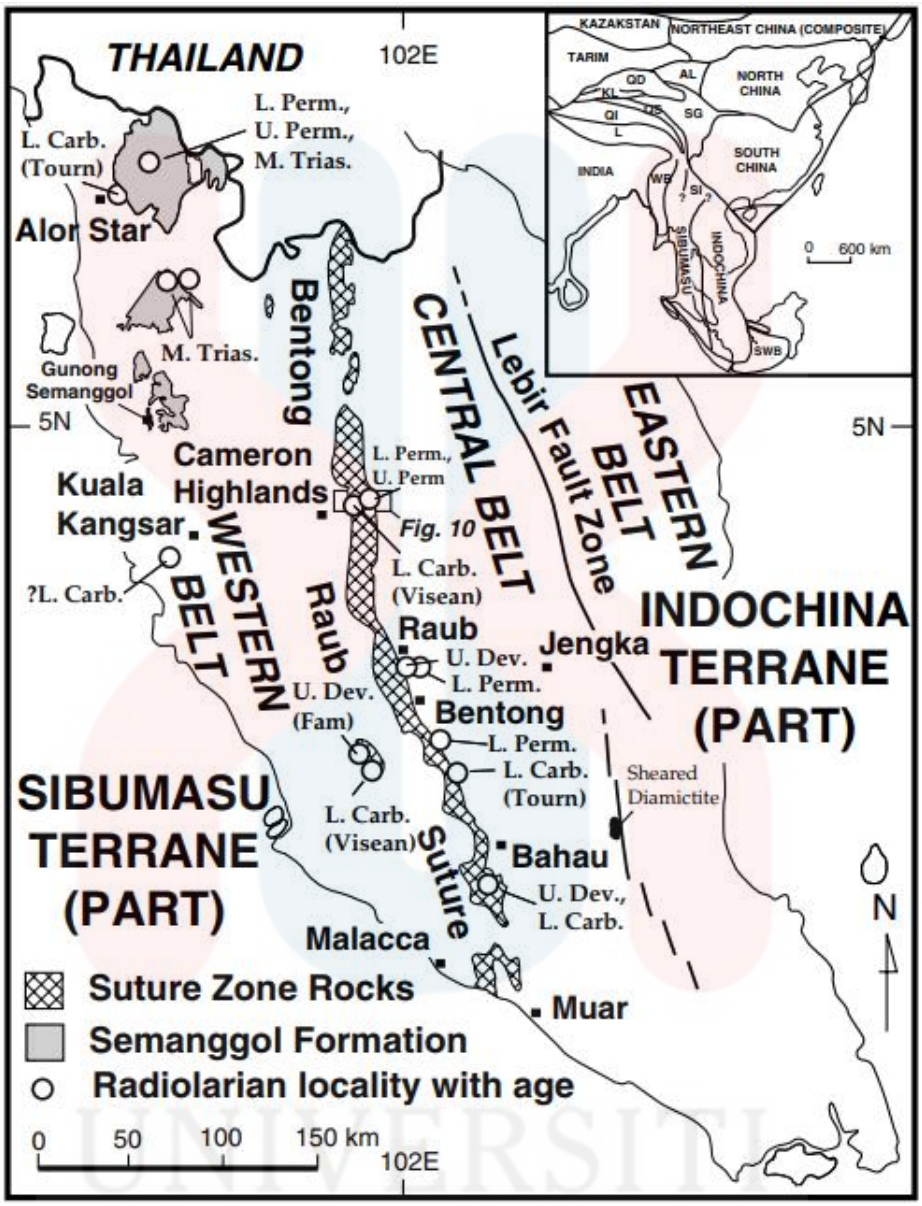


Figure 5.19 : Map of Peninsular Malaysia with major fault zone

(Source: Metcalfe, I. ,2000)

Based on the lineament analysis that has been interpreted in terrain map and topography map as previously, the major distributions of lineaments that formed are trending N-S, NNE-SSW, NE-SW and NW-SE, which can be related to the lineaments of

Bentong Raub Suture Zone. Principal stress that caused the formation of Bentong Raub Suture Zone's lineaments are acted E-Wdirection.

The Bentong Raub Suture Zone is considered as a collision zone between the Sibumasu and East Malaya (Indochina) terranes. The suture zone resulted from northward subduction of the Palaeo-Tethys oceanic crust beneath Indochina (Sukhothai Arc/East Malaya block) continental block in the late Palaeozoic (Permian) and Late Triassic collision and underthrusting of the Sibumasu continental fragment with and under Indochina (Sukhothai Arc/East Malaya block) (Metcalfe, 2000, 2002, 2011, 2013a, 2013b). Figure 5.20 shows the illustration of Bentong Raub Formation due to collision between Sibumasu.and Indochina plate.

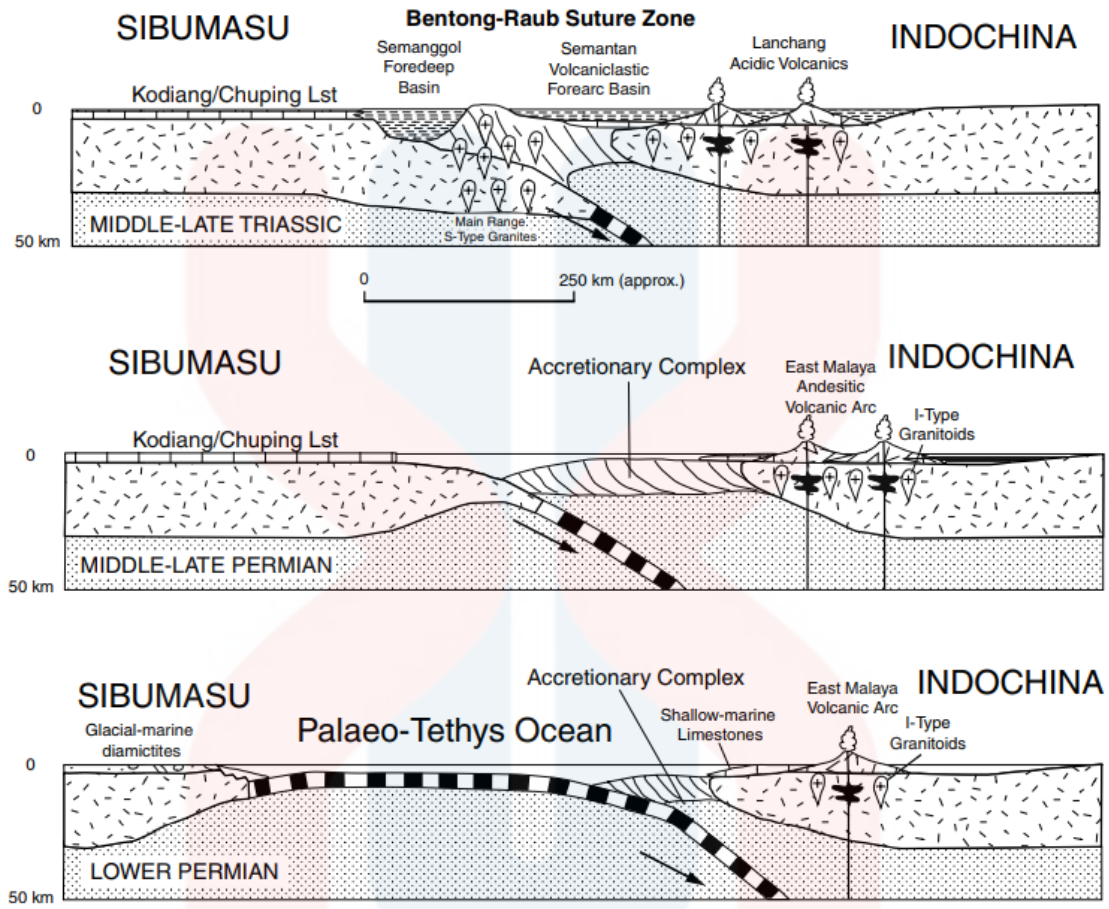


Figure 5.20 : Conceptual cross-sections illustrating formation of the Bentong–Raub Suture by subduction of the Palaeo-Tethys Ocean and collision of the Sibumasu and Indochina terranes.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, the objectives of this research are achieved, by which the main objectives for the research that need to be completed is to produce a geological map of the study area in a scale of 1:25,000 and also to analyse the present of faults in the study area by dynamic and kinematic analysis.

Generally, the geological map of the study area which is Pos Blau, Gua Musang is produced. From the geological map, four units of rock were found in the study area, which consist of schist unit, clastic sedimentary unit, limestone unit and tuffaceous unit. Schist unit composed of schist , while clastic sediment unit composed of mudstone, shale and sandstone. Tuffaceous unit composed of predominant tuff and subordite with chert. The age of rock ranges from Pre –Mesozoic to Late Triassic.

The second objective which is to analyse the fault by using kinematic and dynamic analysis, an interpretation of major fault which are thrust fault and strike slip fault in the study area were analysed and named as Blau Thrust Fault and Brooke Strike Slip Fault. The lineaments were done on terrain map and topography map as to analyse the geological structures present in the study area especially the fault. During field mapping, several indicators that leads to the interpretation of fault were found; in terms of lithology,

structures and geomorphology. Joints analysis in terms of dynamic aspects were also done to determine the direction of the principal stress which trends ESE-WNW.

6.2 Recommendation

For further research, it is recommended to use satellite images and aerial photographs for lineament analysis as to improve the accuracy of lineaments interpretation such as using RADAR and LIDAR. This is because the lineament analysis is a crucial part that leads to interpretation of geological structures and to determine the direction pattern of lineaments in an area. Other than that, further research on fault analysis in the surrounding study area are recommended to know the total extend of the fault occurrence.

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