GEOLOGY AND SPELEOTOURISM POTENTIAL AT GUA PUTERI PULAI, GUA MUSANG KELANTAN.

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Geosciences) with Honors.

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APPROVAL

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

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DECLARATION

I declare that this thesis entitled "**GEOLOGY AND SPELOTOURISM POTENTIAL AT GUA PUTERI PULAI, 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 degree.

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GEOLOGY AND SPELEOTOURISM POTENTIAL AT GUA PUTERI PULAI, GUA MUSANG KELANTAN.

ABSTRACT

Gua Puteri Pulai at the Kampung Pulai, Gua Musang has a good potential as speleotourism site in Kelantan state. The study area for this research are located at Kampung Batu Tongkat with coordinate N 04˚ 53’ 03.4” and E 101˚ 58’ 05.4”. This research was conducted within the box of an area of 5 km x 5 km in Kampung Batu Tongkat and around Kampung Pulai. The highest elevation of the study area is 680 m while the lowest elevation is 110 m. This research was carried out due to there are only big scale research and less information regarding geomorphological and stratigraphy aspects at the study area. Also, the evaluation is conducted using the SWOT analysis and TOWS analysis to determine speleotourism potential at Gua Puteri Pulai, Gua Musang Kelantan. The purposes of this research are to produce a detailed and updated geological map of Kampung Batu Tongkat in the scale 1:25000, carry out a detailed study of speleothem features and karst geomorphology in the study area using secondary data and to obtain the speleotourism potential of Gua Puteri Pulai, Kampung Pulai. There are six types lithology found in the study area is phyllite, shale and slate, limestone, tuff and alluvium. Gua Puteri Pulai is the cone karst types which have speleothem such as column, stalactites and stalagmites. As for the speleotourism potential at Gua Puteri Pulai, Kampung Pulai as speleotourism was identify based on the evaluation using SWOT analysis and TOWS analysis in the internal condition and external condition. The result shows that there is some recommendation to held suitable activities which is rock climbing, spelunking and as cultural or historical place. These activities can attract the local community and tourist to come to this geotourism site. As a conclusion, all the objectives were achieved and this research leading to greater acknowledge the Gua Puteri Pulai as geotourism site.

GEOLOGI DAN POTENSI SPELEOTOURISM DI GUA PUTERI PULAI, GUA MUSANG KELANTAN.

ABSTRAK

Gua Puteri Pulai di Kampung Pulai, Gua Musang memiliki potensi yang baik sebagai laman speleotourism di negeri Kelantan. Kawasan kajian untuk penyelidikan ini terletak di Kampung Batu Tongkat dengan koordinat N 04˚ 53 ’03.4” dan E 101˚ 58 ’05.4”. Penyelidikan ini dilakukan dalam kotak seluas 5 km x 5 km di Kampung Batu Tongkat dan sekitar Kampung Pulai. Ketinggian tertinggi kawasan kajian adalah 680 m sementara ketinggian terendah adalah 110 m. Penyelidikan ini dilakukan kerana hanya ada penyelidikan skala besar dan kurang maklumat mengenai aspek geomorfologi dan stratigrafi di kawasan kajian. Juga, penilaian dilakukan menggunakan analisis SWOT dan analisis TOWS untuk menentukan potensi speleotourism di Gua Puteri Pulai, Gua Musang Kelantan. Tujuan penyelidikan ini adalah untuk menghasilkan peta geologi Kampung Batu Tongkat yang terperinci dan terkini dalam skala 1: 25000, menjalankan kajian terperinci mengenai ciri speleothem dan geomorfologi karst di kawasan kajian menggunakan data sekunder dan untuk mendapatkan potensi speleotourism Gua Puteri Pulai, Kampung Pulai. Terdapat enam jenis litologi yang terdapat di kawasan kajian adalah phyllite, shale and slate, limestone, tuff dan alluvium. Gua Puteri Pulai adalah jenis karst kerucut yang mempunyai speleothem seperti lajur, stalaktit dan stalagmit. Mengenai potensi speleotourism di Gua Puteri Pulai, Kampung Pulai sebagai speleotourism dikenal pasti berdasarkan penilaian menggunakan analisis SWOT dan analisis TOWS dalam keadaan dalaman dan keadaan luaran. Hasilnya menunjukkan bahawa ada beberapa cadangan untuk mengadakan aktiviti yang sesuai iaitu panjat tebing, spelunking dan sebagai tempat budaya atau sejarah. Kegiatan ini dapat menarik minat masyarakat setempat dan pelancong untuk datang ke laman geotourisme ini. Sebagai kesimpulan, semua objektif telah dicapai dan penyelidikan ini membawa kepada pengakuan yang lebih besar kepada Gua Puteri Pulai sebagai laman geotourisme.

TABLE OF CONTENTS

CHAPTER 5 SPELEOTORISM POTENTIAL AT GUA PUTERI PULAI, GUA MUSANG, KELANTAN

CHAPTER 6 CONCLUSION AND SUGGESTION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

N	North
S	South
NW	North west
SE	South east
m	Meter
KM	Kilometer
GIS	Geographic Information System
JMG	Jabatan Mineral Dan Geosains Malaysia
UCGS	United States Geological Survey
DEM	Digital Evaluation Model

LIST OF SYMBOL

°	Degree
‘’	Minutes
‘	Seconds
%	Percent
σ	Sigma

CHAPTER 1

INTRODUCTION

1.1 General Background

A section perspective in cave system called as speleothems where develop in the cave due to the calcium carbonate precipitation either aragonite of calcite from the water trickling that break down with environment in the cave. It will form as crystal deposits on the walls, celling and floor of caves called as stalagmite, stalactites and flowstone. The speleothem formed by saturated water dissolve with calcium carbonate. Water absorbs carbon dioxide and became a weak carbonic acid will cause the water not able to hold in the cave rock. The carbonic acid will dissolve with calcium from limestone and transfer through tiny hole or crack in the rock, then the rock will totally have saturated with the water. This process will produce the calcium carbonate crystal at the entire cave which called as speleothems (Waitomocaves, 2011).

Caves are the karst geomorphology that provide the best study in growth of secondary mineral in form of crystal. Caves formation are related with the secondary mineral that produce by the chemical weathering of the primary mineral. It is also known as speleological objects and geotourism based on its which known as the speleotourism or cave tourism. It is tourism that includes caves with a comparatively recent term granted to tourism which primarily involves speleological formations. Cave tourism have developed in the tourism offer to the country with the wide spread of carbonate terrain. Furthermore, Gua Puteri Pulai is well known for its recreation, nature and enthusiast of the cave. In general, this geosite has important geological and geomorphological importance process and different speleo-morphological units important for science growth and speleology (David, 2015).

Geotourism shows that a sustainable tourist attraction based on discovering the geological features of the earth and preserves the local heritage that has cultural value. It is also will protect geoheritage with promote the geological heritage as well as building communities. In Malaysia, the country nearly achieved the top of the beautiful country that abundance with its own unique in geodiversity (Kiran & Sudipta, 2010). The Gua Puteri Pulai at Kampung Pulai has the opportunities for the nature lover to make the exploration at the astonishing scenery such as at the rich variety of speleothem features. The title of this research is chosen because Gua Puteri Pulai have potential in geotourism purpose especially for the speleotourism aspect.

1.2 Study Area

The research was conducted at South Kelantan in Gua Musang district as shown in the Kelantan state map (Figure 1.1). This research was conducted within box of an area of 5 km x 5 km in Kampung Batu Tongkat and around Kampung Pulai. Based on the base map of the study area in Figure 1.2, a variety of features can be identified such as the main road, main river and stream.

a. Location

The study area is situated in the middle belt of the Malaysian Peninsula. The coordinate of Gua Puteri Pulai is N 04˚47’36.0”, E 101˚56’31.5”, Gua Puteri Pulai or also called as Zhi Xia Dong is a limestone karst hill at the Kampung Pulai with takes in about 8 Km from Gua Musang town to study area. The village of Pulai is known for its beautiful little village, surrounded by stunning scenery of hills, rubber plantations, oil palm plantations and other agriculture. The 5 x 5 km^2 study area (figure 1.2) is surrounded by forest and plantations. The highest elevation of study area is 680 m and the lowest elevation is 100 m. The is a folk tale that says the village was built by the Hakka Chinese people about 600 years ago who came in search of alluvial gold. The gold mines that abounded in Kampung Pulai over 100 years ago and the settlers had to turn to agriculture in order to survive. (Carstens, 2007).

Figure 1.1: Kelantan state map. This map shows the region of study area which is located at Gua Musang region. (Source: Kamaruzzaman, 2016)

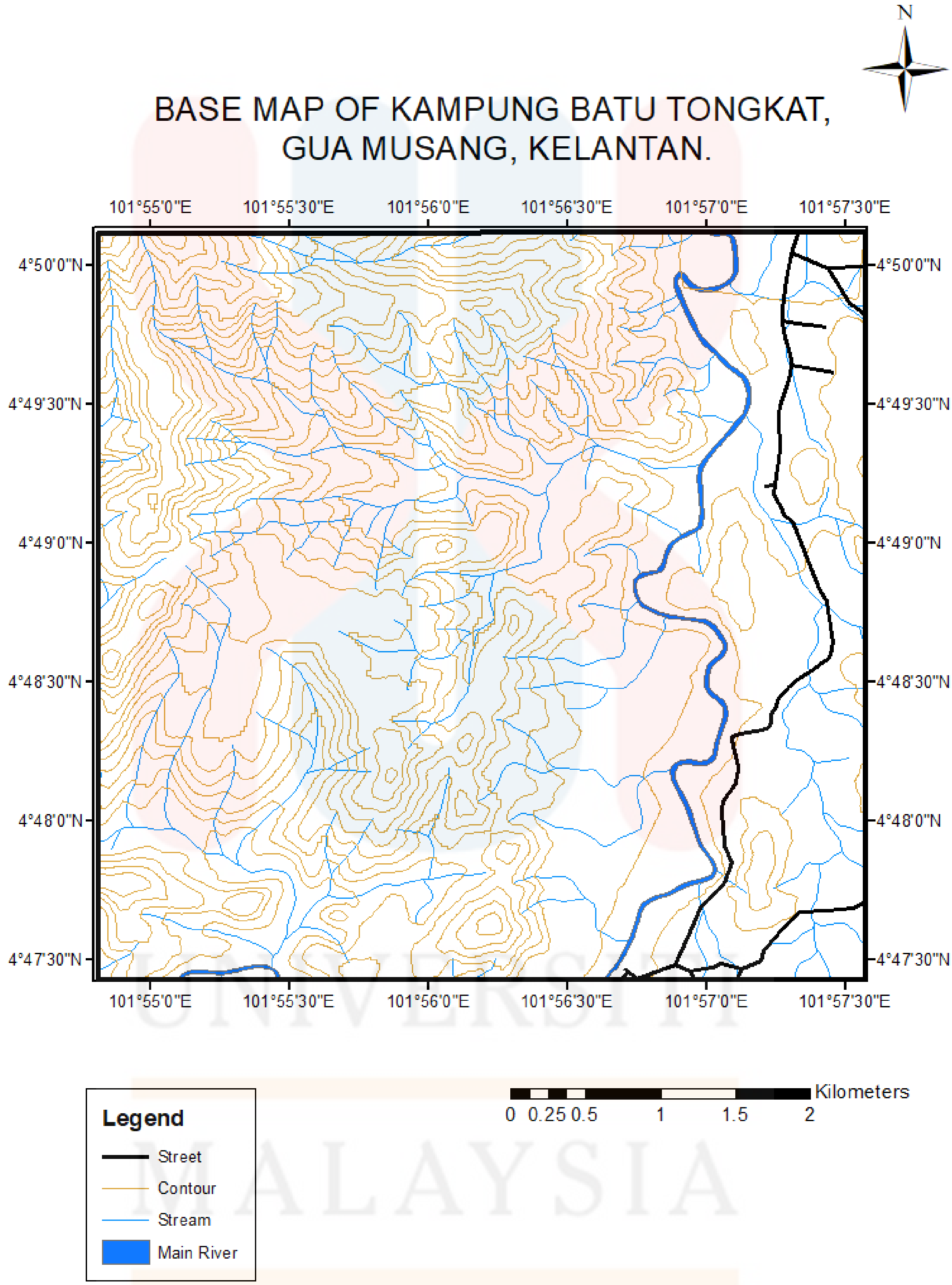

Figure 1.2: Base map of study area at Kampung Batu Tongkat, Gua Musang.

b. Road connection/accessibility

Gua Musang is situated in the south of Kelantan, bordered by the state borders of Pahang, Terengganu and Perak. Kuala Lumpur - Gua Musang Highway connects with Gua Musang area and can be reached from Kuala Lipis – Gua Musang Route. The study area could be reached from the Jeli region via the Kuala Balah – Gua Musang road with the help of effective connectivity of the study area.

c. Demography

Kelantan has an area of 15,0999 km^2 and is situated in the north-eastern region of the Malaysian Peninsula. Kelantan is bounded by a certain ration of southern Thailand to the north, Perak to the west, Pahang to the south, and Terenggan to the south. Kelantan is made up of 10 administrative areas, including Kota Bharu, Gua Musang, Machang, Tanah Merah, Pasir Mas, Pasir Puteh, Bachok, Jeli, Kuala Krai and Tumpat. It is situated in the south of Kelantan which covered by hilly landscapes. These are isolated by the Titiwangsa Mountain.

The regional geology is bounded by shallow marine platforms which characterized with argillite-carbonate volcanic deposited (Mohamed et al., 2016). Forest, grove, rubber plantation, spacious area, mines area, mixed farm and the stream valley. Furthermore, the main streams which is Sungai Baling, Sungai Jeram, Sungai Jinka, Sungai Mek Ketik and Sungai Rempul. The population distribution in the state of Kelantan is endorsed by many factors, which are categorized according to district size, economic opportunities and territory. Both of these voters decide the population commuting to the district. Based on the, the rate of population growth in Gua Musang from 150,254 (8% from 1,853,525) in

2017 to 153,278 (7% from 1,999,432) in 2019 is shifting. This shows that rapid development offers job opportunities for residents and outsiders that have led to population growth in Gua Musang district.

Table 1.1: Kelantan's district total of population.

(Source: Jabatan Perangkaan Penduduk Negara, Negeri Kelantan, 2019)

District	**Year**		
	2017	**2018**	**2019**
Bachok	157,700	151,801	152,647
Kota Bharu	590,776	580,474	567,876
Machang	150,755	151,119	153,644
Pasir Mas	153,654	152,879	153,524
Pasir Puteh	158,988	151,903	152,678
Tanah Merah	138,235	152,021	153,628
Tumpat	148,263	152,574	154,764
Gua Musang	150,254	151,327	153,278
Kuala Krai	151,700	150,361	158,643
Jeli	53,200	50,345	54,345
Total	1,853,525	1,990,230	1,999,432

d. Landuse

Landuse involves the preservation and modification of natural or wasteland environments in urban areas such as towns and semi-natural landscapes of arable lands, pastures and maintained forests. It was also defined as the overall arrangements, activities and inputs with people undertaken in a specific type of land cover. Landuse activity in Gua Musang is dominated by rubber plantation, palm plantation and the pattern of land-use is rapidly changing due to economic changes in Gua Musang region. The landuse of study area is cover with the forest, grove, rubber plantation, spacious area, mines area and mixed farm.

e. Social Economic

Gua Musang region at the Kelantan state undergoing rapid growth. The positive effect of urbanization in Gua Musang district provides work opportunities for both locals and outsiders. The plantation is classified into two types in the study area which is oil palm plantation and rubber plantation. Rubber plantation is the main contributor to social economic development in the Gua Musang region. Plantations are well known in many areas and the expansion of the plantation provides work vacancies to local residents, whether they are working in the estate or in the factory.

1.3 Problem Statements

There are a few topics which relate to the study area. In the geological map in year 1987 at the area of Gua Musang is on a large scale, which the sources of geological data around study area are limited (Nazaruddin, 2017). Therefore, it is important to update the geological map to a smaller scale in order to provide new information and geological data in a specific area that will contribute significantly to the understanding of geological history. On the other hand, the earth is dynamic and there is an unexpected change in the earth process that would not be the same as before which causing the periodically change of geological data at the study area.

The village of Pulai at Gua Musang provide unique limestone karsts that have potentials as geotourism site. However, there are not able to provide a proper planning to conserve and develop this area for tourism site. Princess Hill is located at Gua Musang area where underlies at the Centre Belt of peninsular Malaysia. Although it shows a unique geomorphology at Kampung Pulai, Gua Puteri Pulai still not recognized as tourism site in Gua Musang. Referring to the previous study at the village of Pulai, the authority does not provide any information about the princess hill as geotourism site (Abdullah, 2016). Therefore, the previous study only focus on the determining crude oil in the depositional environment using biomarker analysis at the village of Pulai. It is lack of information about the Pulai Princess cave at the Kampung Pulai that have potential in speleotourism which need to upgrade as geotourism site.

1.4 Objectives

The main objectives of this research is:

i. To produce a detailed and updated geological map of Kampung Batu Tongkat area with the scale of 1:25 000.

ii. To carry out a detailed the study of speleothem features and karst geomorphology in the study area using secondary data.

iii. To identify the potential of speleotourism in study area.

1.5 Scope of study

This research is focusing on updated geological map of the study area with obtain by geological interpretation on the specific map. The map is including in geomorphology map, lithology map, landuse map, mineral map and watershed map. Moreover, this research is mainly on speleology in the tourism aspect. It is focus more on the observation at speleothem features that will attract the tourist to came the Gua Puteri Pulai. This study will be conducted an investigation of speleology tourism in order to find the evidence and proved whether the limestone karst hill has potential in speleotourism.

1.6 Significance of study

The geological interpretation at the study area was conducted to produce an updated geological map of Kampung Batu Tongkat. The area of study is located about 8 km to the Gua Musang, it is a place that have amazing scenery with the uniqueness of limestone hills. People are mostly would come to Kampung Pulai to see the beautiful traditional village which surrounded by limestone hill. The uniqueness of the Kampung

Pulai cannot simply unattended because it is gift from the god for human to protect and care the place.

The Gua Puteri Pulai at the Princess hill still not acknowledge as the tourism site in the Kelantan. Morphology of internal or external is quite different due to the production of speleothem features within the Gua Puteri Pulai that give a different classification compared to the other geomorphology units in Gua Musang. Then, there is no individual responsible to protect and preserve the place as geotourism site to maintain the place.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review defined as research body to gain more knowledge. This is accessible to provide a lot of sources such as books, journals, papers, the internet and other research tools that related to the research and important for some issue, as well as the theory of the study area. The purpose of literature review is to identify theoretical and scientific knowledge and the research paper is made for better understanding. Geology is used for the study of past and present evolution. In general, geological studies are based on desktop studies as the data are gathered from previous research, books, and papers. All the information is gathered and make the surveyed to provide a better understanding of general geology in Kelantan state especially in the study area.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is a central part of the Eurasian plate, and Sundaland is the south-eastern region of Asia (Hutchison, 1989). Geologically, there are three belts which is Western, Central and Eastern, in the Peninsular of Malaysia. According to the Hutchinson (1989), each of these belts is special in geology and tectonic history of Malaysia. Moreover, in the Peninsular Malaysia have deep sea which in the Permian to

Triassic formation. The Semantan and Semanggol Triassic Formations are studied in its sedimentology and paleontology which are known as deep-sea sediments. Malaysia is in general part of eastern Malaysia and the Sibumasu tectono-stratigraphic area (Metcalfe, 1990).

There are four types of rock that are abundance at the Kelantan state which is metasedimentary rocks or sedimentary, granitic rocks, extrusive rocks and unconsolidated (Nazaruddin, 2017). Pulai Princess cave at the Princess hill is the study area that located at Gua Musang, Kelantan. Gua Musang formation is indicate the pyroclastic or volcanic facies, carbonate and Middle Permian to Late Triassic argillite at around Gua Musang area (Yin, 1965). According to Kamal Roslan Mohamed (2016), Gua Musang area are indicate the Gua Musang group which are include Gua Musang formation, Nilam marble, Telong formation and Aring formation. These four division of Gua Musang group divides based on lithology units with the new formation.

The general geological map of Kelantan as seen in Figure 2.1. This geological map reveals the Kelantan state with lithological varieties consisting of igneous rock, metamorphic rock and well-formed sedimentary rocks in a north-south trend in the Kelantan state. Geologically, these three forms of rock are labeled as granite rock, sedimentary or metasedimentary rock, unconsolidated sediment, and extruder rock. The rocks are made up of igneous content. Location of joint and fault geological features in sedimentary rocks while distribution of granite rocks in western Main Range Granite and eastern border of Kelantan State Boundary Range Granite. (Department of Minerals and Geoscience Malaysia, 2003).

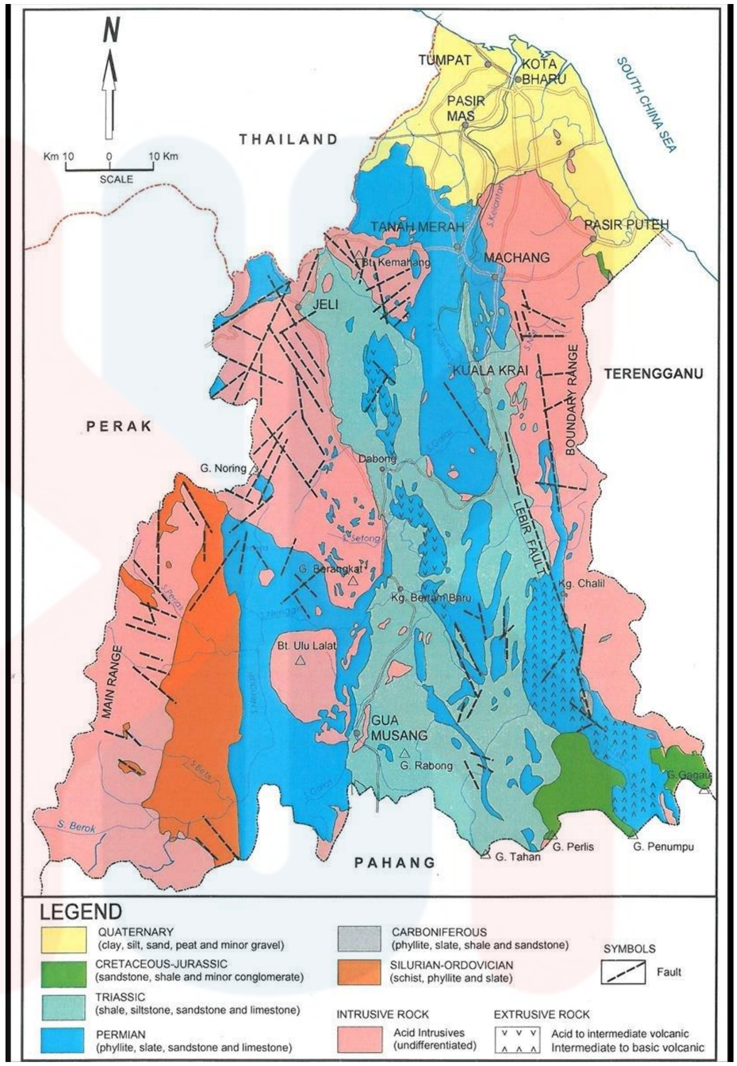

Figure 2.1: Geological map of the Kelantan state (Nazaruddin, 2017).

Hutchison (1973) also suggested the Bentong-Raub axis as the major tectonic border between the western and central belts of the Peninsular of Malaysia. Hutchison (1975) called it the ophiolite line of Bentong-Raub. The Bentong-Raub Suture Zone (Metcalfe, 2000) stretches south from Tomo through Bentong and Raub to Melaka (Tjia, 1989). It is an extension of the Nan-Uttaradit suture from Thailand. The suture area stretches south to Lancangjian, Changning-Menglian, Yunnan Province of Southwest China, and Chiangmai of Northern Thailand (Metcalfe, 2000). Palaeo - Tethys' primary sea is defined by the suture zones of Lancangjian, Changning - Menglian, Chiangmai and Bentong-Raub.

The Bentong-Raub suture region of the Peninsula of Malaysia lies between the Sibumasu Terrane and the East Malaya Terrane (Indochina). Sibumasu's terrane was connected to the map of Cimmeria and the terrane of East Malaya linked to the map of Indochina and the map of South China. The shore, called Paleo-Tethys, divided the parts of Sibumasu and East Malaya. The opening of the Palaeo-Tethys was formed when the plates of North and South China, Indochina and Tarim split from Gondwanaland during the Devonian period. The Palaeo-Tethys decreased when the Sibumasu Terrane collided with the East Malaya Terrane or was known as Indochina during the Triassic period.

2.3 Stratigraphy

According to Geologic map of the Kelantan state (Nazaruddin, 2017) in figure 2.1, Kelantan state are covered with almost metasedimentary and sediment rocks from Ordovician to Cretaceous age. These metasedimentary and sediment rocks can be divide into five categories which are Silurian-Ordovician sedimentary rock, Carboniferous rocks (Gua Musang formation), Permian sedimentary rocks, Triassic sedimentary rocks (Gunung Rabong formation) and Cretaceous-Jurassic sedimentary rocks (Gagau formation) (Mohamed et al., 2016). Based on these arrangements of rocks, the oldest one which is the Silurian-Ordovician sedimentary rock that are metamorphosed rocks outcropping as the main range north trending belt bordering foothills an d extending eastwards up to Sungai Nenggiri. This rock sequence whether in yellow or reddish soil.

Next, the Carboniferous sedimentary rocks that can be found in the southeastern corner of the state which are build up with the calcareous facies and pyroclastic. The Permian sedimentary rocks are usually occurring extensively on the eastern side of the state. These sequences of rocks are included in the Gua Musang formation that made up with pyroclastic rocks, Taku Schist and argillaceous with calcareous bedding. Furthermore, Triassic are confined mainly at the central and south Kelantan state which made up of limestone that have pure carbonate composed of calcite with varying amounts of dolomite. Lastly, the Cretaceous - Jurassic rocks, it is the youngest rock in Gagau Group. These rock sequence are mainly made up with sandstone, minor conglomerates, mudstone, siltstone and few bed of volcanic. The previous study said that the Pulai Village are surrounding with the limestone (Abdullah, 2016).

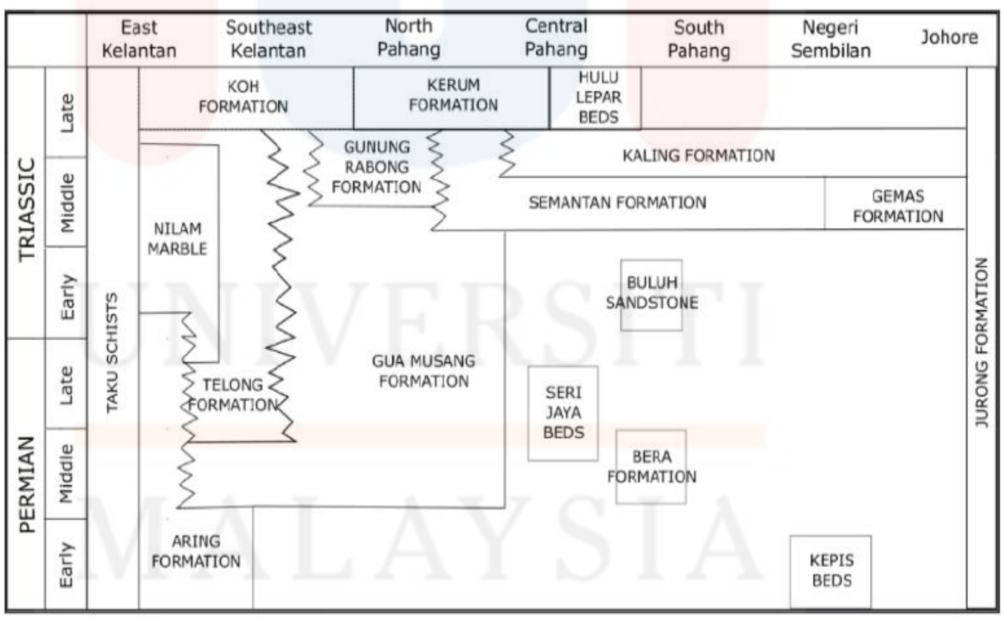

Figure 2.2: Permo -Triassic Stratigraphic correlation chart of Central Belt Peninsular Malaysia (Source: Metcalfe, 1990)

Likewise, the sediments of the Nilam Marble and Telong Formation were parallel to the rocks of the Gua Musang Formation in the east. Foo (1970) proposed that the Telong

Formation be the same as that of Gua Musang Formation as the deposition state and the age of Nilam Marble are close to that of Gua Musang Formation. Mohamed (2016) suggested that the Nilam Marble and Telong Formation should be far south of the Kuala Tembeling area.

Gua Musang Formation is a transitional overlay of Kuala Lipis area Semantan Formation. Kota Gelanggi – Gunung Senyum limestone in the range age from Middle Triassic to Late Triassic and taken from Kuala Tembeling to Triassic Limestone. It is described as Triassic progression in the Gua Musang Formation. The Gua Musang Group is also recognized as the newly formed stratigraphic unit for the Permo - Triassic Period of the Northern Central Belt in Peninsular Malaysia is Gua Musang Formation, Telong Formation, Aring Formation, and Nilam Marble Formation (Mohamed, 2016).

The strong relationship between the shape of Gua Musang, the formation of Telong, the formation of Aring and the marble of Nilam represents the alterations between these formations in the lateral facies. For example, similar lithology to the formation of Gua Musang in Felda Aring is called Aring Formation, while those in Sungai Telong are called Telong Formation (Aw, 1990).

2.4 Structural geology

The state of Kelantan is situated in the northeastern corner of the Malaysian peninsula. The principal compressional force affects Peninsular Malaysia's land mass. The area and locally are the results of this force are made up of fold and fault. Local geological systems formed in sedimentary rocks, while fault and joints occur in granite rocks. In the past, the dominant structure at N-S to NW-SE was developed through the Department of Minerals and Geosciences of Malaysia (2003). The orogenic or orogenic belt develops when a continental plate crumbles and pushed upwards to create one or more mountain ranges, then a combined sequence of geological processes is produced called as orogenesis. Orogeny is the principal process by which mountains are formed on continents.

According the Hamblin (1994), the joints formed by pressure as the rock is uplifted, folded or broken through tectonic movement. A joint is a geological fracture which divides rock into two parts which move away from one another. A joint does not require displacement of the shear and forms when tensile stress crosses the threshold. Tija, (1989) said Peninsular Malaysia 's dominant strike and fold axis occurs mostly in the Gemas and Semantan Formation that dominated Malaysia Peninsula.

However, as the state of Kelantan is located on the central belt of the Peninsula of Malaysia, large structural zones have arisen, such as the Bentong - Raub Suture Zone. The Bentong-Raub Suture Zone is well-exposed along Gua Musang – Cameron Highland Road, Karak Highway and Bentong – Raub Road. Suture is an area of deformed rocks consisting of schist, phyllite, metal sedimentary rocks, sandstone, cherts, olistostrome and melange (Tjia & Almashoor, 1996), approximately 13 km long. Metcalfe (2000) estimated that the suture will be about 20 km long. A belt of melange and olistotrome, composed of blocks or clasts of cherts, sandstone, calcareous, conglomerate, interlaced sandstone, mudstone and mudstone, set in a mudstone sheared matrix, renders the Bentong-Raub Suture Zone evident.

2.5 Historical geology

The geological history of Kelantan's predominantly Gua Musang formation has been traced by Yin (1984) in South Kelantan from middle Permian to Upper Triassic (Mohamed, 1995). The formation is estimated to be 650 m deep, consists of crystalline calcareous, interbedded with thin shale beds, tuff, chert nodules, subordinate sandstones and volcanic. The light grey calcite is hard, brittle, non-porous, and splintery. Small amounts of carbonaceous, argillaceous and pyroclastic impurities are present in the grey to black varieties of the recrystallized limestone. It can always find traces of the bedding and cross-lamination.

According to Department of Minerals and Geoscience Malaysia (2003), the Main Range Granite had been from the late Triassic period between 200 until 230 million years ago. Geologically, the Kelantan rock units were divided into four types, splitting them into unconsolidated sediments, extrusive rocks which are volcanic, granite, and sedimentary rocks or meta-sedimentary rocks. The two main bodies, the Main Range and the Boundary Range classify the granite rock at Kelantan.

2.6 Karst geomorphology and speleothems

Karst is the Indo-European word *kar*, the German form with the meaning of rock. The Italian word is *Carso*, and a *kras* from Slovenia. *Kras orkrš* in Slovenia means 'bare stony land' and is also a rugged area in the country's west. In geomorphology, karst is a landscape in which the dissolving action of water changes porous rocks above and below ground and which bears distinctive features of relief and drainage (Richard John Huggett, 2011). Karst geomorphology usually refers to calcareous terrain that is characteristically absent of runoff water, has a patchy and thin soil layer, including several enclosed depressions and supports a network of subterranean features including grottoes and caves.

Both rocks are to some degree soluble in water and karst is not limited to the most soluble forms of rock. Karst may form under favorable conditions in evaporates such as gypsum and halite, in silicates such as sandstone and quartzite, and some basalt and granite. Karst characteristics can also be created by other means-weathering, hydraulic activity, tectonic motions, meltwater, and molten rock (lava) evacuation. This characteristic is called pseudokarst as solution in their development is not the dominant process.

Table 2.1: Karst and pseudokarst. (Source: Richard John Huggett, 2011)

Formed		**Formative processes**
Karst	Limestone, dolomite, and other carbonate rocks.	Bicarbonate solution
	Evaporites (gypsum, halite, anhydrite)	Dissolution
	Silicate rocks	Silicate solution
Pseudokarst	Basalts	Evacuation of molten rock
	Ice	Evacuation of meltwater
	Soil, especially duplex profiles	Dissolution and granular disintegration
	Most rocks. Especially bedded and foliated ones	Hydralic plucking, some excudation
	Most rocks	Tectonic movements
	Sandstones	Granular disintegration and wind transport
	Many rocks, especially with granular lithologies	Granular disintegration aided by seepage moisture

Princess hill is a features of karst geomorphology where formed from the dissolution in the soluble rock such as dolomite, gypsum and limestone (Abdullah, 2016). This happen due to the underground drainage system, caves and sinkholes. Karst features that produce from the past environment can be distinguished in two types of deposit that grow from the water dripping which is stalagmites (dropping) building up from the cave floor and stalactite (dripping) growing down from the cave building up from the cave floor (Fairchild & Baker, 2012). The pertinent are more continuous deposits that called as flowstone that accumulate beneath thin sheets of water on floors, walls and caves. Stalagmites are commonly appearing like an inverted stalactite that rising from the ground of cave (Fairchild & Baker, 2012). It can be found at the growth that stop for an extended period and continue the crystal grow.

2.7 Speleotourism

Caves are sometimes referred to as speleological structures and in the field of tourism which referred as the speleotourism or cave tourism (Kneţević & Grbac-ÿiković, 2011). Cave tourism is a comparatively recent name given to tourism, which involves speleological systems. Cave tourism can be found in the tourism offerings of countries where carbonate surface is typical as a form of tourism of special interest. Due to the karst characteristics, this form of tourism has been included in the National Caves Association, including labyrinths, arrow tunnels, high humidity and lack of natural light.

A part of speleotourism, the geotourism context can also refer to caves (Cardozo Moreira & Neto de Carvalho, 2013). Geotourism is a sustainable type of tourism, with a primary emphasis on observing the geological characteristics of the earth and producing a geotourism product. Geotourism also preserves the environment, creates communities and fosters geological heritage (Dowling, 2013). Speleotourism economic outlook has great potential. Profits derived directly and indirectly from the tourist exploitation of caves can take on significant local significance (Pulido-Bosch, 1997). Nonetheless, the lack of visit control, an appropriate maintenance infrastructure or management overall can lead to a serious threat to the underground ecosystem and the growth of speleotourism (Waitomocaves, 2011). The study of cave conservation concerning tourism is not simple, as many factors and variables have to be taken into account simultaneously.

It is types of tourism with mainly involves caves exploration with specialized guide or guided in caves through overcome of various obstacles and enable to categorized into many scopes. Some of it more towards recreational tourism which specially in mountain exploration tourism (Moktar, 2015). From the previous study, the tourism become alternative to make people involve visiting the caves with specialized guide besides serving guided excursion in caves though overcome of various obstacles (Olson, 2017).

Gua Puteri Pulai in the princess hill has a good potential as speleotourism site in Kelantan. The caves exploration known as the earliest geotourism attractions and it will become the most appreciated tourism site in the world. The heritage of geotourism element including decoration of varied speleothems with the outstanding caves that give the crucial indicators for development of speleotourism. The cave is decorated with the crystalline deposits such as flowstone, stalagmites, stalactites and column (Antić & Tomić , 2018).

CHAPTER 3

MATERIAL AND METHODS

3.1 Introduction

There are some materials and methods used to complete the data collection process and essential information for geological interpretation and the potential for speleotourism potential at the Gua Puteri Pulai which will support in this research. When the necessary materials and techniques are used, this should make the work smoother.

3.2 Materials

The geological interpretation will have carried out the study area to identify the location of geological characteristics and its recent geological environment. The interpretation is to make analysis on geomorphology map, lithology map, landuse map, drainage pattern map and lineament map to gather the geological information at the study area.

Table 3.1: The description of equipment.

Equipment	Functions
Base map	The data and information of study area to make roughly analysis before to do geological interpretation.
Aerial image	The software that are used to get the aerial image is Google Earth Pro can provide the rough image of the study area such as road connection for accessibility, topography, vegetation and hydrology.
Arcgis 10.3 software	A wide GIS Desktop Technology Suite that helps to create map, spatial analysis and data management.
CoralDRAW 2020 software	To visualize the rough image of cave exterior.

3.3 Methodology

3.3.1 Preliminary studies

It conducted to collect some references from the previous study using qualitative methods with make research on previously published literature. The sources of references are obtaining on the online platform through the internet such as websites, scientific journal or articles and e-books. The other qualitative methods are in the written documents that can obtain at the library in term of the printed scientific journal, articles or books. A description of the research topic can be provided by doing the preliminary study. In general, preliminary study generally focuses on studies of geological heritage, general geology, geomorphology, sedimentology, speleology, and stratigraphy of the Gua Musang region.

The preliminary study of the study area is needed to get the roughly idea about this research topic before make the geological interpretation. All of the material from previous published literatures is gathered to support the geological information about study area. The information is obtained by reading the papers, studies, documents, books and thesis and the review of literature can help to learn more about the geological interpretation which can be used as a guide for performing the research.

3.3.2 Geological interpretation

The Geological Interpretation Method based on the visual interpretation of remote sensing data on morpho-structural picture aspects combined with field data in the GIS framework for the detection of geological features in satellite imagery (Jamal et al., 2013). The analysis is primarily focused on the visual perception of satellite remote sensing data that will be stored in a database format using a GIS system. A dataset containing detailed information on the surface of the earth, such as ground data combined with secondary data on lithology, morphology, observational position, hydrology and other key data used to construct geological maps consisting of local attributes is needed.

The Earth's surface consists of many different lithological units which are reflected in morphological complexity owing to the exogenous and endogenous geological processes involved. Morphological characteristics and the resultant landforms may be studied by field campaigns as well as remote sensed data. The aim of understanding geological features from remote sensed data is to collect geological knowledge for additional applications. The accuracy of the image interpretation results depends on a variety of variables, such as the interpreter, the image data used and the suggestions provided. Specialist knowledge includes experience of image interpreting which distinguishes the abilities of an image interpreter (Jamal et al., 2013).

A preliminary geological map was combined to analyze and develop overlays of various datasets including field data in the form of vector data from previous researchers. The method of the geological interpretation including the identification morphological characteristics in the study area, define the genetics of the landforms, classified the geomorphological groups and to distinguish the lithological units or rock units. The optical satellite imagery will help in access the units of rock in terms of stratigraphy with combine the radar imagery with high resolution to identify rock types and landforms. Data collection for geological interpretation is gather from the USGS earth explorer website such as digital elevation models (DEMs) and shuttle radar topography mission (STRM).

3.3.3 Data processing

Geological interpretation based on satellite imagery was conducted using computer-aided visual interpretation tools. Relevant computer software for digital image analysis, modeling, three-dimensional design, hydroregulation and other visual enhancement capabilities has been used. The interpretation was done by overlaying vector and raster data with information layers to retrieve new detailed geological information. The computer aided software to produce the specific map for geological interpretation is ArcGIS 10.3 software and Google earth software for speleology interpretation.

3.3.4 Data analysis

The map that requires for the geological interpretation including geomorphology map with describe morphological characteristics in a particular area, define the genetics of the landform and group into geomorphological classes. It is a modifier that may be used to better describe the slope position or position on a landform.

Table 3.2: Geomorphology classification. (Source: Zuidam, 1985)

Relief/Landforms	Elevation (m)
Lowland	<50
Lowland interior	50-100
Low hills	100-200
Hills	200-500
High hills	500-1500
Mountains	1500-3000
High mountains	>3000

Then, the lithology map which interpret based on the elevation or slope can differentiating and delineating lithological units or units of rock. Optical satellite images may help assess shapes or units of rock comparatively younger and older. Combining radar images with high resolution can help identify sediments, intrusions, alluvial deposits, metamorphic rocks, and volcanic deposits. The lithology can be assuming by observe its landform such as igneous rock at mountain and the sediment or metamorphic is mostly at the hills or lowland (Zinck, 2015).

Next, land use map is specifically focuses on the reasons for which land is occupied or managed for human purposes. It includes the management and alteration of the natural ecosystem or wilderness to the urban environment, such as cities and semi-natural ecosystems. Furthermore, drainage pattern map is shows the nature of drainage system in the study area. This types of map are interpreting the types of drainage pattern which is dendritic, trellis, radial, sub-dendritic, parallel, sub-parallel, angular, rectangular and pinnate. Each pattern has their own geological significant such as the result of the geological time period, structure of rocks, topography and slope.

Lineament map is draw straight line on the large landscape lines which caused by joints and faults, exposing the structure of the rock basement, main river, tributaries and stream. There are two types of lineament which is positive lineament and negative lineament. Lineament positive usually the strike ridges and dykes, typically show the exposure of resistant rock units whereas negative lineaments on the straight valleys, usually indicate the exposure of non-resistant rock units or rock failure zones.

The other data analysis for this research is the interpretation on the karst geomorphology and speleology with the method of karst geomorphology description and identify speleothems in the caves. This is because the condition for the speleotourism is basically referring to those elements. There are two types observation of karst geomorphology which is interior cave and exterior cave.

The picture interpretation for interior cave are used for identification speleothems features from the photo that are taken by the researcher who had visited the cave before. The hydrology data of Kampung Pulai will give more information about how the cave are form because hydrology in the cave are created by the reaction of water with the bedrock. The rough image of cave will provide in 2D image based on the data and observation previous study at the Gua Puteri Pulai. The observation at the exterior cave will look in lithology data of Gua Musang that will obtain what types of bedrock that form the cave and geomorphology data of Gua Musang to shows how the hills are formed.

Lastly, after collected the geological data and karst landform analysis, to prove the geotourism potential of the study area, the evaluation of speleotourism potential based on the SWOT analysis in strength, weakness, opportunities and threats element towards the local community at the Kampung Pulai. The other variation of SWOT analysis is the TOWS analysis that will obtain others factor with combine the SWOT element (Božac, 2008). TOWS analysis will overcome the SWOT analysis with improve the process of identification in relationship between SWOT analysis element. It will increase the information to prove speleotourism site will give benefit to the local community.

Basically, SWOT analysis will discuss in two condition which is internal and external. Strength and weakness are in the internal condition where the positive and negative things influence the development of the geotourism site at the Gua Puteri Pulai and the things that can control and which can change over environment. Then, the external condition which contributes to the opportunities and threat element that refer to the situation outside the favorable and unfavorable environment affected the Gua Puteri Pulai and the things that influence speleotorism site with the local community and tourist.

Table 3.3: SWOT analysis template.

		Description
Internal condition	Strengths (S)	• . . . • . . .
	Weaknesses (W)	• . . . • . . .
External condition	Opportunities (O)	• . . . • . . .
	Threats (T)	• . . . • . . .

SWOT analysis allows for methods to be built within the TOWS analysis. Strategies within the TOWS analysis are focused on an acceptable combination of factors reflecting strengths, weakness, opportunities and threats. TOWS analysis have four elements which is Maxi – maxi (SO) that represent on strengths and chances, Maxi – mini (ST) to state the strengths in relation to threats, Mini – maxi (WO) to shows the weakness in relation to opportunities and Mini-mini (WT) that represent the weakness in comparison to threats (Antić & Tomić, 2018).

Table 3.4: TOWS analysis template.

		Internal condition	
		Strengths (S)	Weaknesses (W)
External condition	Opportunities (O)	Strengths/ Opportunities (SO)	Weaknesses/ Opportunities (WO)
	Threats (T)	Strengths/ Threats (ST)	Weaknesses/Threats (WT)

For the TOWS analysis in effectively to describes the internal and external aspects of the environment, determines the information used in the study and identifies the main relationship between the environmental variables. It was only then that sustainable tactics could be introduced (Božac, 2008). The Strengths/Opportunities (SO) is the maxi-maxi strategies that focuses around how can exploit the strengths in order to respond to the potential opportunities at the speleotourism site. Next, the Weaknesses/Opportunities (WO) is the mini-maxi strategy that able to take advantage of any possibilities and to resolve weaknesses. Furthermore, Strengths/Threats (ST) states maxi – mini strategy is the management that essentially intend to use in all resources at speleotorism site to minimize or eliminate threats. Last but not least, Weaknesses/Threats (WT) is the mini-mini strategy shows this technique is highly defensive and the goal is to reduce the weakness and avoid threats.

3.3.5 Research flow chart

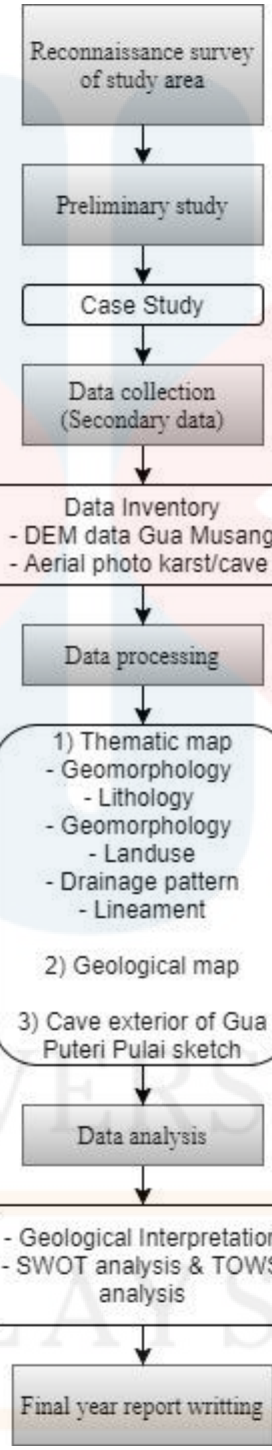

Figure 3.1: Flow chart of method for this research.

CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

This chapter will discuss the general geology of the study area, divided into geomorphology, lithostratigraphy, structural geology and historical geology. Kampung Batu Tongkat is located at Gua Musang district or called as 'Jajahan Gua Musang' in the Kelantan southern state. The district of Gua Musang is near to the borders of Pahang state in the south, Terengganu in the east, Perak state in the west and the Kelantan district of Jeli and Kuala Krai in the north. Gua Musang is the largest district in the Kelantan state that has a town. Limestone hills and caves are surrounding Gua Musang district which has become popular with cavers and rock climbers. A Buddhist temple in Kampung Pulai which is reportedly 400 years old is another fascinating place in Gua Musang.

4.1.1 Accessibility

The study area can be accessed using the road Jalan Jelawang – Gua Musang that takes in about one hour and 46 minutes from the UMK Jeli campus. Gua Musang district has its highway which is Gua Musang – Lojing highway that through along the East area in the study area. Furthermore, accessibility is reachable via the main road, highway road, signboard and paved roads (figure 4.1) that help access the study area.

Figure 4.1: Pave road with the signboard direction. (Source: Google earth, 2014)

4.1.2 Settlement

Kampung Batu Tongkat is surrounding with the rubber plantation and the oil palm plantation which mostly near to the main river in the study area. Moreover, the residential areas are nearby along the street to go to the plantation area, some residents in that area may be workers at the rubber plantation and oil palm plantation.

4.1.3 Forestry

The forestry in the study area is the majority that covered in about 45% and the other area surrounding with the oil palm plantation (figure 4.2) and rubber plantation (figure 4.3) shows in the land use map of the study area (figure 4.4). The nutrient that consists of mineral or element is essential in determining the position is appropriate for that type of plant-based on the growth of the plantation. The area of rubber plantation is at the flat surface which near to the water resources which the main river. In addition to this, the geomorphology that can be seen at the oil palm plantation is a flat surface and low hill which also near to the main river.

Figure 4.2: Oil palm plantation at the study area. (Source: Google earth, 2014)

Figure 4.3: Rubber plantation at the study area. (Google earth, 2014)

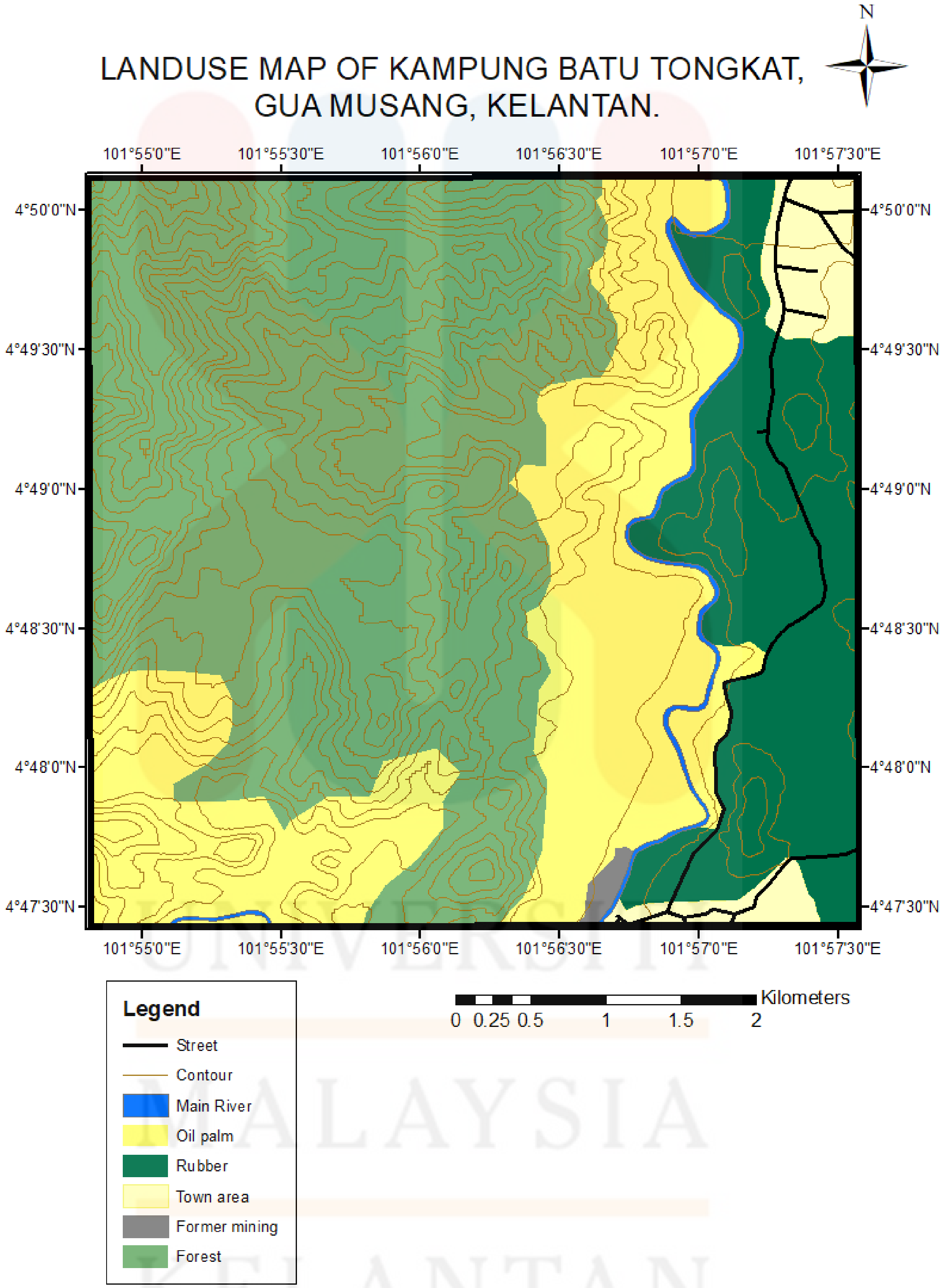

Figure 4.4: Land use map of the study area.

4.2 Geomorphology

Geomorphology is about the study of the shape of the earth's surface and the processes that have occurred on the earth's formation until now. It is also involving the study of earth processes landscapes such as water, wind, ice which can affect the landscape. Landform is any topographical feature composed of differential rock forming and the deposition of the resultant debris under the influence of exogenetic and endogenic geomorphic forces. The influences working on the terrestrial atmosphere, the lithosphere, the cryosphere, and the interface of the hydrosphere. The mechanisms that produce these forces are the main agents of debris erosion, transport and deposition. These involve fluvial, aeolian, glacial, groundwater and marine processes as well as mass movement processes.

4.2.1 Geomorphologic classification

There are three elements in the geomorphologic classification which is morphology, morphometric and morphogenetic.

i. Morphology

Any physical aspect of the surface of the Earth that has a distinctive, recognizable shape and is formed by natural causes. The Geomorphic Classification Landform component is directly related in a hierarchical way to the Geomorphic Process component mentioned above.

ii. Morphometric

Prediction and statistical study of the structure of the earth's surface and the form of the earth and the proportions of the earth's surface. In the same way, it is to provide the quantification required to ensure consistent implementation for mapping, correlation, and interpretation purposes which most often applied to a geomorphic map unit.

iii. Morphogenetic

A part of the classification that allows more than one geomorphic form at any given position on the ground that known as overprinting to be recognized and registered. Moreover, overprinting happens due to the impact of climatic shifts and tectonics, two or more separate geomorphic processes have worked on a region at different periods of time. The determination of each landform's geomorphic generation will define the genesis of each of the landforms, the relationship between the landforms, and the status of the mechanism that created the landforms or continues to form them.

The geomorphology units that can be identify from the interpretation based on the all element in the geomorphologic classification at the study area (figure 4.5) which is flat surface, sedimentary valley, metamorphic hill and steep metamorphic hill. The table shown below (table 4.1) the geomorphology characteristic at the study area.

Table 4.1: Geomorphology characteristic of study area (Kampung Batu Tongkat).

Geomorphology units	Legend	Morphology			Morphometric			Morphogenetic		
		Landform	Drainage pattern	Valley shape	Elevation (m)	Slope (%)	Contour density	Lithology	Process	
									Endogenous	Exogenous
Sedimentary valley		Lowland	Parallel, dendritic, Rectangular	U	0 - 200	0 - 7	Huge gap	Limestone, tuff	Volcanism	Depositional
Sedimentary valley		Lowland inland	Dendritic, Parallel	U	200 - 300	0 - 15	Huge gap	Limestone, phyllite, shale, slate	Metamorphism	Depositional
Metamorphic hill		Low hill	Dendritic	U	300 - 400	7 - 30	Huge gap	Phyllite, shale, slate	Metamorphism	Depositional
Steep metamorphic hill		Hill	Dendritic	V	400 - 500	15 - 30	Close to each other	Phyllite, shale, slate	Metamorphism	Erosional
Steep metamorphic hill		High hill	Dendritic	V	> 500	15 - 70	Close to each other	Phyllite, shale, slate	Metamorphism	Erosional

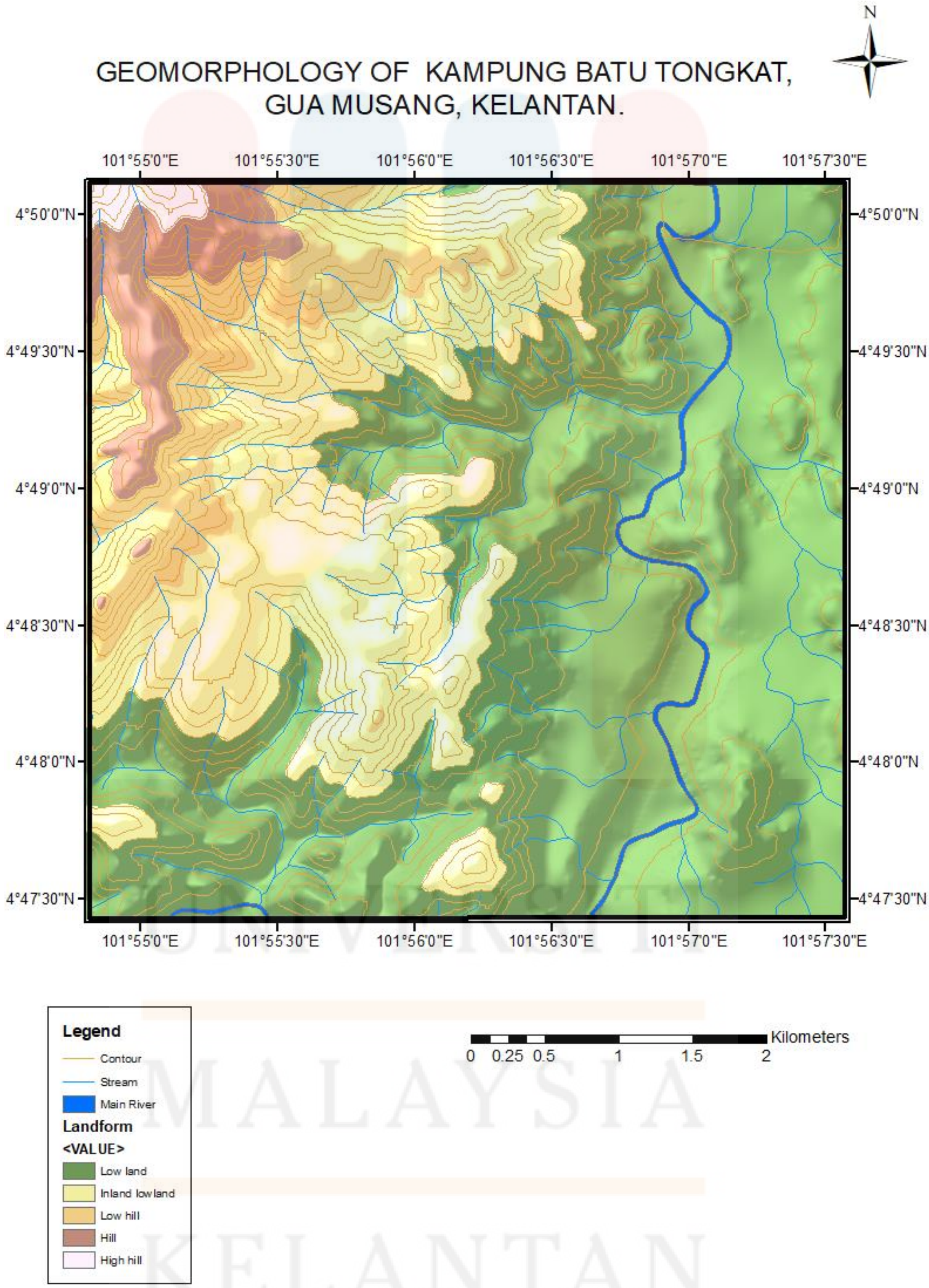

Figure 4.5: Geomorphology map of study area.

4.2.2 Drainage pattern

Drainage pattern is the pattern that demonstrates the flow of water with the presence of a topographic area that receives runoff from a stream by flow and groundwater flow. Runoff is happening when there is no further water from precipitation sources can be absorbed by the soil, it flows across the land until it comes into contact with a source of drainage that will cause the land to be eroded. In additional, the flow of the stream starts when water from rainfall and groundwater is applied to the surface. The related channels which is as called a drainage network. Over the time, the continuous erosion of the stream would cause the drainage to change the shape of valley.

The map of topography (figure 4.6) is shows the study area have three types of drainage pattern which is dendritic, parallel and rectangular. These three pattern of drainage have its own specific geological significant.

i. Dendritic

The most common type and the shape of the stream looks like tree roots' branching pattern. This dendritic pattern is occurred in regions underlain by homogeneous material. There is a similar resistance to weathering in subsurface geology thus no apparent influence over the course the tributaries take. Tributaries are form at an acute angle of less than 90 degrees from the main river or joining other stream and develop where the stream channel influence by the slope of the terrain. The geological significant for this pattern is the rocks types must be impervious and non-porous.

ii. Parallel

It is a form where the surface has a steep slope with some relief. It also forms in valleys which, parallel to each other, are elongated in regions such as the outcropping of resistant rock bands. The tributaries tend to stretch out parallel to the slope of the surface. The stream that has this pattern may indicate the presence of a major fault that cuts through a steeply folded bedrock area.

iii. Rectangular

It is developed on rocks which have a uniform resistance to erosion, but which have two ways of joining at an estimated right angle. Streams accompany the river where the surface is weak in resistance and concentrated in places where the weakest rock is exposed. Surface displacement has arisen due to faulting off the direction of the stream. As a result, the tributary streams make abrupt turns and proceed from the other stream at high angles. This types of pattern are found in the area where the faulting has occurred.

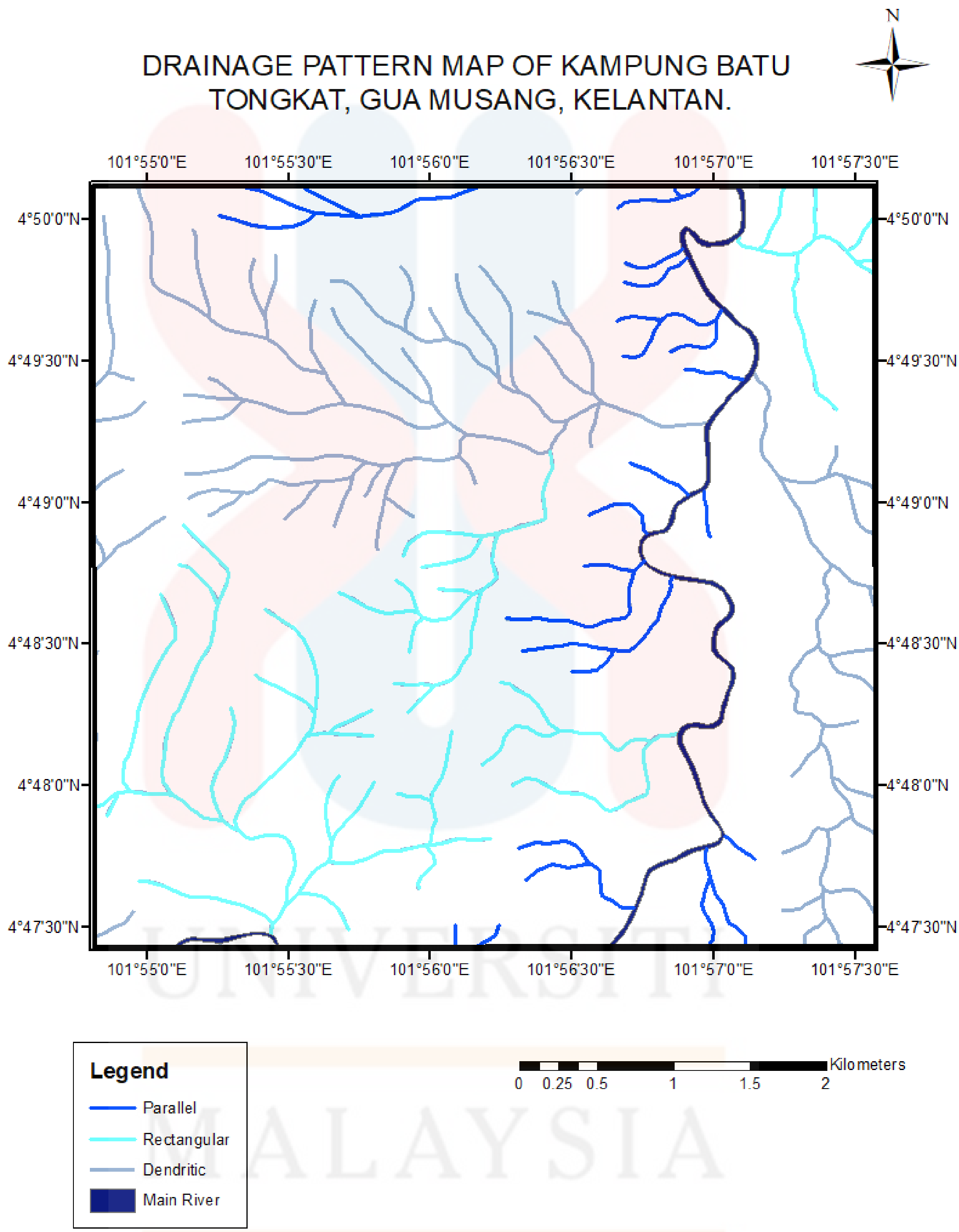

Figure 4.6: Drainage pattern of study area.

4.3 Lithostratigraphy

The definition of lithostratigraphy is the stratigraphic factor that addresses the description and nomenclature of the Earth's rocks based on their lithology the organization, on the basis of their lithological properties including the stratigraphic relations of rock bodies into units. The distribution of the rock types in the study area has been recognized by the geological interpretation and reference from the JMG geological map of Malaysia**.**

The geological map of the study area is shown in figure below (figure 4.7). From the analysis and interpretation, in the study are covered with the phyllite, shale and slate unit, limestone unit, tuff unit and alluvium unit. Geological map shows the lithology of rocks, structural geology, cross-section and column of stratigraphy that helps to understand the geology of the study area. Stratigraphy column (table 4.2) which related with the geological map of study area are refers to the Gua Musang group that were studied by previous researchers.

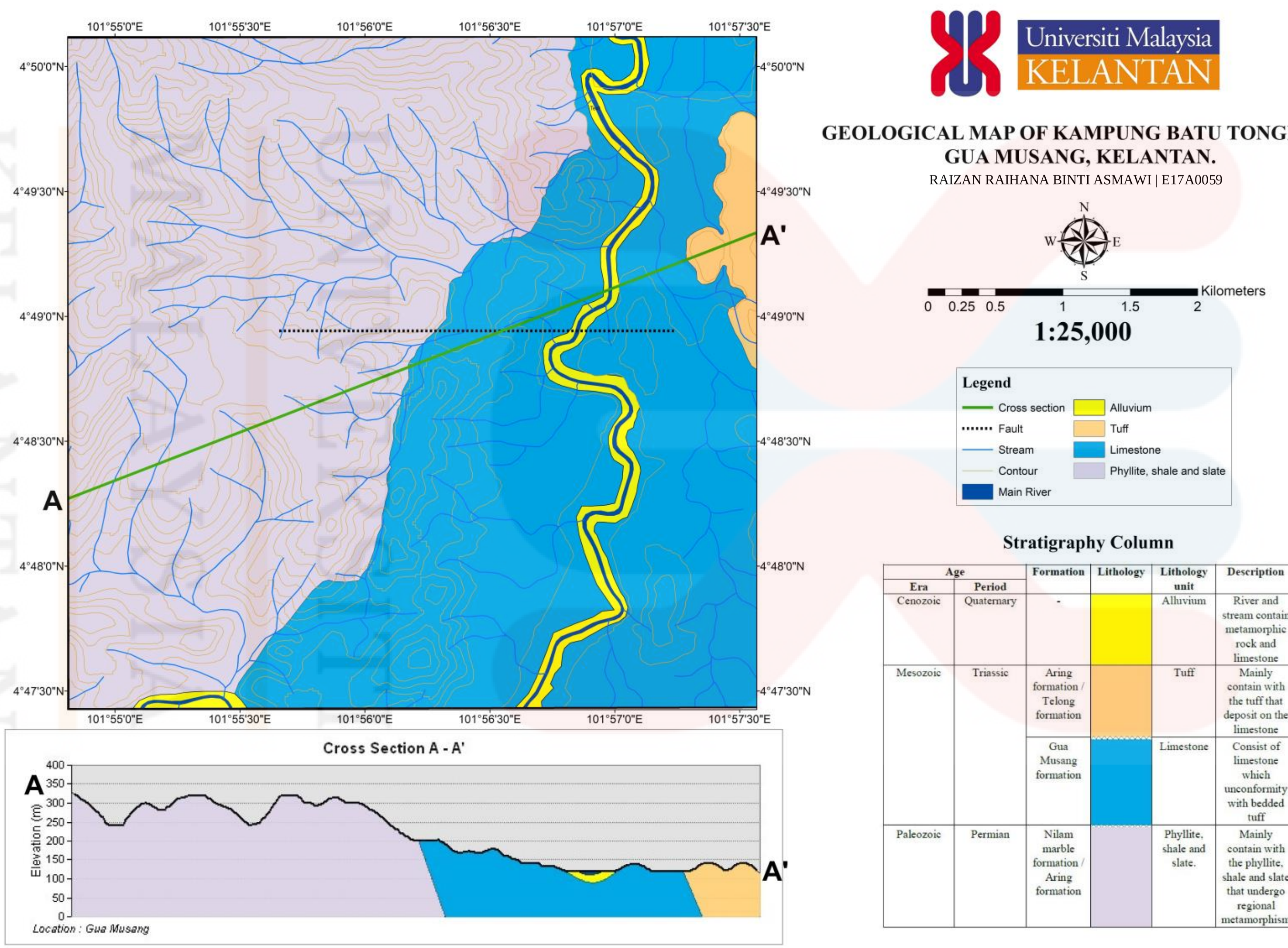

Figure 4.7: Geological map of study area.

Table 4.2: Stratigraphy column of study area.

Age		Formation	Lithology	Lithology unit	Description
Era	**Period**				
Cenozoic	Quaternary	-		Alluvium	River and stream contain metamorphic rock and limestone
Mesozoic	Triassic	Aring formation / Telong formation		Tuff	Mainly contain with the tuff that deposit on the limestone
		Gua Musang formation		Limestone	Consist of limestone which unconformity with bedded tuff
Paleozoic	Permian	Nilam marble formation / Aring formation		Phyllite, shale and slate.	Mainly contain with the phyllite, shale and slate that undergo regional metamorphism

4.3.1 Stratigraphic position

The stratigraphy column (table 4.2) shows all the lithology of study area which show rock sequence from oldest to youngest are involving in the Gua Musang Group. In general, Gua Musang group have four formations which is Gua Musang formation (argillaceous and calcareous rocks interbedded with volcanic and minor presence of arenaceous rocks), Telong formation (sequence of presominantly argillite associated with tuff and the turbidtes occurred), Nilam Marble formation (Tuff interbedded with calcitic marble) and Aring formation (argillo-tuffaceous limestone, basal dolomite marble, subordinate lavas, pyritiferous, celcareous argillite and tuff). The depositional environment for Gua Musang formation and Telong formation have similarity which occurred at the shallow marine while Nilam marble formation are occurred at the open marine. Furthermore, Aring formation are involve neritic with volcanic environment (Mohamed, 2016).

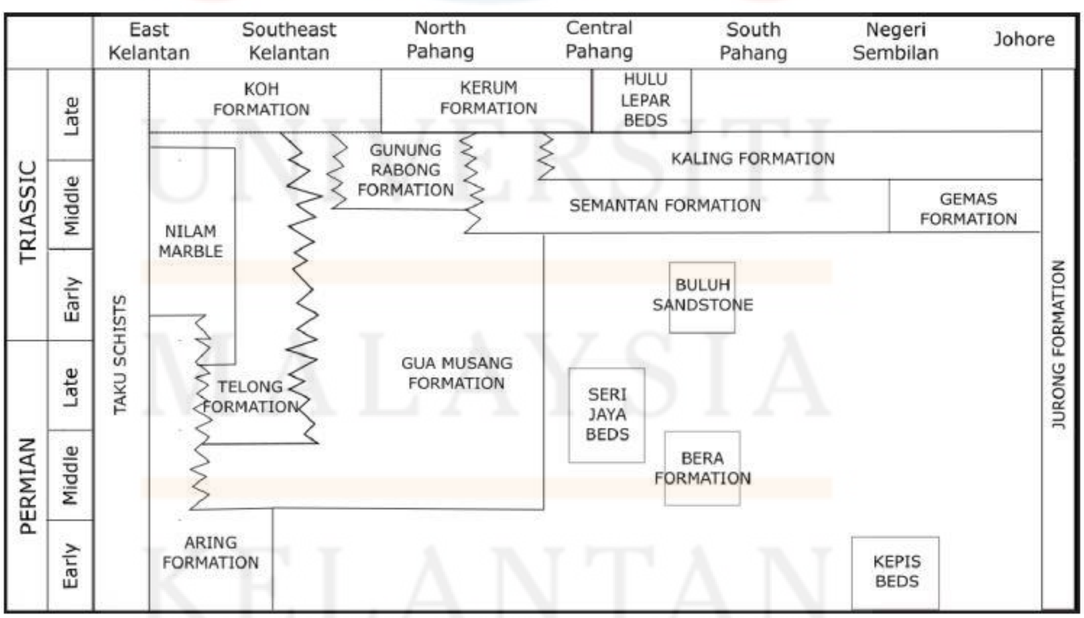

Figure 4.8: Stratigraphic correlation chart of Central Belt Peninsular Malaysia. (Source: Metcalfe and Hussin, 1990)

Based on a newly proposed stratigraphic unit of Gua Musang Group, Yin (1984) mapped the Gua Musang formation in South Kelantan-North Pahang to define Middle Permian to Late Triassic argillite, carbonate and volcanic facies in Gua Musang. Gua Musang Formation was taken from the original name known as Gua Musang at the South Kelantan according to Lee (2004) and the age for this formation is Middle Permian to Late Triassic with consisting of argillaceous and calcareous rocks mixed with volcanic as well as some arenaceous participation. In the Gua Musang and Telong formations, argillaceous facies consisting of shale, siltstone, mudstone, slate, and phyllite are the dominant facies and occur as interbeds or lenses in the Aring Formation and Nilam marble.

Moreover, exposed of carbonate bodies which including steep-sided trending N-S calcareous hills and paving, have created extraordinary karst topography. The dominant facies in the Nilam marble formation and as extensive facies in the formation of Gua Musang formation are carbonate forming beds or lenses in the Telong formation and Aring formations. Northern limestone bodies are metamorphosed into marble while micrites and allochemes are still distinguished between the southern bodies. The platforms undergo the deposition process of argillite, carbonate and volcanic facies during the middle Permian to late Triassic periods. In South Kelantan to North Pahang, argillite, carbonate and pyroclastic or volcanic are classified as late Triassic argillite, at the time of middle Permian carbonate and volcanic facies and depositional climate (Mohamed, 2016). The lithology that can be observed on the basis of field observation is the metamorphic unit, marbled calcareous unit and mudstone unit.

4.3.2 Unit explanation

a. Phyllite, shale, slate unit

These three types rock are undergo regional metamorphism where occur at huge area that have high degree of deformation under differential stress. The structure that will form on the rock is a strongly foliated due to differential stress which typically the product of tectonic forces causing rock compression. Furthermore, large continental crust areas usually associated with mountain ranges are covered by regional metamorphism rock especially those associated with convergent tectonic plates or the roots of previously eroded mountains. The observation at terrain map and analysis on the topography in the study area, these rock units are covered with phyllite, shale, slate according to high elevation in ranges 250 m – 625 m.

b. Limestone unit

This rock unit in the study area are covered in about 45% at 125 m – 250 m elevation ranges. Limestone rock is including non-clastic sedimentary rock types which primarily made up of calcium carbonate ($CaCO_3$) with a large amount of impurities such as silica, dolomite and clay in different amounts.

c. Tuff unit

It is an igneous rock that created by the explosive volcanic eruption which blasts rock, ash, magma and other materials from its vents. In the region around the volcano when the eruption is occurred, the ejected material are flies through air and falls down to the earth surface. It is commonly in thickest layers near to the volcanic vent and the thickness of layers can increase through the distance from the volcano. Near to the groundside of the vent or the side of the vent where the blast was directed where the tuff rock may be thickest. On the geological map of study area (figure 4.7), the tuff rock indicates only 10% of the study area. The area that distributed with the tuff that may interbedded with the limestone rock are the valley between two mountain range with elevation in about 1000 m and 1400 m.

d. Alluvium unit

Alluvium are the material that deposited along the main river. It is usually most present in the lower section of the river that created floodplains and deltas, but may be deposited at any point where the river runs along the banks or the velocity of the water movement in the river is tracked.

4.4 Structural geology

Structural geology is an analysis of the architecture and geometry of the earth's crust and the forces that formed the structure. It is a study of the changes in the form of the rock bodies created by the tectonic forces that will make the forces fold, split the rock, make deep faults and lift the mountains. Moreover, the geological structure uses on current measurements of rock geometry to discover knowledge on the history of rock deformation and to explain the stress field in the strain and geometries observed. The structural geological that can be interpreted on the terrain map is faulting which produce the lineament map to obtain where the faulting are occurred in the study area.

4.4.1 Fault

In the rocks of the Earth's crust, a plain or gently curved fracture where compressive or tension forces induce the relative displacement of the rocks on the opposite side of the fracture is known as the fault. The faulting can be interpreted at lineament analysis (figure 4.9) at the study area. Lineament analysis is linear characteristics that provide information about the underlying geological structure. It is the identification of geological linear structures for the structural analysis and tectonic interpretation in the stable platform domain. There are two forms of lineament analysis which is negative lineament and positive lineament.

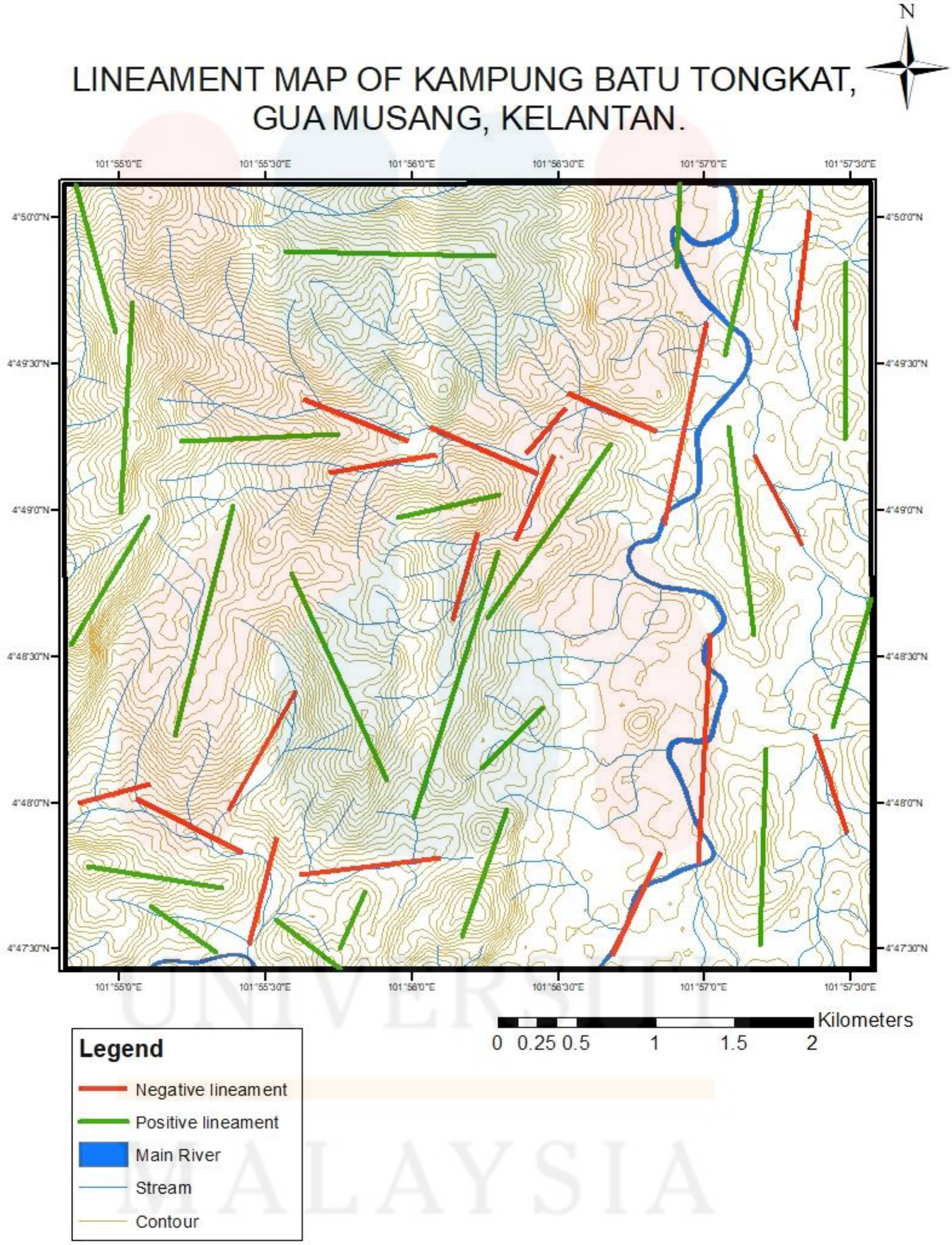

Figure 4.9: Lineament map of study area.

i. Positive lineament

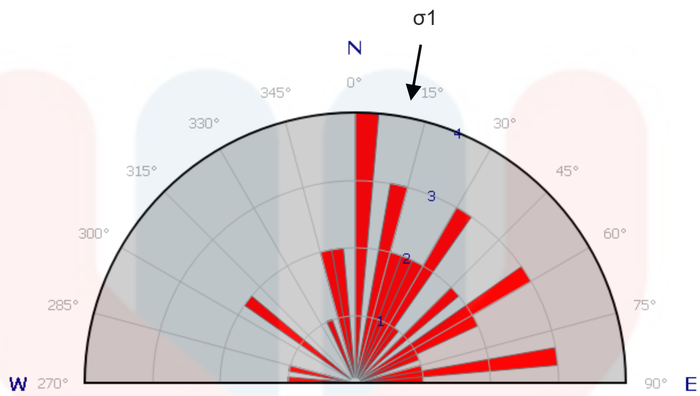

Figure 4.10: Rose diagram for positive lineament.

This types lineament usually at the exposure of resistant rock units is commonly characterized as strike ridges and dykes.

ii. Negative lineament

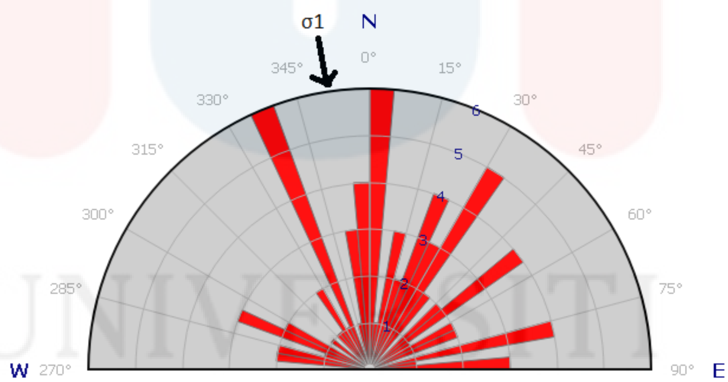

Figure 4.11: Rose diagram for negative lineament.

Negative lineament on the straight valleys represent the exposure of non-resistant rock units or rock weakness zones.

4.4.2 Mechanism of structure

In the study area, the structural mechanism is interpreted as occurring due to uplifting during tectonic movement. After the force was released from the crust underneath the earth, the earth's surface is raised to create a hilly terrain in the study area. Lineament analysis is often used as a guideline to identify the geological interpretation of the predicted fault in the study area. Due to the formation of ridges and valleys, this predicted fault can occur in the geological map (figure 4.7). Based on the rose diagram of positive lineament (figure 4.10), the major forces which is σ1 where the forces come from N-E direction which shows the fault that occurred in the study area is the sinistral strike slip fault.

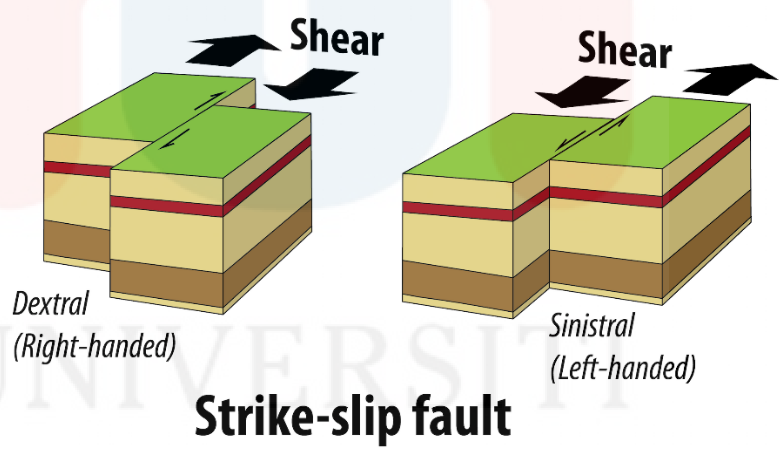

Figure 4.11: Strike-slip faults illustration. (Sources: Saskatchewan, 2015)

Strike slip fault (figure 4.12) is the faults that have the acceleration which mainly horizontal and along the fault's strike or duration. These fault are occurred where the shear stress on the rock causes the rock move to sideways to each other block that create a transform boundary. There are two types of strike slip fault which is dextral (right-handed) and sinistral (left-handed).

4.5 Historical Geology

Study area are enveloped with the shallow marine shelf depositional environment where it consists of active volcanic activity from long time ago. Basically, the Gua Musang group formation are involve in three facies which is argillaceous facies, carbonate facies and volcanic facies. Facies is rock or stratified body which differentiated by its shape or composition. In argillaceous facies, the area will made up of shale, slate, phyllite, siltstone and mudstone which recognized as the majority facies at the Gua Musang formation and Telong formation (Mohamed, 2016). This facies also interbedded and form lenses structure in the Nilam marble and Aring formation. In contrast to those occurring in the southern region of the Gua Musang Group are more fossiliferous for the rock distribution than in the northern area.

The other facies that build up the study area are carbonate facies that have a unique karst topography, such as the steep-sided N-S trending limestone hills and the pavement, formed by exposed carbonate bodies. The dominant facies in Nilam marble are carbonate and become the large facies in the formation of Gua Musang produced by beds or lenses in the formation of Telong and Aring. In southern Kelantan to the north of Pahang, rich limestone mogots are inferred as a continuous carbonate platform deposited in the Gua Musang Platform during the Permo-Triassic period before erosion and karst formation have occurred.

Lastly, the study area consists of the volcanic or pyroclastic facies where majority in the Aring formation. This facies is interlayered in other formations in the Gua Musang Group with carbonate and argillite. In additional, it is made up with the agglomerates, tuffs, lapilli, volcanic breccia, and interfingered agglomerates of limestone and tuffaceous shale. The layers of tuff are greenish grey and dark brown coloured. More ryolitic composition on the western side, near the Gua Musang - Kuala Lipis area in the south west of Kelantan and more andesitic composition on the eastern side, near the Chiku - Sungai Aring zone, generally reflects volcanic activity in the south east of Kelantan. These volcanic activities cause to marine topographic elevations occured for the deposition of limestone were produced in shallow marine fauna during the Permo-Triassic era in the Central Belt.

CHAPTER 5

SPELEOTOURISM POTENTIAL AT GUA PUTERI PULAI, GUA MUSANG, KELANTAN.

5.1 Introduction

Speleotourism is also known as cave tourism which refers to a relatively recent name given to tourism which includes structures of speleology. Speleology is a scientific discipline that deals with all aspects of cave systems and caves. However, this chapter will discuss the karst geomorphology of Gua Puteri Pulai influence the speleotourism potential. The speleotourism potential is evaluated using SWOT analysis and TOWS analysis. From this analysis, the speleotourism potential at the Gua Puteri Pulai can give an idea to held the amusement and adventures activity to attract public and local community came to the geotourism site.

5.2 Karst geomorphology

Karst is a land on which soluble rocks are altered above and below ground by the dissolving action of water and which has distinctive relief and drainage characteristics (Richard John Huggett, 2011). Weathering, tectonic motion, meltwater, hydraulic action and the evacuation of molten rock can also influence the characteristics of karst. In this part will be discussed about the exterior and interior of karst geomorphology at the Gua Puteri Pulai.

5.2.1 Geomorphological structure of cave exterior

Gua Puteri Pulai (figure 5.1) is the karst tower types which form with kind of tower shape due to the humid temperature of climate or affected by the humid tropical. In the humid tropics, the severity of the karstification process is partly due to high runoff rates and partly due to the thicker soil and vegetation cover that causes high levels of carbon dioxide in the soil. In general, karst tower or mogotes are the residual hills with elevation of 100 m or higher and highly steep to overhanging lower slopes (David, 2015).

Figure 5.1: The view of the Gua Puteri Pulai. (Source: Muhammad hazim, 2018)

This types of cone karst usually form at the broad alluvial plains with swampy environment and flat-floored depressions (Huang, 2014). Furthermore, Former caves form a wide valley and the limestone persists as hills between them meanwhile the tower karst is the result of a late stage of growth where it refers to the combination of tectonic uplifting and tropical karst erosion of this form. The height of Gua Puteri Pulai (figure 5.2) will increase in erosion through these combinations as the solution is larger than the valley.

Figure 5.2: Gua Puteri Pulai at Princess Hill. (Source: David, 2015)

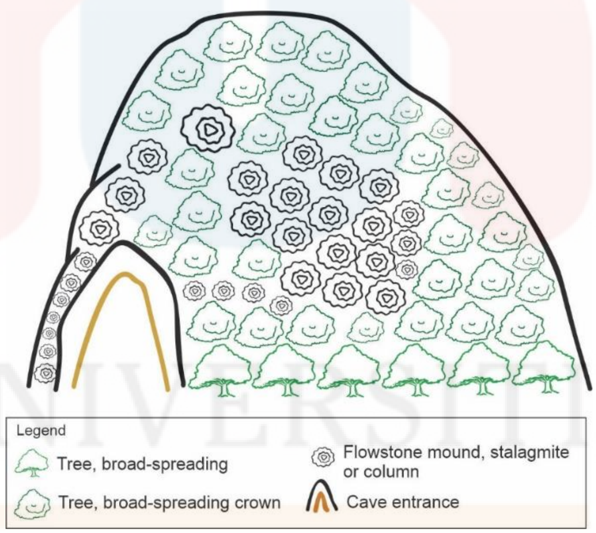

Figure 5.3: Roughly sketch of Gua Puteri Pulai karst formation from front view.

5.2.2 Geomorphological structure of cave interior

This tower karst of Gua Puteri Pulai is made up with limestone, dolomite, carbonate rocks and evaporates rocks (Muhammad hazim, 2018). The formative processes that formed the karst tower is bicarbonate solution and dissolution (Huang, 2014). Since limestone is the majority content in the karst formation, the important karst processes are the solution and deposition. The waters which carrying organic acids released by vegetation will also tends to be more soluble and very soluble in waters contained with sulphuric acid formed by weathering sulphide minerals. The main solvent in karst formation is carbonic acid and calcareous limestone that quickly dissolve to carbonation. The process to formed dolomite are same to limestone in natural waters but under normal conditions it tends to be significantly less soluble than limestone. Evaporites are more soluble than limestone or dolomite but carbon dioxide not involved in both rock solutions (Muhammad hazim, 2018).

The processes of this cave are created by these chemical weathering agents. It created from the water flow and inside the limestone fracture when the slightly acid groundwater dissolves limestone around the joints and bedding and passes into the space inside the fracture, allowing the fracture to expand larger and to melt the rock inside it. Water from the water flow and within the fracturing of the limestone, which is the rainy season, is acidic and moves into the gap inside the crack, causing the fracture to become wider and the rock within to wear away. Naturally, this cave exists beneath the chamber or is known as the underground chamber. In certain situations, the water of rivers flowing on the calcareous surface will begin to erode by slowing down and then dissolve downward on the surface between the fracture (Waitomocaves, 2011).

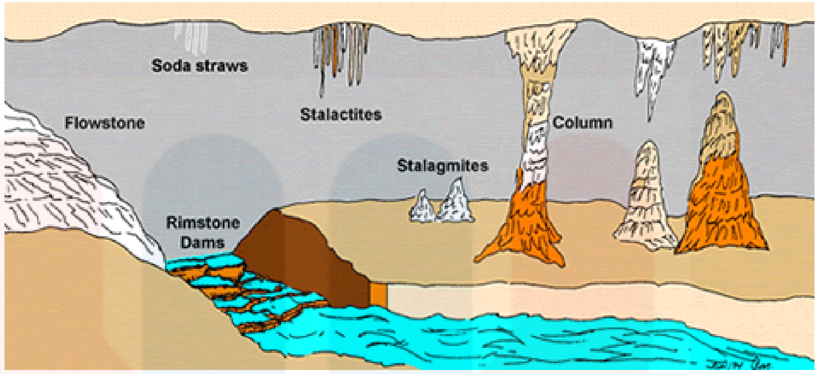

Figure 5.4: Cave formation or speleothem in general. (Source: Hill & Forti, 1995)

Speleothem (figure 5.4) that occurred in the Gua Puteri Pulai based on figure above is column (figure 5.7.a), stalactites (figure 5.7.b) and stalagmites (figure 5.7.c). The column feature is formed from deposited of water dripping or water flowing over cave walls or floors. Stalactites and stalagmites sometimes grow in pairs to form columns and often grow together. But often they grow individually, or in sizes that are very uneven. Stalactites cannot form stalagmites above water (Hill & Forti, 1995). All the calcite can be deposited on the ceiling by a slow drip on a stalactite and leave nothing to form a stalagmite. Little calcite can stick to the ceiling with a fast drip but build up a large stalagmite instead.

Next, the stalactites are speleothem formations that spread from the cave roof downwards. They form when a bathtub ring of the first water drip falls form the cave roof. The calcite collects forming a hollow tube of crystallized calcite or soda straw. The other speleothem in the Gua Puteri Pulai is stalagmites that formed from every drop of water from the roof or from stalactites overhead, solid dripstones that grow up from the cave floor. The shape of stalagmites depends on the gravity and resemble candles at the floor of cave (Muhammad hazim, 2018).

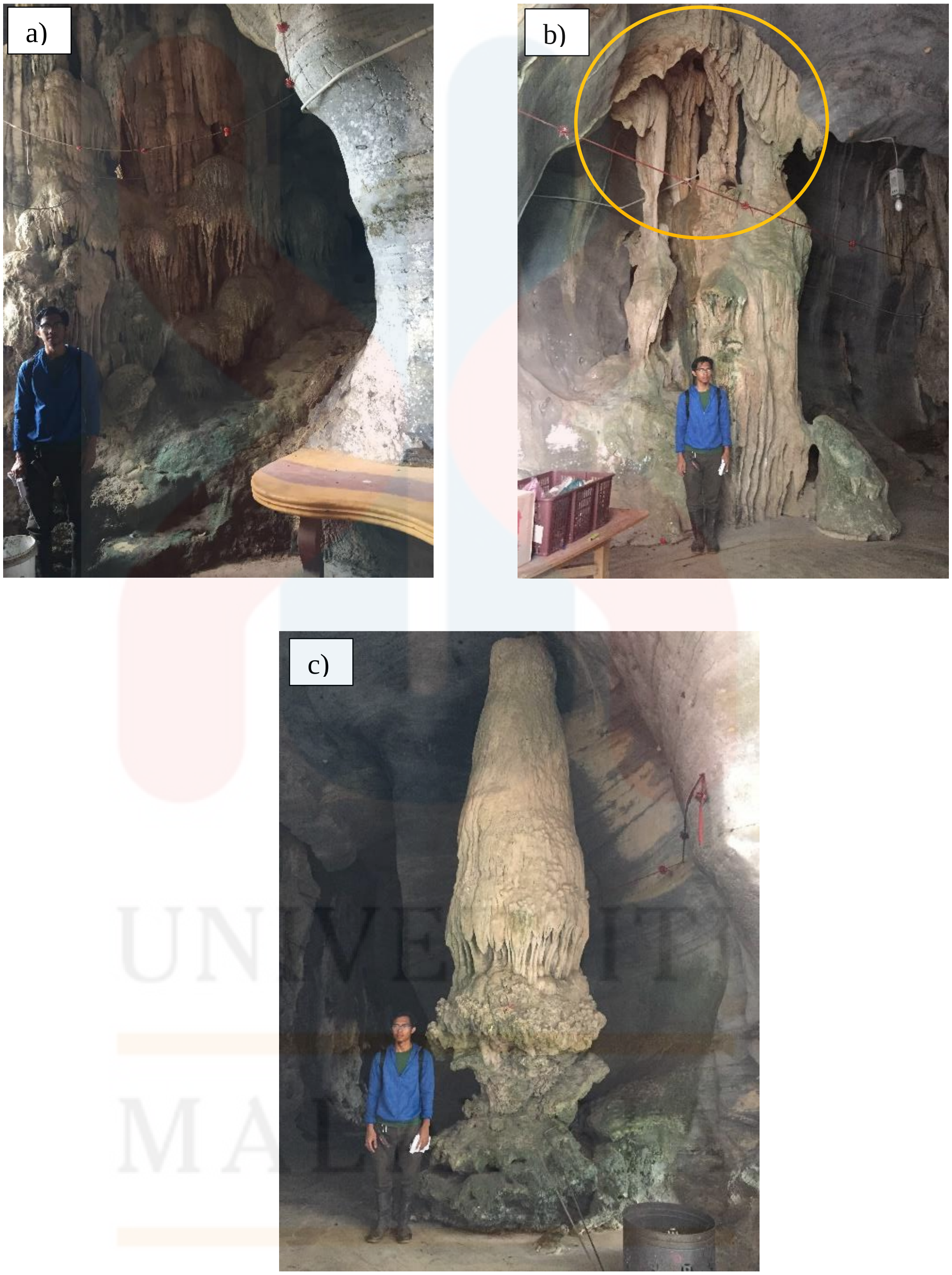

Figure 5.5: Speleothem in the Gua Puteri Pulai. a) The column inside the cave b) stalactites c) stalagmites (Source: Muhammad hazim, 2018)

5.3 Speleotourism at Gua Puteri Pulai, Gua Musang, Kelantan

5.3.1 Swot Analysis and Tows Analysis

This analysis is conducted at the Gua Puteri Pulai, Gua Musang (figure 5.6) by studied its karst geomorphology and adventures activities for speleotourism potential evaluation. The SWOT analysis shows that Strengths (S), Weaknesses (W), Opportunities (O) and Threats (T) must be identify in this cave. Moreover, strength (S) and weakness (W) are internal condition, while on the other condition, opportunities (O) and threats (T) are external condition in the table below.

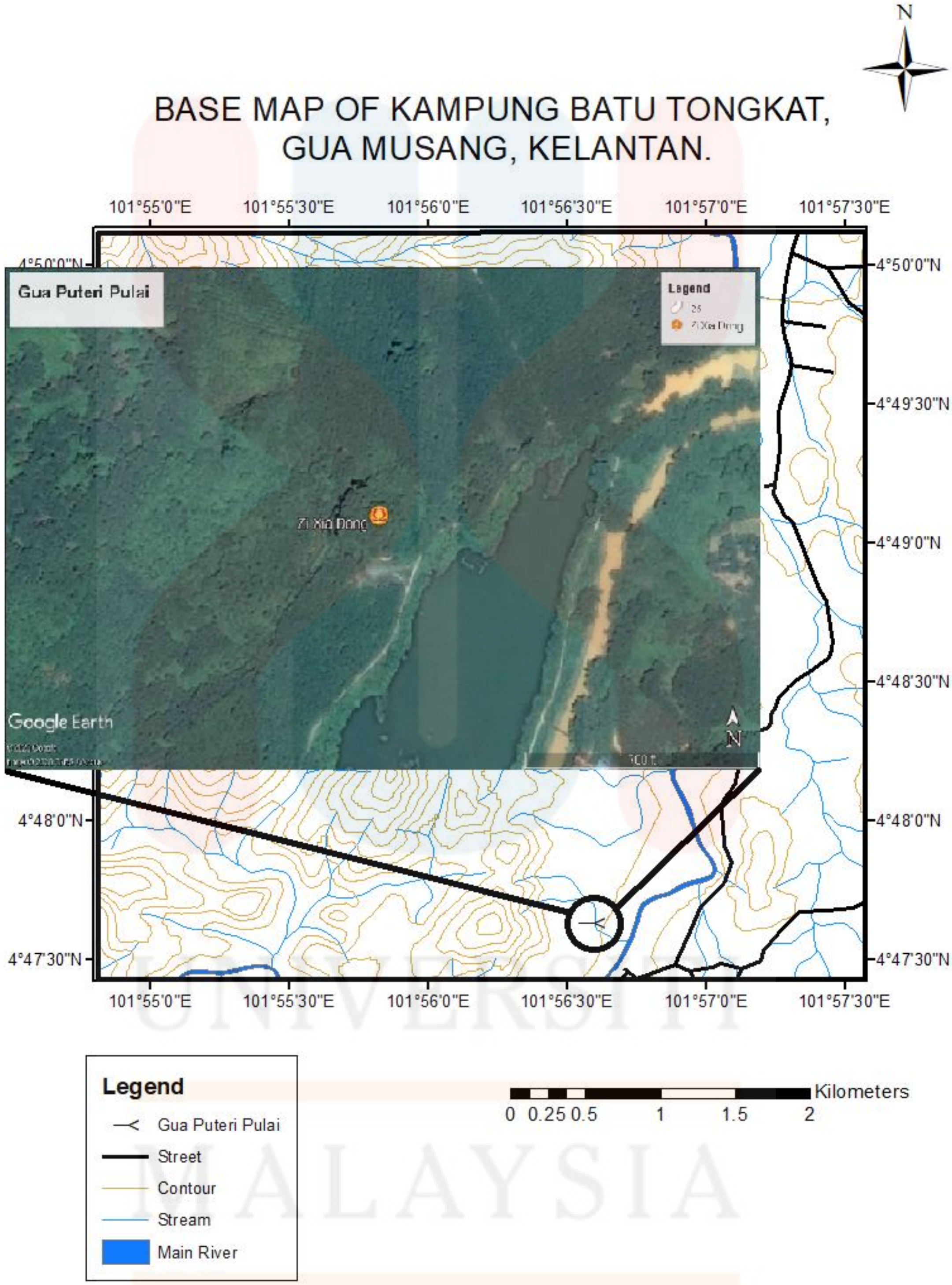

Figure 5.6: Location of Gua Puteri Pulai. (Google earth, 2014)

Table 5.1: SWOT analysis of speleotourism potential at Gua Puteri Pulai, Gua Musang, Kelantan.

		Description
Internal condition	Strengths (S)	S1 – Easy to access S2 – Scientific value (Speleothem) S3 – Cultural and historical value
	Weaknesses (W)	W1 – No marketing for cave tourism W2 – Lack of facilities
External condition	Opportunities (O)	O1 – Development for cave tourism O2 – Job opportunity for local community
	Threats (T)	T1 – Lack interest by the local community T2 – Competition with other local market

The other evaluation on speleotourism potential at Gua Puteri Pulai, Gua Musang is the TOWS analysis to obtain the relationship between the element in internal condition and external condition of SWOT analysis. The element that involve in this analysis is SO (Strength-Opportunities), WO (Weaknesses-Opportunities), ST (Strength-Threats) and WT (Weaknesses-Threats) as can be seen in the table below.

Table 5.2: TOWS analysis of speleotourism potential at Gua Puteri Pulai, Gua Musang, Kelantan.

		Internal condition	
		Strengths (S)	Weaknesses (W)
External condition	Opportunities (O)	SO1 - Make the documentary and publishing the uniqueness of karst geomorphology for cave tourism.	WO1 - Improving community knowledge about the potential of speleotourism/geotourism.
	Threats (T)	ST1 - Provision of processes of conservation and sustainability for current and future generations.	WT1 - Enhance local community and the general public's importance of environmental sustainability and conservation.

The strengths-opportunities (SO1) is the strategy to embrace the element strength to capitalize on the opportunities to make the documentary at the uniqueness of karst geomorphology at the Gua Puteri Pulai. The documentary can be published on media social to spread about cave tourism information to attract people surrounding country or worldwide. Next, strength - threat (ST1) is to fight external threats using the element strengths where the provision of processes of conservation and sustainability for current and future generations. We can create awareness with design the calming and relaxing environment with the beauty of nature surrounding the cave and manage the safety of visitors with assured dangerous and unsafe conditions need well-developed standard guidelines.

The other strategy in TOWS analysis is weaknesses - opportunities (WO1) which need to improve community knowledge about the potential of geotourism. It is to make the local community understand the importance of tourism in the conservation of the environment through the direct economy, benefiting from tourists who pay some money to visit the destination, cleaning and maintaining the destination. In the marketing plan and promoting the cave to the public and local community, the geotourism plans must also be well managed to achieve the goals. Lastly, the weaknesses – threat (WT1) is the strategy to overcome weaknesses and counter threats with enhancing the local community and the general public's importance of environmental sustainability and conservation. Establishment the geotourism growth and conservation plan that will boost community attractions, economic needs and implement strategies to reduce socio-cultural impacts and boast the reputation of the cave tourism.

5.3.2 Speleotourism and Adventurous Activities

This geotourism site able to provide amusement and adventures activities to welcome public especially tourists from outside of the state to experience the fun. Suitable activities that can held at the Gua Puteri Pulai is rock climbing and spelunking. Rock climbing is an activity in which participants climb up or down on natural rock formations which at the karst tower of Gua Puteri Pulai.

The objective of rock climbing activity is to climb until reach to the top of tower karst without falling down. It is a physically and mentally challenging activity which need mental discipline, to tests the stamina, endurance, and the limit balance when climbing. It can be a dangerous sport and it is important for the safe completion of routes to know the correct climbing techniques and the use of specialized climbing equipment.

The other activities that can be arranged at the caves are spelunking or caving where the participant needs to explore the interior of the cave until reach to the underground or the endpoint of the cave. This activity challenges the participant that may arise at any level of difficulty including the need to negotiating steep ascents or descents, tight spaces and even the possibility of cave diving.

Moreover, Gua Puteri Pulai has potential for the historical or cultural place at the Kampung Pulai. Gua Puteri Pulai was known as cave temple which called as the Water and Moon Temple. It is one of the oldest temples at Malaysia which found by the Hakka Chinese people over 600 years ago. When the first paved road at the Kampung Pulai entered the village in 1978, traditional Hakka culture was well preserved surrounding the village. This types of speleotourism potential can attract the tourist to come to the Kampung Pulai that can learn how early Hakka people explore the gold site at the Kampung Pulai.

CHAPTER 6

CONCLUSION AND SUGGESTION

6.1 Conclusion

In conclusion, this research aims to update the geological map of the study area as well as to access the speleotourism potential of Gua Puteri Pulai. The geological interpretation in the study area to accomplish the first objective. From the geological interpretation conducted, the lithology that abundance at the study area is phyllite, shale and slate, limestone, tuff and alluvium. Based on the interpretation there is strike slip fault in the study area. A geological map with scale 1:25 000 has produced using the geological interpretation method.

Then, a detailed study of speleothem features and karst geomorphology in the study area are using secondary data to interpret the landform. The secondary data is obtaining from the google earth and the picture from the previous research. Gua Puteri Pulai is identify as cone karst types which have the speleothem such as column, stalactites and stalagmites. Furthermore, the rough sketch of the exterior cave is produce to shows the significant of the scientific value for geotourism site information.

Lastly, the speleotourism potential of Gua Puteri Pulai was identify based on the evaluation using SWOT analysis and TOWS analysis. These both analyses resulted in the internal condition to make the documentary and published the uniqueness of karst geomorphology for cave tourism and improve the community knowledge about the potential of geotourism. The external condition which resulted from the analysis to make the provision of the processes of conservation and sustainability for current and future generations of the geotourism site and enhances the local community and the general public importance of environmental sustainability and conservation. After providing the element in the evaluation of speleotourism potential at the Gua Puteri Pulai, the recommendation to held some activities which can attract the local community and tourist to come to this geotourism site which is rock climbing, spelunking and cultural or historical place to visit.

6.2 Suggestion

From this research, the geological interpretation on the geological map is lack of secondary data such as mineral data structural data of Gua Musang, Kelantan. Some of the data on the online resources cannot be approached by the student itself and have the complicated procedure to obtain the data from data provided company. So, the student must apply the data in advance before starting the geological interpretation.

Next, karst's topography is unique and has the anesthetic meaning of its own. Any areas of the karst region of Gua Musang can be more appealing if well-taken care. The limestone in the research area consists of a cave that needs to be restored and protected. Also, some of the research sites have a speleotourism significance correlated with scientific, aesthetic, cultural and economic value. Speleotourism or cave tourism is speleological objects involve the tourism aspect. Geological structure of formation that has signed for the geotourism must be protected and established because it is part of the speleotourism.

Geoconservation is a method of geological preservation of the phenomenon of formation and physical destruction that has a theoretical significance showing the different geology of the earth and the geological mechanisms of change. To maintain the geological structure such as karst accelerated growth requires careful preparation or management to escape geological processes that have destroyed heritage value. It is then the responsibility of geologists or educational institutions to convey to society the importance of protecting geological resources.

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