



Universiti Malaysia
KELANTAN

**GEOLOGY OF TAMAN BANDAR UTAMA AND LIMESTONE
KARSTS GEOHERITAGE MAPPING USING GIS, GUA MUSANG
TOWN, 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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UNIVERSITY OF MALAYSIA KELANTAN**

2023

DECLARATION

I declare that this thesis entitled “Geology of Taman Bandar Utama and Limestone Karsts Geoheritage Mapping Using GIS, Gua Musang Town, 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 hereby declare that I 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 (Geosciences) with Honours”.

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Date :.....



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GEOLOGY OF TAMAN BANDAR UTAMA AND LIMESTONE KARSTS GEOHERITAGE MAPPING USING GIS, GUA MUSANG TOWN, GUA MUSANG, KELANTAN

ABSTRACT

Bandar Utama Gua Musang are known with its own unique geomorphological appeal due to the various limestone karst or karsts landscape and features such as stalactite, stalagmite, pinnacle, and cave, hilly (mostly high elevation) and plantation. The objectives of this study are to update the geological map of Taman Bandar Utama with the scale of 1:25,000, to produce Limestone Karsts Geoheritage Map for Gua Musang town, and to propose the suitable potential geoheritage value for selected limestone karsts. The study area for updating geological map is located at latitude 4°54'34.24"N to 4°51'51.84"N and longitude 101°59'57.71"E to 101°57'12.23"E within Taman Bandar Utama, Gua Musang which cover 25 km². Meanwhile, for specification study area is located at latitude 4°53'9.91"N to 4°49'53.59"N and longitude from 101°58'40.89"E to 101°56'29.43"E that covers nine limestone karsts which include Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu Papan, Batu Machang, Gua Madu, Etnobotany 1 and Etnobotany 2. The method to update the geological map include fieldwork, secondary data collection, rock sampling and data collection using drone of limestone karsts landform and features. The rock outcrop location was updated in the ArcGIS software. Eight rock samples were process for petrographic analysis and rock identification by using QAPF diagram. From petrographic analysis, there were three metamorphic rocks (marble, slate and quartzite), and two types of igneous rocks (quartzolite and alkali feldspar granite) were identified by using. The data collected will be processed to generate the geological map by using ArcGis software. Drone data of the limestone karsts were processed in the Agisoft software. Six thematic maps of geoheritage value were prepared which includes scientific and educational, aesthetic, economical, conservation, recreational, cultural, and historical. All thematic maps were weightage by using quantitative method and overlaid using multi-index overlay analysis. Based on Limestone Karsts Geoheritage Map produced, Etnobotany 1 shows the highest percentage of area suitable for recreational value, Gua Batu Papan shows the highest percentage of area suitable for scientific and educational, Gua Musang shows the highest percentage of area suitable for economic value, Gua Madu shows the highest percentage of area suitable for conservation value and aesthetic value, then Gua Musang shows the highest percentage of area for cultural and historical value.

Keywords: Geological mapping, Digital mapping, Bandar Utama Gua Musang, Karst features, Limestone Karsts Geoheritage Map.

GEOLOGI TAMAN BANDAR UTAMA DAN PEMETAAN GEO WARISAN KARS BATU KAMAR MENGGUNAKAN GIS, BANDAR GUA MUSANG, GUA MUSANG, KELANTAN

ABSTRAK

Bandar Utama Gua Musang terkenal dengan tarikan geomorfologinya yang unik kerana pelbagai landskap kars atau karst batu kapur dan ciri-ciri seperti stalaktit, stalagmit, puncak, dan gua, berbukit (kebanyakannya ketinggian tinggi) dan perladangan. Objektif kajian ini adalah untuk mengemas kini peta geologi Taman Bandar Utama dengan skala 1:25,000, menghasilkan Peta Geowarisan Karst Batu Kapur bagi bandar Gua Musang, dan mencadangkan nilai potensi geowarisan yang sesuai untuk kars batu kapur terpilih. Kawasan kajian untuk mengemas kini peta geologi terletak pada latitud $4^{\circ}54'34.24''\text{U}$ hingga $4^{\circ}51'51.84''\text{N}$ dan longitud $101^{\circ}59'57.71''\text{E}$ hingga $101^{\circ}57'12.23''\text{E}$ dalam kawasan Taman Bandar Utama, Gua Musang yang meliputi 25 km². Manakala bagi kawasan kajian spesifikasi pula terletak pada latitud $4^{\circ}53'9.91''\text{U}$ hingga $4^{\circ}49'53.59''\text{N}$ dan longitud dari $101^{\circ}58'40.89''\text{E}$ hingga $101^{\circ}56'29.43''\text{E}$ yang meliputi sembilan karst batu kapur yang merangkumi Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu Papan, Batu Machang, Gua Madu, Etnobotani 1 dan Etnobotani 2. Kaedah untuk mengemas kini peta geologi termasuk kerja lapangan, pengumpulan data sekunder, pensampelan batuan dan pengumpulan data menggunakan dron bentuk muka bumi dan ciri karst batu kapur. Lokasi singkapan batu telah dikemas kini dalam perisian ArcGIS. Lapan sampel batuan telah diproses untuk analisis petrografi dan pengecaman batuan dengan menggunakan rajah QAPF. Daripada analisis petrografi, terdapat tiga batuan metamorfik (marmar, batu tulis dan kuarzit), dan dua jenis batuan igneus (kuarzolit dan granit feldspar alkali) telah dikenal pasti dengan menggunakan. Data yang dikumpul akan diproses untuk menghasilkan peta geologi dengan menggunakan perisian ArcGis. Data dron karst batu kapur telah diproses dalam perisian Agisoft. Enam peta tematik nilai geowarisan disediakan yang merangkumi saintifik dan pendidikan, estetika, ekonomi, pemuliharaan, rekreasi, budaya dan sejarah. Semua peta tematik adalah wajar dengan menggunakan kaedah kuantitatif dan ditindih menggunakan analisis tindanan berbilang indeks. Peta Geowarisan Karst Batu Kapur yang dihasilkan, Etnobotany 1 menunjukkan peratusan keluasan tertinggi yang sesuai untuk nilai rekreasi, Gua Batu Papan menunjukkan peratusan keluasan tertinggi yang sesuai untuk saintifik dan pendidikan, Gua Musang menunjukkan peratusan keluasan tertinggi yang sesuai untuk nilai ekonomi, Gua Madu menunjukkan peratusan tertinggi kawasan yang sesuai untuk nilai pemuliharaan, dan nilai estetik, kemudian Gua Musang menunjukkan peratusan tertinggi kawasan untuk nilai budaya dan sejarah.

Kata kunci: Pemetaan geologi, Pemetaan digital, Taman Bandar Utama Gua Musang, Ciri karst, Peta Geowarisan Karst Batu Kapur.

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LIST OF ABBREVIATIONS

E	East
N	North
Km	Kilometers
PPL	Plane Polarized Light
GIS	Geographic Information System
GPS	Global Positioning System
JMG	Department of Minerals and Geosciences
HCl	Hydrochloric acid
KESEDAR	Lembaga Kemajuan Kelantan Selatan
FELDA	Federal Land Development Authority
RPT	Rancangan Pembangunan Tanah
FRIM	Forest Research Institute Malaysia
XPL	Cross Polarized Light

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LIST OF SYMBOLS

%	Percentage
'	Minutes
"	Second
°	Degree



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CHAPTER 1

INTRODUCTION

1.1 General Background

This research was divided to two main focus which is updating geological information and mapping for Bandar Utama, Gua Musang and geoheritage value studies for selected limestone hills surrounding Gua Musang town.

1.1.1 Geology of Bandar Utama Gua Musang

Gua Musang is the largest district in Kelantan, Peninsular Malaysia, and also notable for its gold mineralization (Yao, Pradhan et al. 2017). According to previous findings, metasedimentary rock, limestone, granite, quartzite, and alluvium are the five types of geological units found in Bandar Utama Gua Musang. As shown in the lithostratigraphy column, the oldest rock is the Early Triassic metasedimentary rock, while the youngest is the alluvium, which is recent (Lilly Azleena Azreen, 2019).

Gua Musang, on either side, is primarily made up of Permian-Triassic clastic, volcanic, and limestones and is found in Kelantan's southern region. Gua Musang is a key district with its own unique appeal due to the various limestone karst or karts landscape. It had a rich flora and fauna, as well as geological features with geological significance.

Furthermore, when viewed from a geological standpoint, the karst limestone's distinctiveness reveals several geological heritage qualities such as scientific value, aesthetic value, and recreational value.

1.1.2 Geoheritage and Geotourism Value in Malaysia

Geoheritage is the study of geological features that are linked to heritage that has been passed down through the generations. Our nation's geological legacy includes notable geological features, landforms, and ecosystems that are conserved for a variety of reasons, including scientific, aesthetic, cultural, environmental, educational, recreation, tourist, and other considerations (Dony Adriansyah et.al, 2015).

Geo-heritage, which includes unique sites and artifacts that play a significant part in our understanding of the nature of the planet, such as rocks, minerals, fossils, and ecosystems, is also an important component of geological heritage. Furthermore, geo-heritage is an important aspect of the growth of geotourism.

Geotourism is a new movement helping travelers to increase their knowledge about natural resources, the cultural identity of host communities, and ways of their preserving (Belij et.al, 2018). It is great importance to support and enhance the global movement about geotourism generally and specifically into geoparks.

Geoheritage conservation of global, national, state, and local significant on geology, that are sites of culturally important, offering information or insights into the evolution of the Earth, or into the history of science, or that can facilitate research, teaching, or geological references (A. Rahman et.al, 2012).

Many geological characteristics exist in Malaysia, including uncommon naturally beautiful landscapes, landforms, various types of rocks, minerals, and fossils that have been developed over time through a long and complex geological process. Malaysia is known for its naturally abundant hilly landscapes, mountains, seas, rivers, and caverns, which are mostly calcareous karst and vary by region (Bentivenga et.al, 2019).

According to geological characteristics, the Peninsular of Malaysia can be divided into three longitudinal belts which is Eastern, Central, and Western. Kelantan State, located in Peninsular Malaysia's Central Belt, contains many beautiful and intriguing geological characteristics that make up good geological sites with geoheritage values and are geared toward conservation geotourism.

The Malaysian state of Kelantan includes a diverse range of geological sites and features with potential for geotourism and geoheritage. Gua Musang is an industrial, rural, and government constituency in southern Kelantan, Malaysia. It is one of Kelantan's most important districts. Gua Musang, for example, has its own charms, such as flora and fauna, which can add to the existing heritage value.

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1.2 Problem Statement

There are a few issues with the research region, such as the lack of an up-to-date geological map. The geology map of Bandar Utama Gua Musang was last updated by previous senior or researcher, Lilly Azleena in 2019. The study area's research in this topic is considered new, and it must be carried out to address the issue of a lack of information on the district's general geology and geological heritage features. As a result, a detailed geological map and the identification of geological heritage elements will require additional time and effort in research.

Despite of that, for specification, this studies also includes the evaluation of geoheritage potential value such as cultural, educational, aesthetic and recreational value that exists in the study area for geotourism purpose. This study covers two study area in Gua Musang town, which is one for geological mapping and the other one for geoheritage mapping.

Next, many karst limestone features are expected to fulfil the geological heritage value in the study area, but the karst limestone is not adequately exposed to the public, and even locals are unaware of the values it holds. With adequate promotion and exposure, however, this karst limestone can captivate both locals and foreign visitors. This study must be carried out in order to identify the study area's geological features and geological heritage assets.

1.3 Research Objectives

The main objectives for this research:

- i. To update the geological map of Bandar Utama with the scale of 1:25,000.
- ii. To produce Geoheritage-Geotourism Ranking Value Map for Gua Musang town with the scale of 1:25,000.
- iii. To identify the potential geoheritage factor in Gua Musang.

1.4 Scope of Study

The project's goal is to create a detailed geological map of the study area and to interpret the data. The structural geology, geomorphology, and lithology of the studied area are the geological data needed to create a detailed geological map. ArcGIS software can be used to create this detailed geological map.

Following that, this study looks into finding the geological heritage element that can help conserve the environment and geological heritage value in Gua Musang, Kelantan. This can be used to generate geoheritage-geotourism map. This element of geological heritage also includes biodiversity and geodiversity, which lead to geotourism. Geological heritage aids in the provision of data and knowledge on geological history, origin, and occurrence based on geological structure and features discovered.

1.5 Significant of Study

The geological map was last updated by Lilly Azleena Azreen in Bandar Utama Gua Musang in 2019. Until this year, there are no case study was done in the study area, which means there are no updated geological map of Bandar Utama Gua Musang. Within those four years, there must be any reaction or process like weathering to the structure there due to the long exposure to the surrounding. Thus, this study needs to be done to update the geological map. There also 50 % of overlapping within this study area and Lilly's area (previous box). Thus, the comparison can be made.

The goal of this project is to create a detailed geological map of Bandar Utama Gua Musang at a scale of 1:25000, as well as a detailed geoh heritage-geotourism high-rank value map of the study region at a scale of 1:25000. Geological heritage elements with potential for geotourism development in Bandar Utama Gua Musang can be determined using the geological map and geoh heritage map produced.

The term "geoh heritage" refers to a geologically defined site or area with scientific, educational, recreational, aesthetic, and cultural significance. With those values, the geoh heritage-geotourism map will be generated. It the first approach to interpret geoh heritage by using GIS, which means it apply the new method and analysis. It helps to promote public and local, national and global communities's knowledge of geoh heritage occurrence by knowing its potential for geotourism development.

Moreover, this study also used the drone technology to be apply in the specification area, for geoheritage studies. The drone will be the up-to-date advance technology that will gives a good results and easier way especially in viewing and capturing image of the 8 limestones karsts in the study area.

Through this research, it will open the eye of all community in Gua Musang to protect the potential geoheritage park because of many geoheritage values that it holds especially the 8 limestone karsts. The geoheritage park could also be used for geotourism purpose which can also lead to economic enhance for society there.

1.6 Study Area

This research study area is conducted at two (2) different study areas within Gua Musang town, Kelantan.

1.6.1 Bandar Utama, Gua Musang, Kelantan

The first study area is located at Gua Musang District, Kelantan, which centered with Bandar Utama Gua Musang. The study area, Bandar Utama, Gua Musang is located at the residential area and was nearby with the area of karst limestone caves. This study required to generate a detailed geological map of the study area, (5x5) km² of Bandar Utama, Gua Musang with the scale of 1:25000.

1.6.2 Limestone Karsts, Gua Musang, Kelantan

For study area 2, the study area also located at Gua Musang District but in the different location of box. The study area with (6 x 4) km² that covers 8 limestones

caves or places that rich with limestones. Those 8 places are Gua Musang, Gua Serai, Gua Batu Boh, Batu Neng, Batu Machang, Batu Papan, Gua Madu and Etnonotany Park.

This area was mostly covered with karst limestone caves and high elevation karst. From the maps generate, geological features and site that has potential for conservation and geotourism development in study area can be determine. This study also required to generate the geoheritage-geotourism ranking value map within the study area.

1.6.3 Location

The mapping study area is located at latitude $4^{\circ}54'34.24''\text{N}$ to $4^{\circ}51'51.84''\text{N}$ and longitude $101^{\circ}59'57.71''\text{E}$ to $101^{\circ}57'12.23''\text{E}$. Geological features such as river, Sungai Ketil, and Sungai Galas, streams, and contours can be seen in base map of study area.

For the specification study area, it is located at latitude $4^{\circ}53'9.91''\text{N}$ to $4^{\circ}49'53.59''\text{N}$ and longitude from $101^{\circ}58'40.89''\text{E}$ to $101^{\circ}56'29.43''\text{E}$. Same in here, all the geological features can be seen in the base map.

Both base map of the study area can be seen in the Figure 1.1 and Figure 1.2 below. Pahang state, Terengganu state, Perak state, and the Kelantan district of Kuala Krai and Jeli form the southern, Terengganu state, eastern, and western borders of Gua Musang, respectively. The study area is a region with rapidly expanding infrastructure and development. Furthermore, even though study's area is located in Gua Musang's major town, it is nevertheless encircled by a forest and steep terrain.

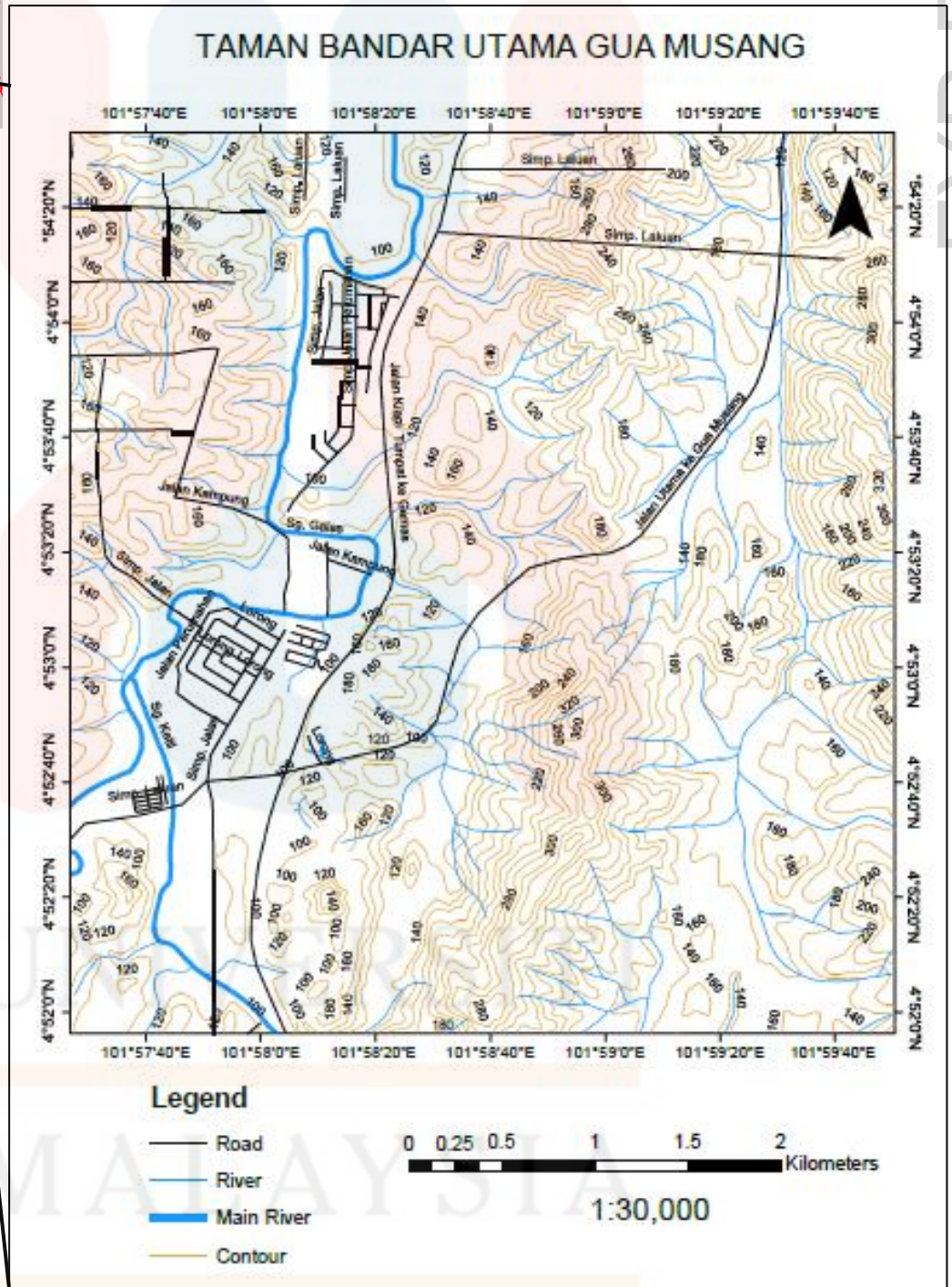
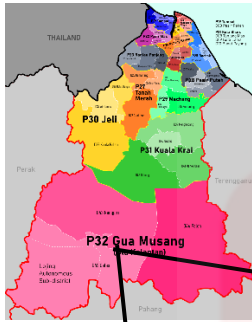


Figure 1.1: Base map of study area for geological mapping.

Sources: Data from Department of Mineral and Geoscience Malaysia (JMG) Kelantan.

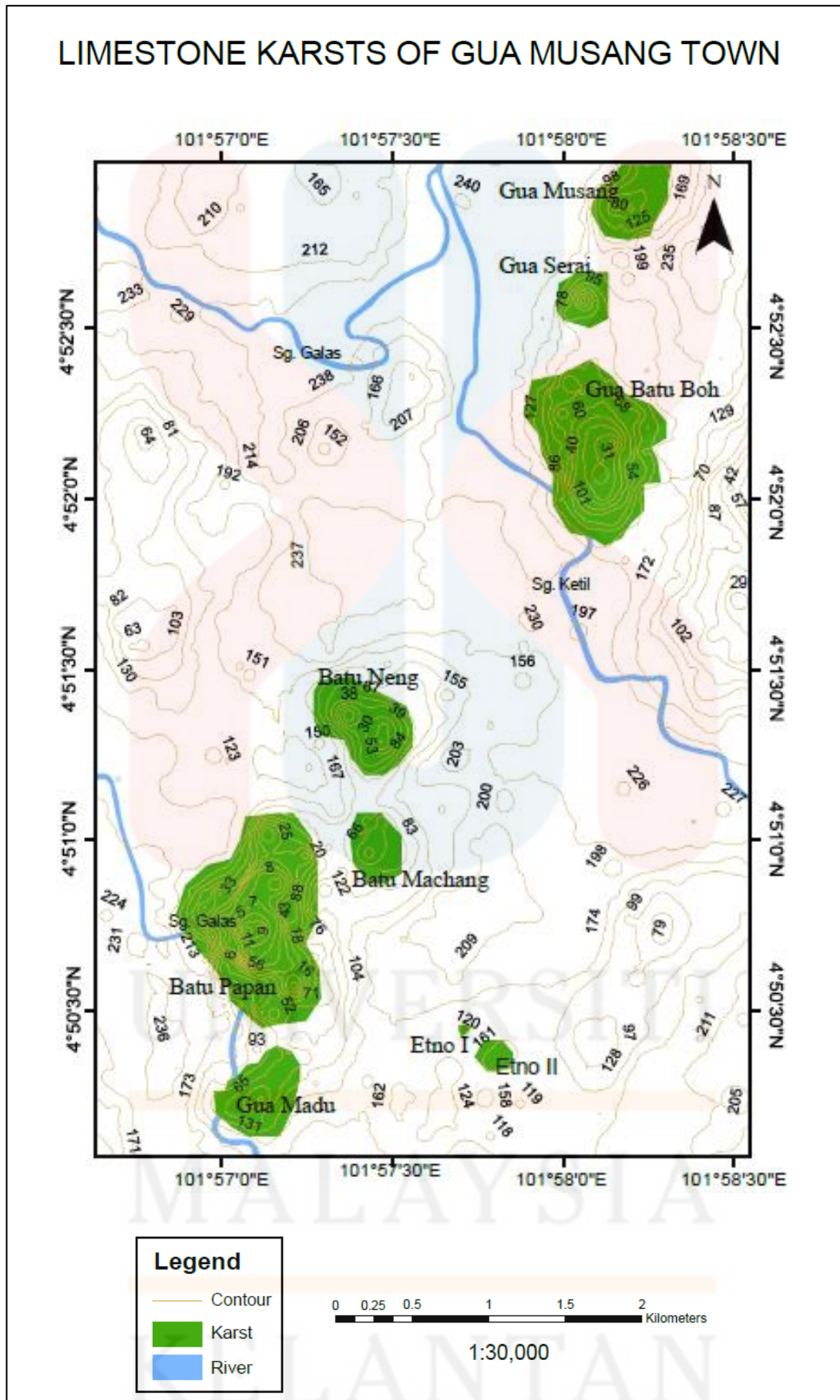


Figure 1.2: Base map of selected Limestone Karst in Gua Musang Town.

Sources: Data from Department of Mineral and Geoscience Malaysia (JMG) Kelantan.

1.6.4 Road Connection/ Accessibility

The main roads of the Kota Bharu-Gua Musang and Gemas-Tumpat railways can be used to reach the research region. According to Figure 1.3 A, travelling by automobile from Kota Bharu to Gua Musang through the Kota Bharu-Gua Musang main route (blue line) takes about three hours, whereas travelling via the main roads of Rantau Panjang, Jeli, and Dabong takes about three hours and a half (grey line). Moreover, it only takes around 2 hours and 19 minutes and 1 hour and 45 minutes, respectively, to drive from Tanah Merah (Figure 1.3 B) and Jeli (Figure 1.3 C), to get to Gua Musang (blue line). In the meantime, travelling by train via the Gemas-Tumpat Railway from Tumpat to Gua Musang (red line) takes around 6 hours.

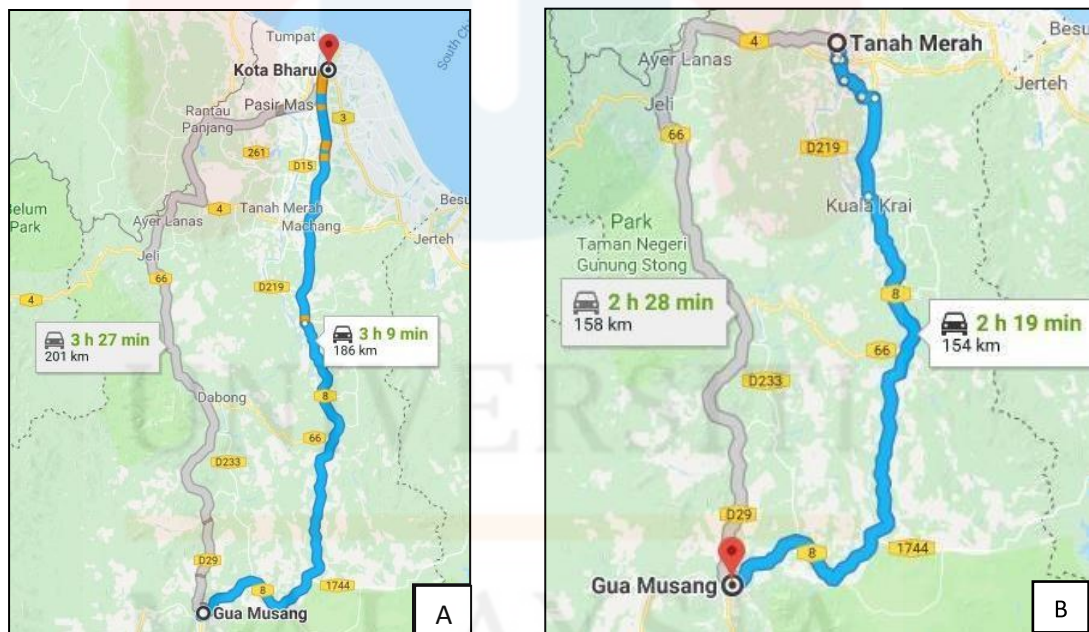
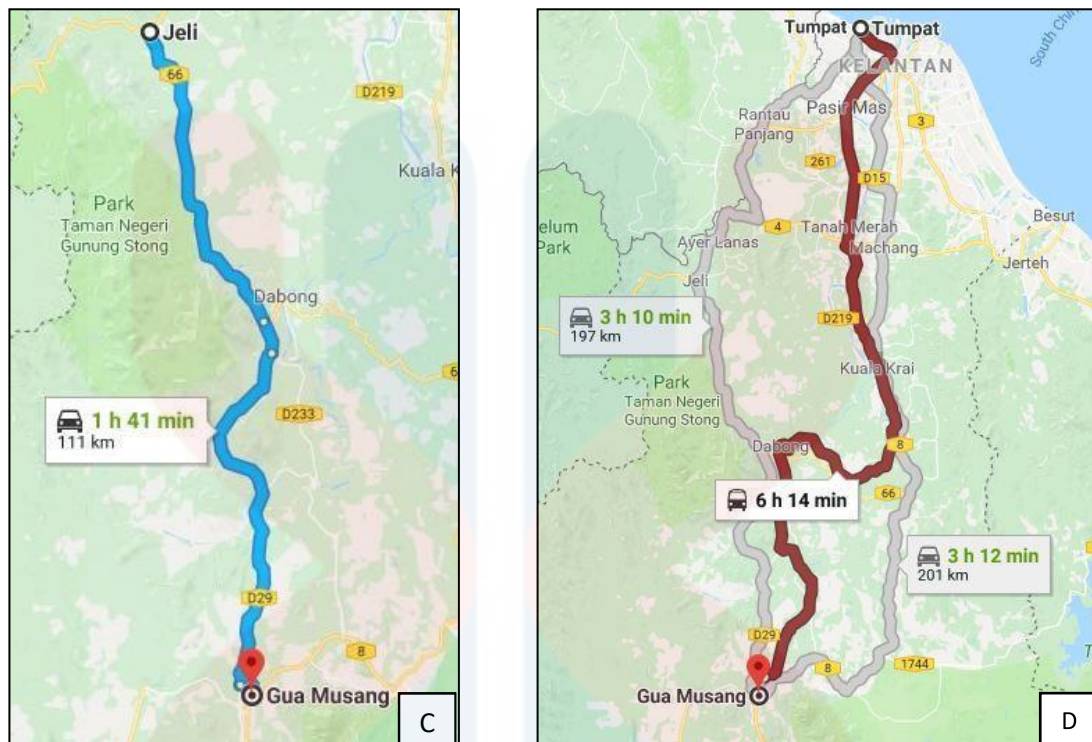


Figure 1.3: Accessibility to Gua Musang. (A) From Kota Bharu to Gua Musang by using a car. (B) From Tanah Merah to Gua Musang by using a car.



(C) From Jeli to Gua Musang by using a car. (D) From Tumpat to Gua Musang by using a train.

Sources: (Google, n.d).

1.6.5 Demography

The northeastern region of Peninsular Malaysia is dedicated to the 17,100 km² state of Kelantan. A part of southern Thailand borders Kelantan to the north, Perak to the west, Pahang to the south, and Terengganu to the south. Kota Bharu, Gua Musang, Machang, Tanah Merah, Pasir Mas, Pasir Puteh, Bachok, Jeli, Kuala Krai, and Tumpat are the ten administrative regions that make up Kelantan. In Kelantan's southern region, there are hilly terrains. They're bordered by the Titiwangsa Mountain.

A fertile shoreline is a clear indicator of the regional geology downstream. The stream valley is governed by paddy development, rubber, oil palm, tropical foods, and hardwood. Sungai Nenggiri, Sungai Lebir, Sungai Golok, Sungai Kelantan, Sungai Kemasin, Sungai Semerak, Sungai Pergau, Sungai Pengkalan Chepa, and Sungai

Pengkalan Datu are larger class streams. Numerous factors, grouped into district size, economic prospects, and area, influence the population distribution in the state of Kelantan.

Gua Musang population is at the eight ranking of highest population among the 10 districts. Total Kelantan population in 2000 is 1,287,367 and gradually increased to 1,630,891 in 2010 and 1,828,256 in 2020. The increase in population is due to the factors of birth rate, death rate and people migration that always change throughout the year.

District	Year		
	2000	2010	2020
Bachok	109,384	142,110	157,288
Kota Bharu	398,835	509,600	555,757
Machang	77,762	101,300	110,008
Pasir Mas	162,312	212,000	230,424
Pasir Puteh	104,404	123,191	136,157
Tanah Merah	101,509	133,400	150,766
Tumpat	130,414	177,700	182,200
Gua Musang	74,988	103,300	114,500
Kuala Krai	91,771	120,800	136,500
Jeli	35,988	48,000	54,656
TOTAL	1,287,367	1,630,891	1,828,256

Table 1.1: Total population in Kelantan district.

Sources: (Department of Statistics Malaysia, 2020).

1.6.6 Landuse

The majority of the land is covered by palm oil plantations in the study area's southern and eastern regions, followed by rubber plantations and banana plantations. In the central part of both of the study area was mainly the town and residential area. Three major organizations, Lembaga Kemajuan Kelantan Selatan (KESEDAR), Federal Land Development Authority (FELDA), and Rancangan Pembangunan Tanah, oversee the landuse of plantations activities in Gua Musang (RPT).

There are many government buildings, including schools, hospitals, police stations, fire stations, and other facilities, due to the infrastructure's rapid growth and development. In addition to government buildings, there is a private structure that was constructed for educational purposes, including kindergarten and private institutions. Public amenities include things like telephones, mosques, bus stops, important roads, railroads, and others. In addition, there also some active construction of homes and buildings is ongoing.

1.6.7 Social Economic

The majority of the Gua Musang population's economy is based on plants. People built palm oil and rubber plantations primarily as their main economic pursuits. Bandar Utama Gua Musang is largely covered in palm plantations, which provide the majority of the city's residents with a living. Additionally, people in Gua Musang engage in agricultural activities including cultivating banana trees and other fruits and vegetables.

In addition, locals run their own businesses there, including fruit stands, supermarkets, and grocery stores. One of the occupations that the residents of Gua Musang engage in to boost their economy is quarrying.

People also work as teachers, police officers, firefighters, and hospital employees in addition to having businesses. Since there are several educational institutions, including kindergartens, primary schools, secondary schools, and private institutions, people in Gua Muang are also concerned about their education.



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, it will discuss about the geology of the study area that consists of the regional and tectonic setting, stratigraphy, structural, historical and the geoheritage-geotourism value mapping for the 8 limestone karsts in the study area.

2.2 Regional Geology and Tectonic Setting

Tectonically, Peninsular Malaysia is part of the Eurasian Eastern Plate, north of the active subduction arc zones of Sunda (Kamar Shah Ariffin 2012). Lojing, Gua Musang is located in the Kelantan region of southern and part of the Central Belt of Kelantan. Lojing was part of the Gua Musang Group that recently proposed the definition of argillite-carbonate-volcanic deposited during the Permo-Triassic period. It consists of argillaceous, carbonate, volcanic or pyroclastic faces and was divided into four formations: Aring Formation, Telong Formation, Gua Musang Formation and Nilam Formation (Kamal Roslan Mohamed, et al., 2016).

The general geological map of Kelantan is shown in Figure 2.1. Based on the geological map of Kelantan, it shows that the lithology of Kelantan varied as it consisted of multiples rocks such as igneous, sedimentary, and metamorphic rocks (Department of Minerals and Geoscience Malaysia, 2003).

The regional geology of Kelantan, according to Goh (2006), consists of a sedimentary centre zone and meta-sedimentary rocks flanked on the east and west by Main Ranges Granite and Boundary Ranges Granite. The Kelantan state can be categorized into four landscape types based on geomorphology: hilly areas, mountainous areas, coastal areas, and plain areas. Except for the coastal areas, which are exclusively found in the northern portion of Kelantan, these types of terrain can be found in the Gua Musang district.

Gua Musang, the study area, is located in Kelantan's southern section and is part of the Central Belt. The Permian-Triassic clastic, volcanic, and limestone dominate the Central Belt (Mohamed, 2016). Gua Musang had distinct morphological characteristics and was surrounded by karst limestone with numerous geological features. Peninsular Malaysia, Sarawak, and Sabah have a lot of limestone landscape or karst topography.

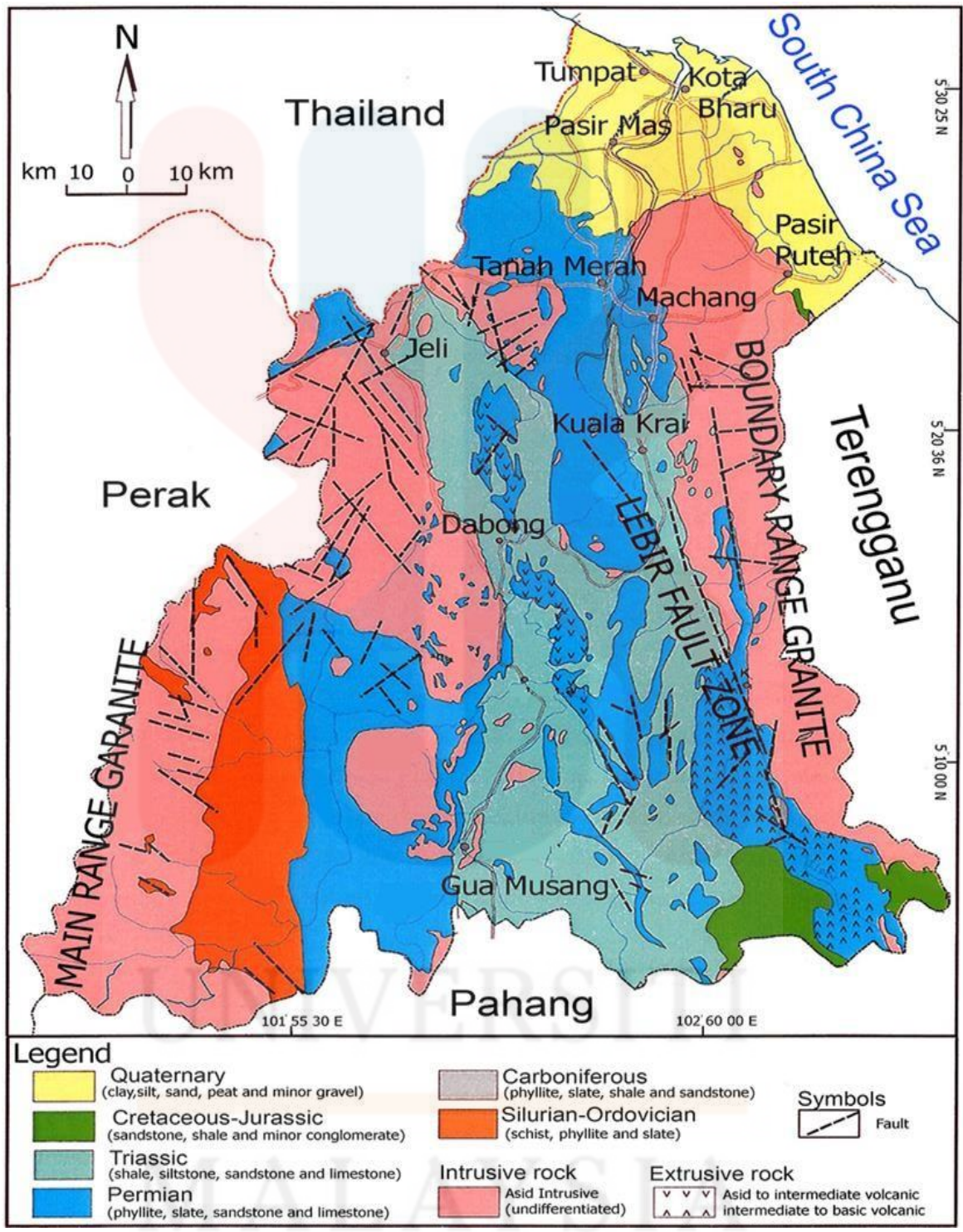


Figure 2.1: Geological map of Kelantan. (Source: Department of Minerals and Geoscience Malaysia, 2003).

KELANTAN

2.3 Stratigraphy

The Gua Musang Formation and the Gunung Rabong Formation are two formations in the Gua Musang area. According to Yin (1965), the Gua Musang Formation is made up of argillaceous and calcareous intercalation of volcanic rock, with arenaceous rock to the south. From the north and south of Kelantan, the units stretch to the north of Pahang. Ammonoids and pelecypods are fossils that date from the Permian through the Middle Triassic periods (Ichikawa and Yin, 1966).

The Gua Musang Formation was overlain in the stratigraphic layer by the Gunung Rabong Formation, which is called after the town of Gua Musang in Kelantan's south. In the southern Kelantan district of Gua Musang, the Gunung Rabong formation is predominantly arenaceous and argillaceous in nature, with subordinate calcareous, volcanic, and rudaceous bands.

The Gunung Rabong Formation, found in southeast Kelantan and north Pahang, dates from the Middle to Upper Triassic and is laterally comparable to the Telong and Semantan Formations. It sits atop the Gua Musang Formation in an unconformable manner. Lanis conglomerate is overlain by Kerum Formation, which dates from the Late Triassic (Yin, 1965).

Furthermore, based on the lithostratigraphy column of Bandar Utama Gua Musang (Figure 2.2) can be classified as meta-sediment (dominantly slate, slaty tuff, phyllite, meta-limestone) in Early Triassic, limestone or marble (composed of limestone and recrystallized limestone) in the Middle to Late Triassic, Quartzite (mainly quartzite subordinate with conglomerate) and Granite (granite and alkali feldspar granite) in Cretaceous and lastly the alluvium in the recent century (Lilly Azleena, 2019).

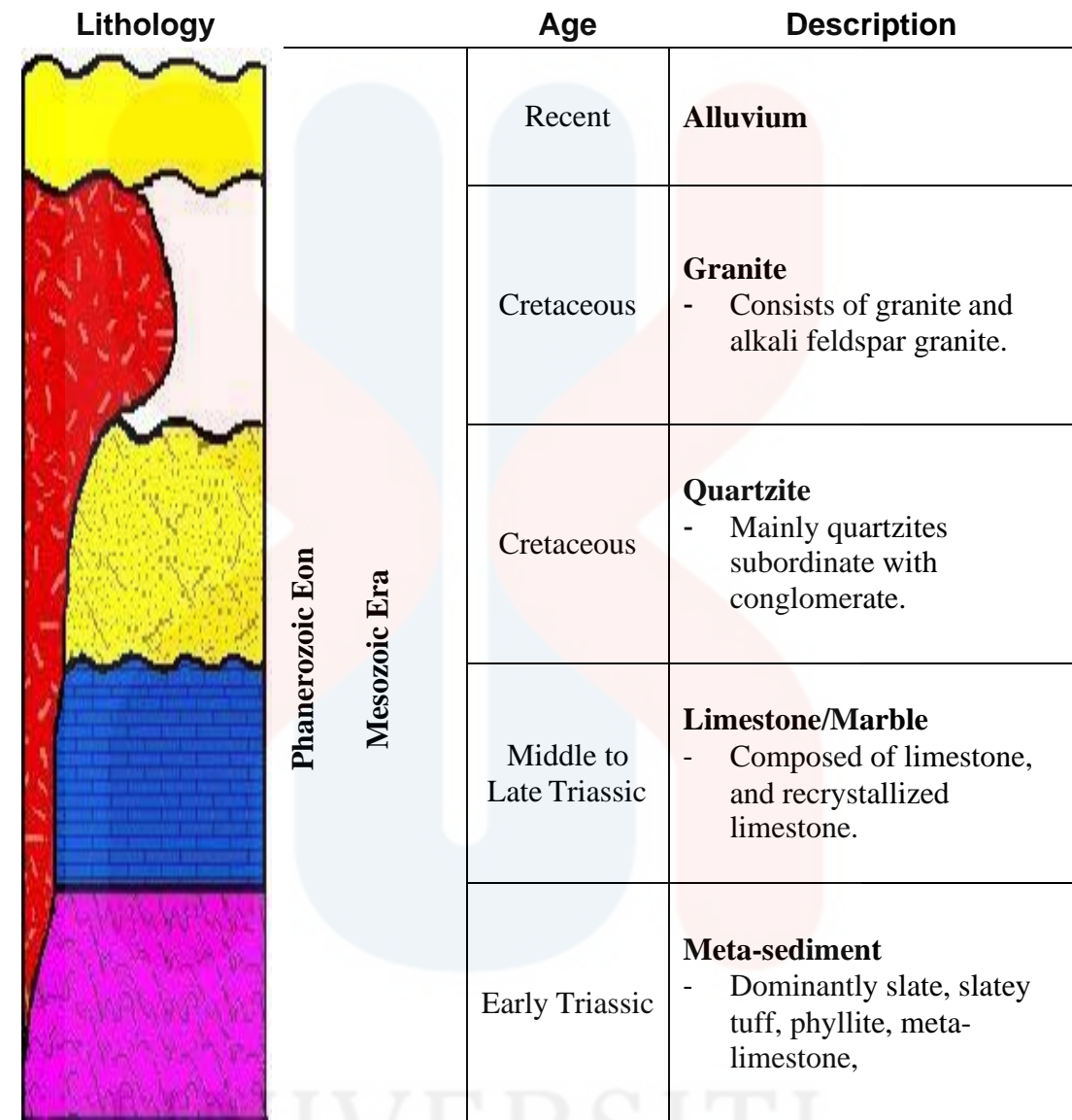


Figure 2.2: Lithostratigraphy column of Bandar Utama Gua Musang (Lilly Azleena, 2019).

2.4 Structural Geology

Gua Musang has unique physical characteristics and a large limestone karst area. Stalactite and stalagmite, caverns, and pinnacles are some of the structural geologies found in Gua Madu, Gua Musang's Permian limestone (Irfan, 2016). The underground limestone bedrock was the most likely location for karstic phenomena. The limestone karsts had been impacted by dissolution and weathering processes, and structural

research revealed that each limestone's stability had been compromised. According to Irfan (2016), certain areas of the lithology in the Gua Musang area had made contact or were influenced by the contact metamorphism process due to faulting and granite intrusion.

A large structural zone known as the Bentong-Raub Suture Zone has emerged in Kelantan state, which is located in the central belt of Peninsular Malaysia. The Central Belt's Bentong-Raub Suture Zone is a stretch of the primary Devonian to Middle Triassic Paleo-Tethys Ocean that forms the boundary between Gondwana and the Sibumasu and Indochina terranes (Metcalf, 2000).

In previous research, three depositional contacts have been identified: the contacts between quartzite and conglomerate, between fine- and coarse-grained limestone, and between silicified tuff and carbonaceous shale. Along the main road from Gua Musang to Kuala Krai, granite and hornfels has intrusive contact or also known as contact metamorphism (Lilly Azleena, 2019).

2.5 Historical Geology

Gua Musang has unique morphological features such as hills and is surrounded in the limestone sections by karstic morphology, which has a variety of geological elements. Limestone terrain, often known as karst topography, may be found throughout Peninsular Malaysia, Sabah, and Sarawak. The state of Kelantan can be categorised into four categories of landscapes based on geomorphology: mountainous areas, hilly areas, plain areas, and coastal areas (Tanot et al., 2001). Except for the coastal areas, which are only found in the northern section of Kelantan, all of these landscape types may be found in the district of Gua Musang.

The study area consists of two formations which are the Gua Musang Formation and Gunung Rabong Formation. As mentioned by Abdullah (2009) and Yin (1965), Gunung Rabong is underlie by Gua Musang Formation reflects that Gunung Rabong Formation is younger than Gua Musang Formation. In Gua Musang Formation, the rock that found in the field consists of limestone unit, slate unit, volcanic tuff unit and granite unit. For Gunung Rabong Formation, it is composed of meta-sediment (Lilly Azleena, 2019).

The intrusion of granite gave rises to the formation of hornfels in Gua Musang. This hornfels is the results of the contact metamorphism process between the granite intrusion and the country rock. Under the Gunung Rabong Formation, the rocks that found are the quartzite with minor conglomerate intercalated with sandstone and siltstone. In contrast with Abdullah (2009), no shale was found. This is due to the rock have undergo the metamorphism process.

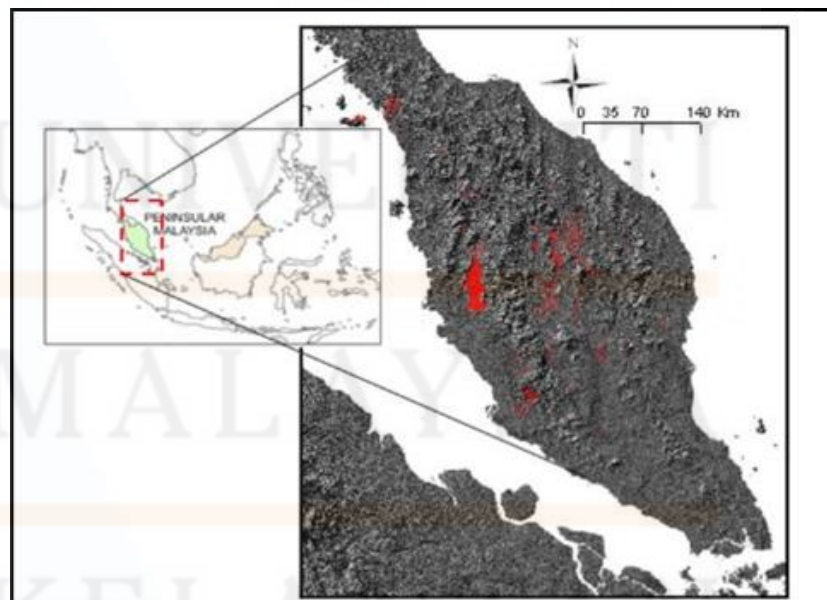


Figure 2.3: The distribution of limestone or karst topographic in Peninsular Malaysia (Source: Department of Mineral and Geoscience Malaysia).

2.6 Geoheritage and Geotourism Value Mapping

2.6.1. Geoheritage-Geotourism Definition

Geological heritage is defined as an applied scientific discipline which focuses on unique, special and representative geosites. This discipline supports the science of geology. Geoheritage is an integral part of the natural heritage which encompasses the special places and objects that have a key role in our understanding of the history of the Earth (its rocks, minerals, fossils, and landscapes) (Dony Adriansyah, 2015).

2.6.2. Value of Geoheritage and Geotourism

The Geological Society of America (GSA, 2012) defines "geoheritage" as a broad term that refers to geologic features or sites that have substantial scientific, educational, cultural, or aesthetic value.

2.6.3. Geoheritage-Geotourism Ranking Value

By quantitative method, the heritage value will be identified with range (0-5). Thus, the geoheritage-geotourism ranking value mapping will be generated by ArcGis processes and based drone generated image.

i. Scientific

Related to geologic features and landscapes, distinctive rock or mineral types, unique or unusual fossils, or other geologic characteristics that are significant to research. Important for geological records and Earth's history.

ii. Educational

Simple value related to education, such as how to educate people to appreciate the geological sites and features. Scientific value is more systematic and

comprehensive. To train and educate professional geoscientists, university/school students, and the general public.

iii. Cultural

Related to places where geologic features or landscapes played a role in cultural or historical events.

iv. Aesthetic

Related to features, landforms/landscapes that are visually appealing because of their geologic features or processes.

v. Recreational

Related to tourism and recreational activities that can be conducted in the sites.

vi. Economical

The financial value of the resources depending of their nature.

vii. Historical

History of the study area.

2.6.4. Geoheritage-Geotourism Ranking Value Mapping

The geoheritage value will be identified in the specification study area. Then, the values will be group out with polygon with the value (cultural, aesthetic, educational, recreational, scientific, economical).

No.	Geological feature	Scientific (and educational) value	Aesthetic value	Recreational value	Cultural value	Historical value	Economical value	Functional value	Total
1.	Gunung Reng	5	5	5	0	3	3	0	21
2.	Jeli Hot Spring	5	3	4	0	0	0	3	15
3.	Pergau Lake	3	4	5	0	0	4	4	20
4.	Gold deposits in Kg. Kalai	5	3	2	0	3	5	0	18
5.	Lata Janggut	5	4	5	0	0	0	0	14
6.	Sungai Rual	5	4	4	5	0	0	0	18
7.	Lata Renyok	5	5	4	0	0	0	5	19
8.	Lata Chenai	5	4	4	0	0	0	0	13
9.	Setir Cave complex	5	4	3	0	0	4	0	16

Note: 0 = none; 1 = very bad; 2 = bad; 3 = fair; 4 = good; 5 = very good

Figure 2.4: Example of the numerical assessment of geoheritage value/ resources for ranking in Jeli districts, Kelantan, Malaysia (Dony Adriansyah et.al, 2015).

2.7. GIS-cater for both geological mapping and geoheritage-geotourism value mapping.

For geological mapping, GIS really give the benefit and good tools to generate the geological map in the study area. It very useful for map analysis and geographic data compilation. The GIS (ArcMap) can produce a many geological types of maps which include the topography, drainage, geomorphology, fault and lineament map. All relevant thematic maps were classified and overlaid in the spatial analyst tool using the weighted overlay approach in this study and include GIS (ArcGIS software).

New technical, technological, and methodological discoveries, such as those based on Geographic Information Systems (GIS), are applied in scientific investigations of the conservation state of local, national, or global cultural heritage. These systems are among the most innovative technologies that allow for the spatial and cartographic depiction of the features included in relational databases; these databases allow for the visual portrayal of the geographic distribution of historical monuments (Dony Adriansyah, 2015).

CHAPTER 3

MATERIALS AND METHOD

3.1 Introduction

There are several materials and methods used in order to complete the process in collecting data and the important details for geological mapping and geoheritage value in Bandar Utama, Gua Musang that will help in this investigation. The suitable materials and appropriate method have to apply to get the concrete results.

3.2 Materials/ Equipment

The mapping is carried out in the study area to determine the location of geological characteristics and their recent geological conditions. The mapping was conducted to gather detailed information including geomorphology, lithology, stratigraphy and geology of the structure.

3.2.1 Topography Map

Used for information about conditions, location, distance, travel routes and communication. Topographic maps also display regional variations, vegetation cover levels and differences in contour height.

3.2.2 Arcgis Software

ArcGIS is a platform for organizations to create, manage, share, and analyze spatial data. It consists of server components, mobile and desktop applications, and developer tools.

3.2.3 Drone Technology

The drone technology will be used to capture image at the high elevation of the 8 limestone karsts. The drone will be taken up from the faculty of Earth

Science.

3.2.4 Agisoft software

The Agisoft Metashape software will be used to process the image and generated to 3D view.

3.2.5 Global Mapper, DEM

The global mapper software also will be generated the image in 3D with depth and the structure of the area.

3.2.6 Secondary Data

Data that was gathered from online database like JMG (Department of Minerals and Geosciences) and from agencies. The data is used to process, analyze and interpret the geology study area. The data is collected in spatial and attribute data.

No.	Data Type	Data	Data Description
1.	Spatial	Geological Map of Kelantan	Sources: Department of Mineral and Geoscience Malaysia (JMG) Scale: 1:1,000,000
		Data of GIS Kelantan	Source: Department of Mineral and Geoscience Malaysia (JMG) Format: Shapefile (shp)
		Aerial/ Satellite Imagery	Sources: Google Earth Pro Year: 2015 Resolution: 30 meters

Table 3.1: Table of inventories

Material	Functions
Topographic Map (Base map)	The data and information of the study area is gain through base map before going to field.
Drone	To view and capture image from above and will generate by Agisoft software.
Global Positioning System (GPS)	The coordinate and the track also outcrop at the location is record and mark in the GPS.
Geologic Hammer	Use to take the sample of rocks and acts as tools to real scale for the rock samples.
Brunton Compass	The strike and dip of geological structures such as bedding is measure by using Brunton Compass.
Hand Lens	The Hand lens is used to examine the rocks sample closely including fossils, minerals and other materials in tiny scale.
Sample Bags	The rocks sample are place in the sample bag which will label with coordinate of location where the sample is taken.
Measuring Tape	The length and width of the outcrops are measured at the field.
Field Notebook	To write and record all the data.
Camera	Acts as tool to snap the outcrop photo and geomorphology view.
HCl	Hydrochloric acid was used to test on the sample to identify the carbonate rocks.

Table 3.2: Lists of materials and their functions.

3.3 Methodology

3.3.1 Preliminary Study

The preliminary study in doing this research was to conduct a preliminary investigation. It serves as a desktop study from which data on the research topic was gathered. There are numerous sources of information, including books, essays, journals, geological maps, and the internet. This strategy can aid in the explanation of the study topic. Preliminary study often focuses on geological heritage studies, general geology, geomorphology, sedimentology, palaeontology, and stratigraphy in the Gua Musang area. The preparatory study must be completed before mapping the study area.

All of the data has been compiled from previously published research. The material is gathered by reading journals, papers, articles, books, and theses, and the literature review will aid in learning more about the research topic and can be used as a guide for doing the study.

3.3.2 Geological mapping

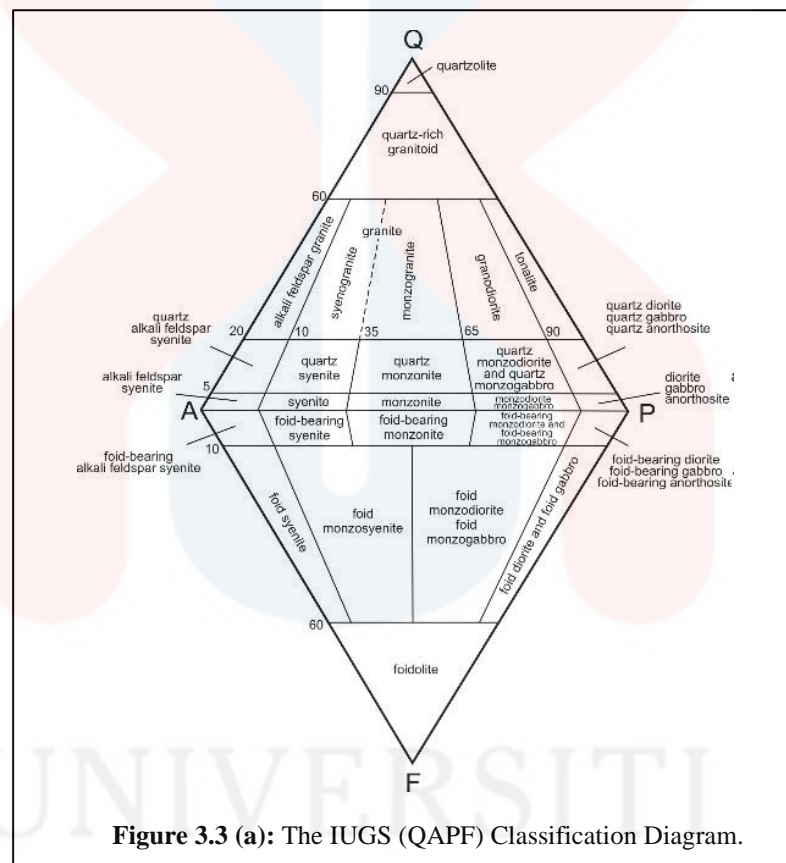
3.3.2.1 Data Collection/ Field Studies

Field studies entail seeing and interpreting the research region while collecting data using various techniques and equipment such as GPS, hammer and Brunton compass. Before visiting the study area, the locality and study area were observed and recorded. The data was then transferred into ArcGIS Software to update the map version after crossing. Geomorphology, current lithology, and structural geology in the research area are also observed during field studies. It also entails rock sampling in order to assess facies correlations.

3.3.2.2 Sample Preparation and Data Analysis/ Laboratory Work

A tiny piece of the sample must be prepared in order to analyze it. It is proposed that thin sections of rock samples be prepared in order to undertake petrographic analysis and determine the mineral content and structure of the rock. For the classification of rocks and the interpretation of rock formations' environments, both mineral composition information and rock texture are critical. The optical microscope will be used to examine the thin section.

The data gathered at the sites will be processed, analyzed, and interpreted at this stage in order to gain all of the information on the geological features in the study area. For petrographic study, the mineral composition, textures, grain sizes, and fossil content data have been recognized and classified in their appropriate classifications. The mineral's name was given to it because of its properties. The mineral content of the rock can also be used to name it precisely by referring to QAPF diagram.



Data from geological mapping was interpreted and examined in this study, including coordinates, lithology, structural geology, geomorphology, and landform drainage patterns. Aside from that, the research area's designation is based on the area's major geological and geomorphological aspects. This information will aid in determining the structure's geology. In addition, the geological map at the research site is created using ArcGIS software. Map analysis and geographic data synthesis are also made easier with ArcGIS.

3.3.3 Geoheritage-Geotourism mapping

3.3.3.1 Data Collection/ Field Studies

In determining the geoheritage-geotourism value in Bandar Utama, Gua Musang, it all relies on the evaluation of study area. The analysis of the landscape was conducted based on procedure to study the heritage value at the place. First, the study area that consist interesting structures need to be identified. The drone technology also will be applied in this study to capture the image of the limestone karsts.

Next, the geoheritage value will be evaluate by using the quantitative assessment. It is mainly focused on some geodiversity (and geoheritage) values, mainly scientific (or intrinsic) and educational values and additional values such as aesthetic, recreational, cultural, historical, economical, functional, and so on (Gray, 2004, 2005). In addition, levels of significance should also be assigned for the ranking of geoheritage resources, such as international, national, state/regional, and local (Brocx and Semeniuk, 2007).

The quantitative method, related to the need to assess the geological features numerically (valuing) and to rank the features (Kubalikova, 2013). This approach was conducted by assessing numerically the potential geoheritage features based on their geodiversity and geoheritage values. For a case study, we can propose six classes of values which were simply established for this purpose: 0 (none), 1 (very bad), 2 (bad), 3 (fair), 4 (good) and 5 (very good).

3.3.3.2 Data Processing, Analysis and Interpretation

i. Agisoft software

Agisoft Metashape is a professional-quality image-based 3D modelling system. It works with random photos and is effective in both controlled and uncontrolled environments, thanks to the newest multi-view 3D reconstruction technology. Photos may be taken from any angle as long as the rebuilt item is visible in at least two of them. The 3D model reconstruction and picture alignment are both entirely automated (Wingtra Knowledge Base, n.d.).

ii. Global Mapper

Global Mapper is a cutting-edge GIS programme that offers a full set of spatial data processing capabilities to both novices and experienced geospatial experts, as well as access to an unprecedented range of data types. Global Mapper's straightforward user interface and logical organisation assist flatten the learning curve and guarantee that users will be up-and-running in no time. Organizations of any size soon experience a considerable return on investment brought about by fast data processing, precise map production, and optimal spatial data management (Blue Marble Geographics., 2022).

iii. Multi-criteria weighted-overlay analysis

Multi-criteria weighted-overlay is used to generate the Geoheritage-Geotourism value mapping. All of the geoheritage value that has been evaluated during fieldworks will be mapped and converted into raster, with polygon analysis. The raster then will be weighted from all of the data layers. After all of the layers have been weighted, the geoheritage-geotourism ranking value mapping will be generated by using the weight overlay tools from ArcGIS Pro 10.8 software.

3.4 Research Flow Chart

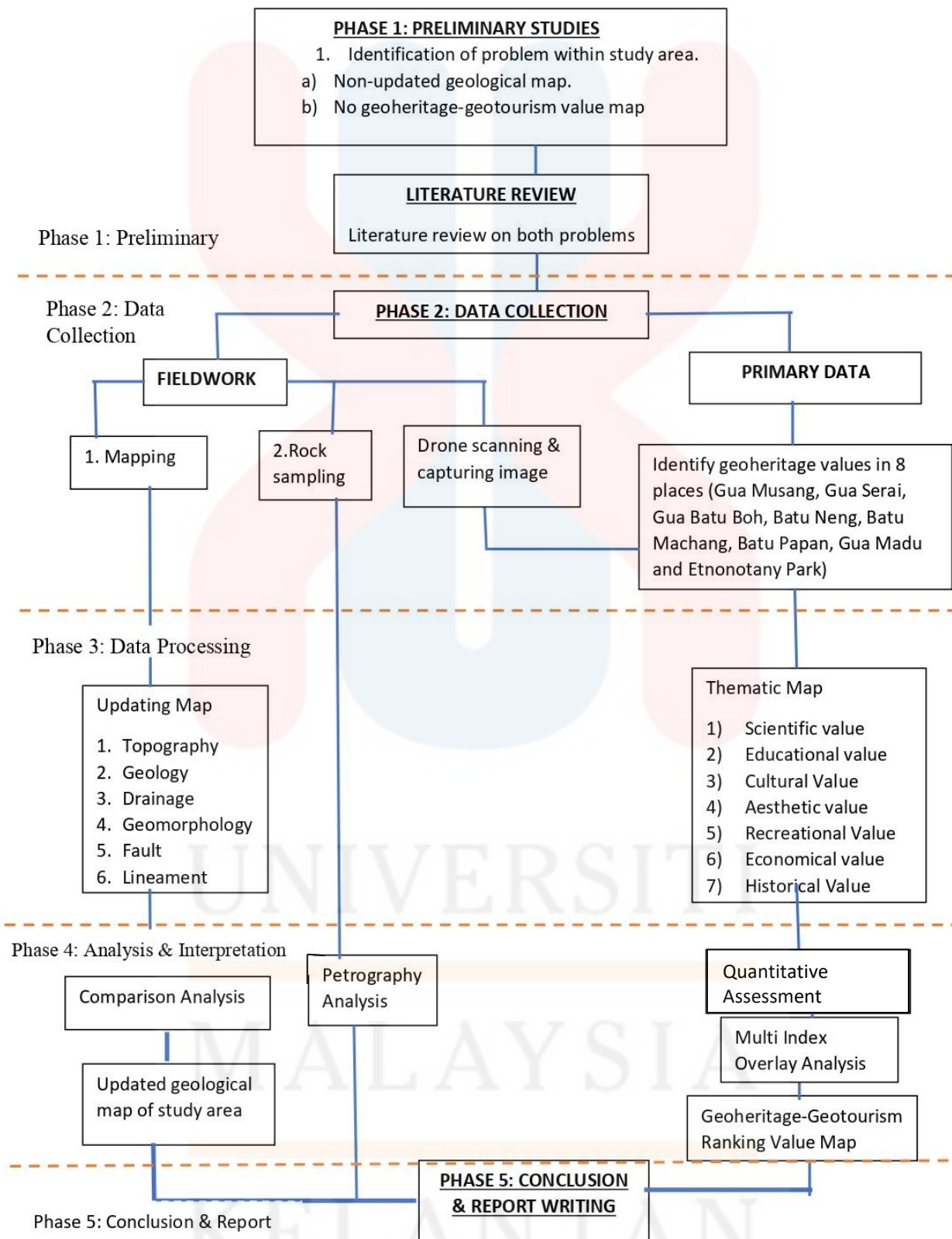


Figure 3.3 (b): Research Flowchart.

CHAPTER 4

GEOLOGY

4.1 Introduction

This chapter discusses all the data or information that was gathered and retrieved during the mapping operations at Bandar Utama Gua Musang. All the study area's geology, including geomorphology, lithostratigraphy, geological structure, historical geology, and structural mechanism, is covered by the data or information. For a deeper knowledge of the landform and properties of the research area, the chapter includes the traverse and observation map, drainage map, and geomorphology map. Additionally, the geological map of Bandar Utama Gua Musang was created using all the material and data in this chapter.

For the geologist to learn about or recognize the historical occurrences that had taken place in the study area, this chapter is highly essential. The accessibility is rather good because the study area is in Bandar Utama Gua Musang, where the majority of the area is a palm oil plantation accessible by main road and by road, respectively.

4.1.1 Accessibility

The ability of the research region to be reached from other destinations was examined in the accessibility section. It required a road, such as a main road, byroads, or a resident's route, as well as a specific mode of transportation, such as a motorcycle, four-wheel car, or other vehicle that was compatible with the physical characteristics of the route and the telecommunication system. In the study area, the communications infrastructure is decent. There is little coverage in all areas save for select rural and woodland areas. Additionally, Bandar Utama Gua Musang residents' socioeconomic status has an impact on accessibility.

This is due to the fact that the main roads, by-roads or off-roads, and railway availability were invented due to the presence of the city, school, mosque, and plantations that significantly contribute to the social and economic well-being of the Taman Bandar Utama Gua Musang's people. The mapping initiatives are therefore extremely successful.

4.1.2. Settlement

Settlement explained the process of human settlement comprises a private or public agreement to establish a community. The Gua Musang District Council's official website states that the district was created as a consequence of activities to expand the area from 1.76 km² to 129.5 km², which included the Kampung Star, Kampung Pulai, Pasir Tumbuh, Chegar Bogor, Kampung Kerinting, Limau Kasturi, Batu Papan, and Lapan Jaya. Additionally, they claimed that the addition of Galas, Bertam, and Chiku districts extended the Gua Musang district's overall authority to 7,979.77 km². The settlements Kampung Sungai Terah, Kampung Rahmat, Kampung Tembaga, and Kampung Baru Gua Musang are among those that have settled in the study area. The western quarter of the research region is where all of these communities are situated.

4.1.3. Vegetation

Bandar Utama Gua Musang is mostly composed of three different vegetation types: forestry, rubber plantations, and palm oil plantations. A palm plantation, a rubber plantation, and some forestry mainly composed around 80%, 15%, and 5%, respectively, of the research area. The key factors opening up job chances for residents in Gua Musang to improve their income and standard of living are vegetation like palm and rubber plantations.

The primary vegetation that encompasses almost the entire study region is palm oil. KPF Plantation Sdn. Bhd. Company owns this palm plantation. The majority of the palm trees were planted in mountainous terrain, changing some of

Bandar Utama Gua Musang's topography. The hill was chopped in order to grow the palm saplings, which resulted in a change in the scenery. As a result, the physical characteristics of the hill have changed, and Figure 4.1 illustrates how the hill now appears to be deserted. While, in Figure 4.2 shows other palm plantation in the study area. The rubber plantation is next to the KPF Plantation and is located at the base of Gunung Rabong. The Rubber Plantation in the Foothill of Gunung Rabong and view is seen in Figure 4.3 and Figure 4.4.



Figure 4.1: KPF plantation palm sapling.



Figure 4.2: View of Palm Oil Plantation



Figure 4.3: Rubber Plantation at Gunung Rabong Foothill.

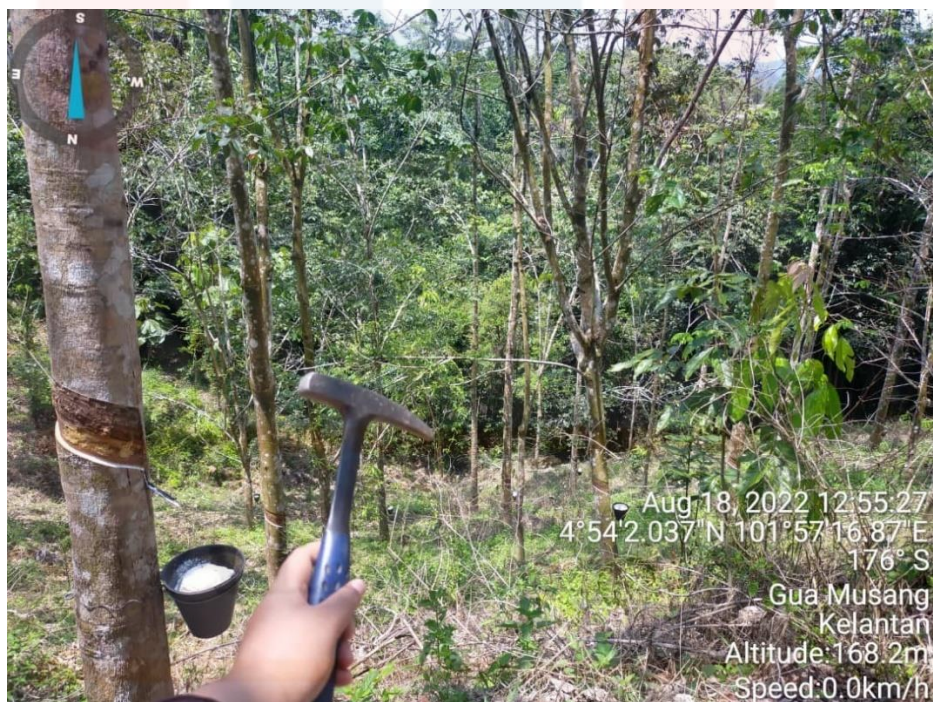


Figure 4.4: Close-up view of rubber plantation.

4.1.4. Traverses and observation

The traversing and monitoring approach is used in mapping activities to gather data and sample rocks. This method of traversing and observation involves entering the subject area via a road or river. The stream is being travelled because, often, fresh outcrops or outcrops that have been exposed to the elements can be found there. The place is chosen, and the path is prepared prior to traversing and observation. To determine the lithology of an area before traversing or viewing, different contour patterns in a topographic map are first investigated. The GPS data for the traverse's path and observing point will be used as reference to point the area that has been mapped.

Additionally, each observation point that is highlighted on the GPS is also noted in a notebook for a more thorough description. The description included details such as coordinates, elevation, lithology, strike and dip, level of weathering, rock color, or plant varieties. There are several portions of the research area that cannot be crossed due to their steep slopes and lack of accessibility.

4.2 Geomorphology

The topography categorization, weathering process, and drainage pattern of the research area are covered in the geomorphology section. The geomorphology of a place can be observed and studied to assist the observer recognized multiple kinds of landscape and landform features, spot physical changes to the earth's landforms, and get a hint about potential hazards that may arise naturally or due to environmental

factors. Additionally, through comprehending geomorphology, humans can organize and grow their socioeconomic system in a secure and effective manner. By accessing the greater slope or high elevation of the research region across Bandar Utama Gua Musang, one can observe the geomorphology of a certain location. The geomorphology of Bandar Utama Gua Musang and geomorphology of specification area can be seen in Figure 4.5 and 4.6.



Figure 4.5: Geomorphology of Bandar Utama Gua Musang.



Figure 4.6: Geomorphology of Specification Area.

The two main mechanisms that affect how the landform transforms in the studied area are endogenic and exogenic. Exogenic processes are those that are fueled by forces that originate above or outside of the earth, whereas endogenic processes are those that are fueled by forces that originate inside the earth. Human emissions can hasten this exogenic process. Diastrophism, volcanism, and metamorphism are among the endogenic processes at work in the research region, whereas mass movement, weathering and erosion, and volcanism are exogenic activities.

4.2.1 Geomorphology Classification

Based on its topographic and rock formations, Bandar Utama Gua Musang's geomorphology can be divided into many categories. The research area's terrain can be split into two types: rolling and undulating and hilly and mountainous. The karst landform, the granite landform and slate are the three types of rock landforms.

According to Figures 4.8 which show a 2D geomorphology map, the research region is dominated by hilly and mountainous landforms, with mean elevations above sea level ranging from 150 to 900 metres. The Gunung Rabong, which is in the southeast of the map, has the highest elevation. The western portion of the research area is then covered in a rolling and undulating terrain. The geography of the research region is rolling and undulating, as seen on the geomorphology map where flat plain and gently undulating slope alternated. This terrain's average elevation ranges from 0 to 150 metres. The rolling and undulating landscape at Gua Musang is a result of the karst formations.

The carbonate rock that arises to karstic landscapes like caves and high rock cliffs is what creates this karst landform. Then, one of the geomorphologies in the research area is the granite landform. The granite landform extends across the western portion of the research region from north to south, with a mean elevation above sea level that ranges from 0 to 320 meters. Figure 4.7 depicts the granite rock formation along the main road from Gua Musang to Kuala Krai. The granite landform, which has a considerable outcrop, is also present along the torrents in the southern part of KPF Plantation.



Figure 4.7: Granite landform along Gua Musang – Kuala Krai main road.

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GEOMORPHOLOGICAL MAP OF TAMAN BANDAR UTAMA GUA MUSANG

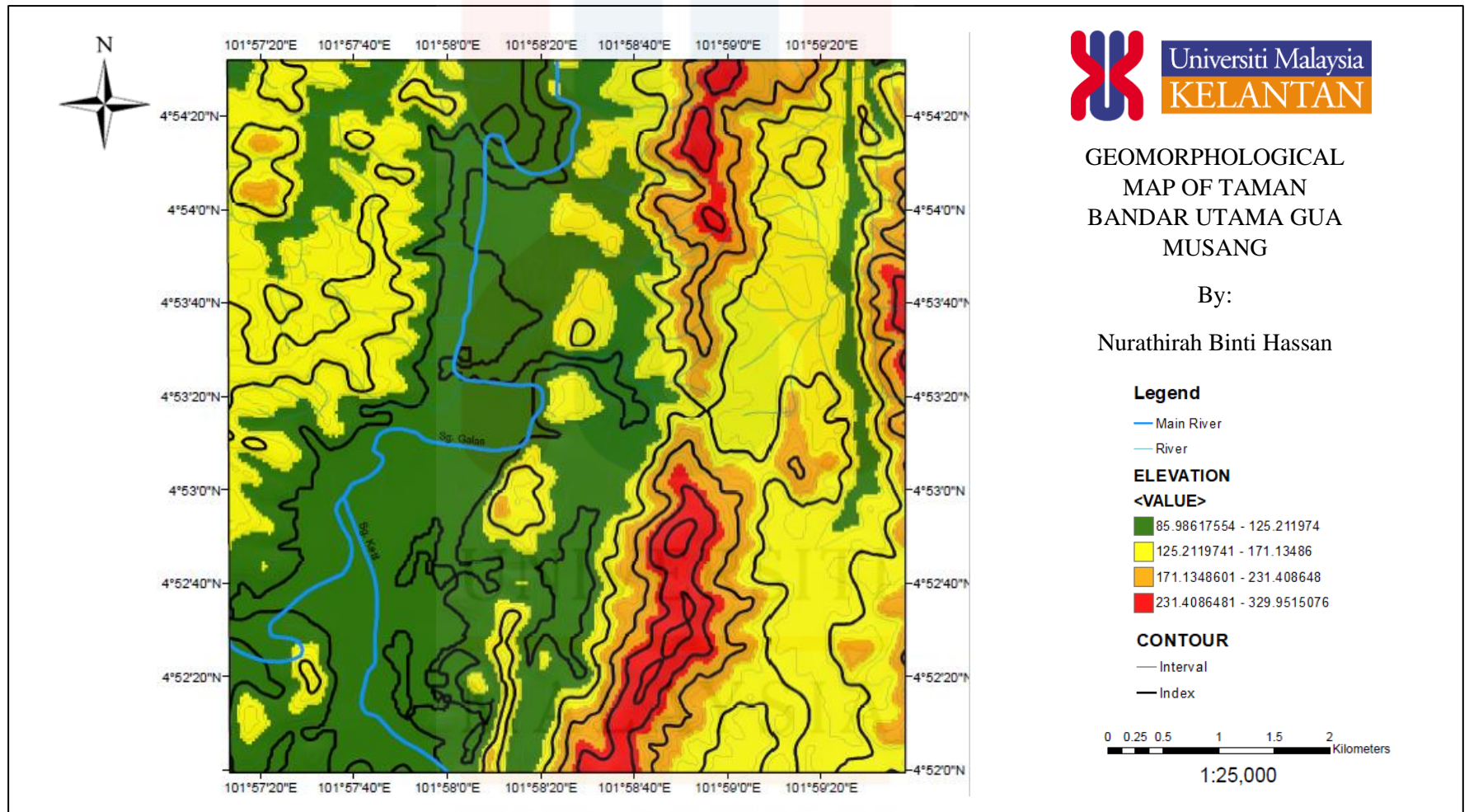


Figure 4.8: Geomorphological Map of Taman Bandar Utama Gua Musang.



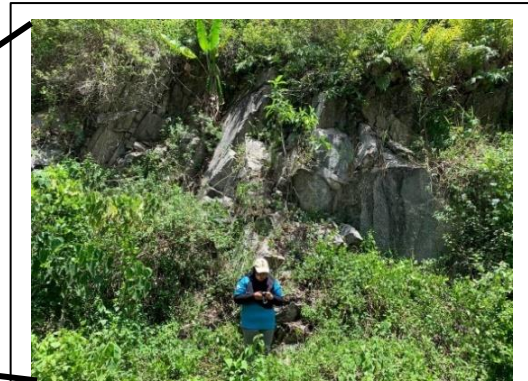
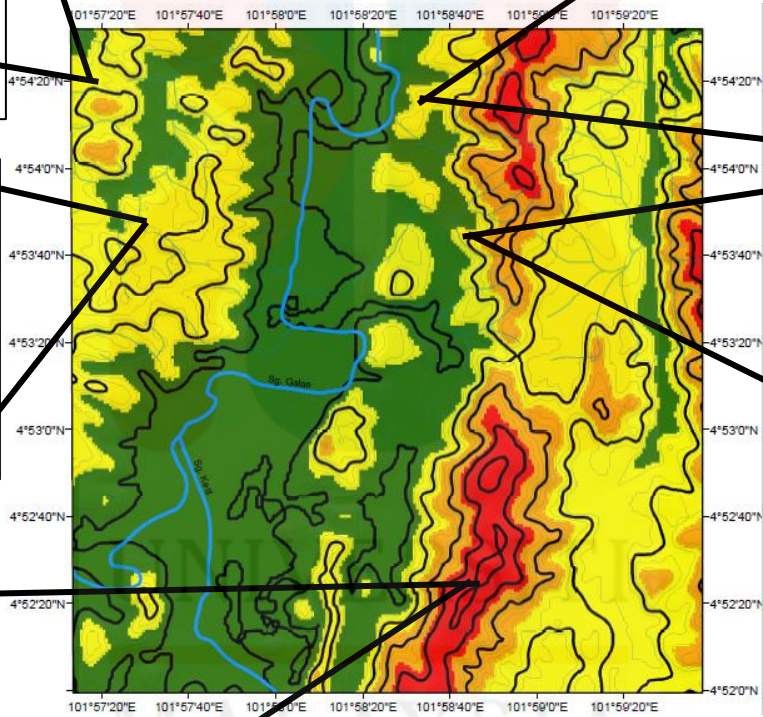
Slate



Quartzite



Limestone Karsts/Marble



Granite



ELEVATION

<VALUE>

- 85.98617554 - 125.211974
- 125.2119741 - 171.13486
- 171.1348601 - 231.408648
- 231.4086481 - 329.9515076

4.2.2 Weathering

The three different types of weathering processes which are physical weathering, chemical weathering, and biological weathering, can all be discovered in the research area. Any rock that weathers will eventually turn into regolith or soil. Soil composition varies depending on the kind of parent rock that has undergone weathering. The weathering process has an impact on daily life because, after the rock transforms into soil, the soil may be utilized to grow plants, build houses, mine stone, manufacture clay, and other things.

The process of physically weathering involves breaking down rock into tiny pieces without altering the chemical makeup of the rock. Physical weathering that can be found in the study area are abrasion by wind and water, frost wedging and block integration. The stress caused by the rocks' alternating expansion and contraction causes a series of fractures or joints, which eventually separate the rocks into blocks. Block integration is the term for this.



Figure 4.9: Physical weathering. (A) Abrasion by wind. (B) Abrasion by water through river. (C) Block integration. (D) Potholes that cause by the frost wedging process.

In addition, chemical weathering alters the composition of rocks by dissolving them through chemical reactions. Carbonation, oxidation, and solution are three kinds of chemical weathering that are observed in the research region.

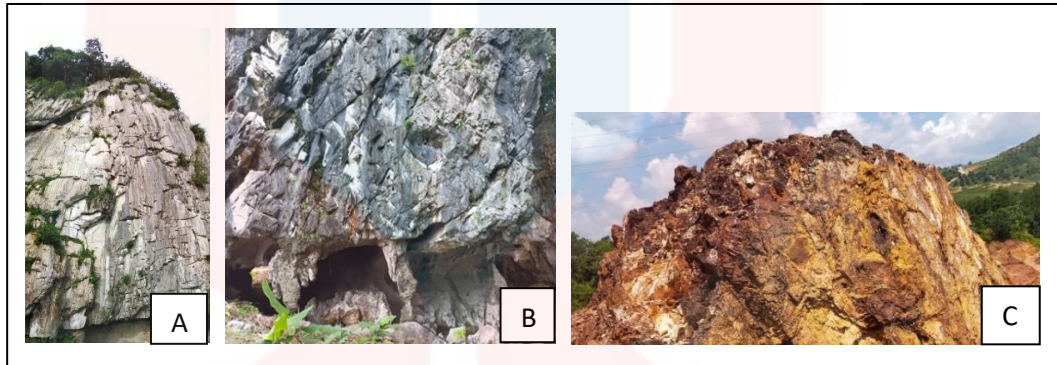


Figure 4.10: Chemical weathering of rock. (A) Carbonation process forms a cave. (B) Solution weathering forming the stalactites and stalagmites. (C) The rock rusty-like look cause from oxidation process.

The weathering process known as biological weathering occurs when plants, animals, or microorganisms break down the rock. Two types of biological weathering are present in the research area, including root penetration by plants into rocks and growth of black algae on rock formations.



Figure 4.11: Biological weathering process where the tree and plant roots penetrate into the rock cause them to crack and breaks.

4.2.3 Drainage Pattern

Dendritic pattern and annular pattern are the two different sorts of drainage patterns present in the research area, as shown by the drainage pattern map in Figure 4.12. Dendritic patterns resemble trees shaped and are made up of branching tributaries and the mainstream that shows V-rule or V-shaped valley and happen on homogeneous rock. While, annular appears in ring-shaped, form near circular bedrock structures that have been eroded (dome) and happen on igneous intrusion that breaks through sedimentary rock.

DRAINAGE PATTERN MAP OF TAMAN BANDAR UTAMA GUA MUSANG

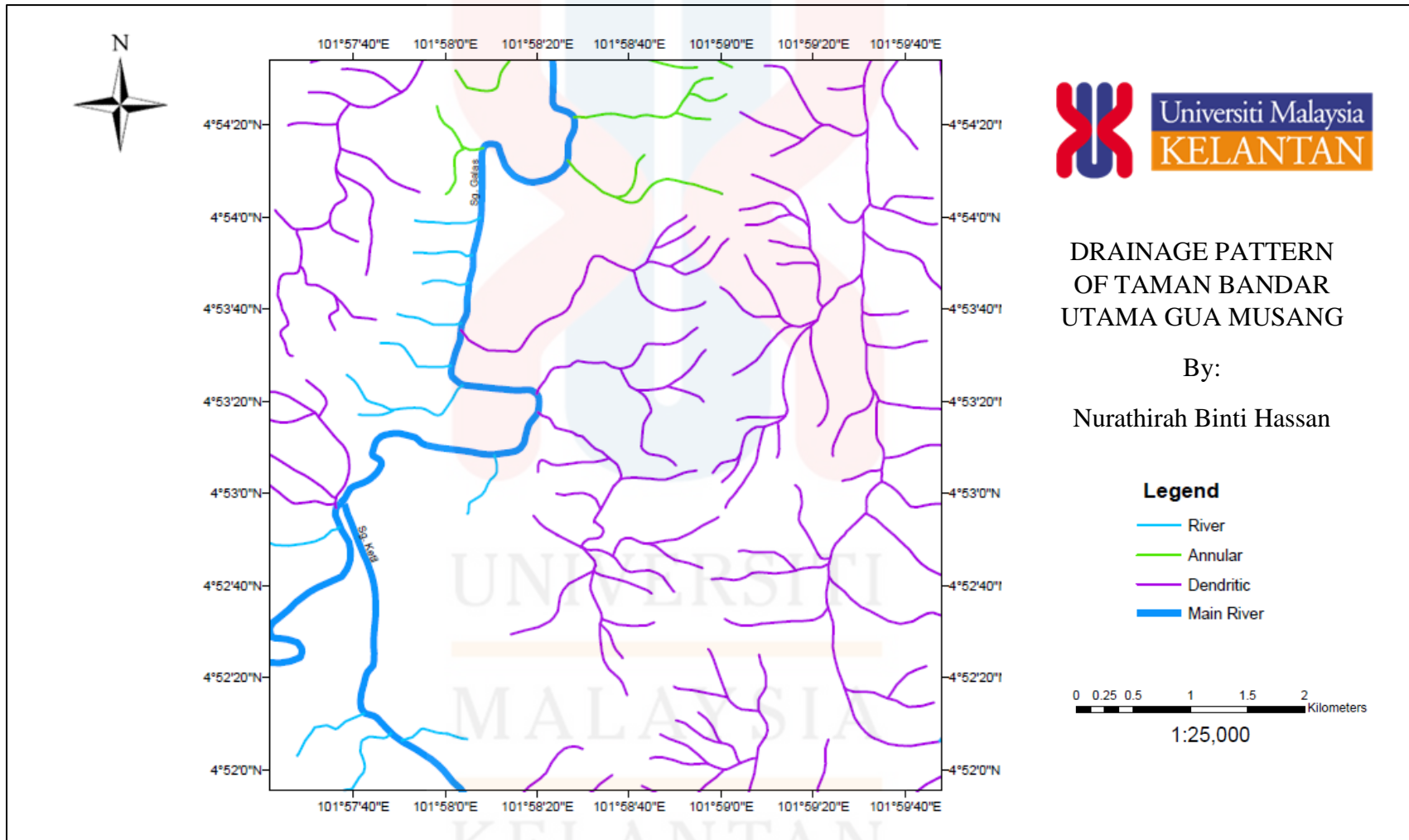


Figure 4.12: Drainage Pattern Map of Taman Bandar Utama Gua Musang.

4.3 Lithostratigraphy

The study of lithology involves describing a body of rock based on its physical characteristics, such as color, texture, composition, and grain size. Stratigraphy, on the other hand, is the studies of the configuration, distribution, chronological succession, or sequence of rock creation. Lithostratigraphy, which means analyzing the physical relationship among the rock units is a combination of lithology and stratigraphy. It is crucial to examine the lithostratigraphy because it enables us to put the events that took place in the studied area in chronological order.

4.3.1 Stratigraphy

In the stratigraphy section, the research area's rock units are arranged chronologically. The rock unit is the type of rock that was widely dispersed in the field and whose size may be mapped at a scale of 1:25, 000. Based on the geological map in Figure 4.13 (Geological Map), there were five types of rock formation which are marble, slate, quartzite, granite and quartzolite. The oldest rock is the metasedimentary rock during the Permian and the youngest is the quartzolite during Quaternary as shown in stratigraphy and lithostratigraphy column in Figure 4.14 and Figure 4.15.

GEOLOGICAL MAP OF TAMAN BANDAR UTAMA GUA MUSANG

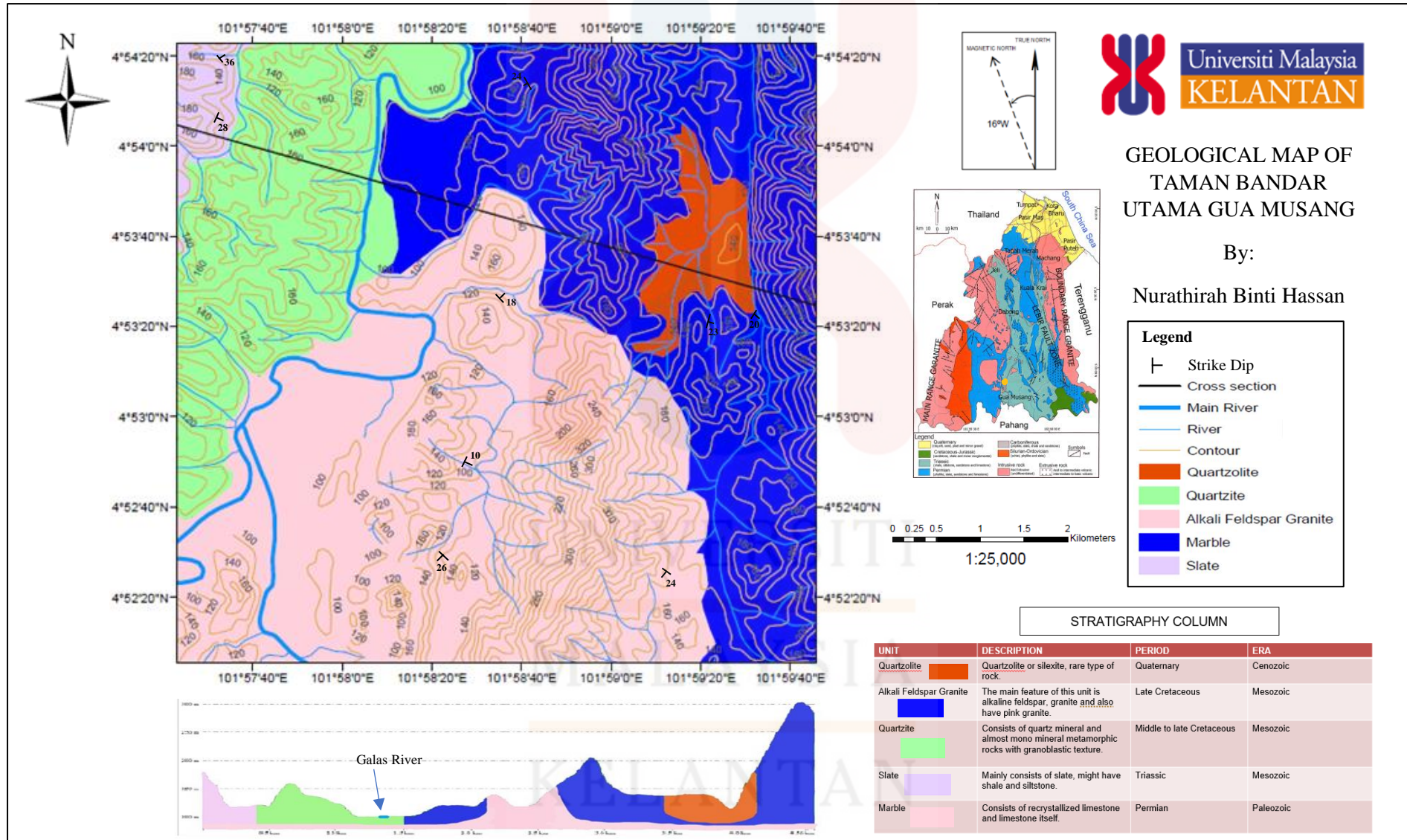


Figure 4.13: Geological Map of Taman Bandar Utama Gua Musang.

STRATIGRAPHY COLUMN			
UNIT	DESCRIPTION	PERIOD	ERA
Quartzolite	Quartzolite or silexite, rare type of rock.	Quaternary	Cenozoic
Alkali Feldspar Granite	The main feature of this unit is alkaline feldspar, granite and also have pink granite.	Late Cretaceous	Mesozoic
Quartzite	Consists of quartz mineral and almost mono mineral metamorphic rocks with granoblastic texture.	Middle to late Cretaceous	Mesozoic
Slate	Mainly consists of slate, might have shale and siltstone.	Triassic	Mesozoic
Marble	Consists of recrystallized limestone and limestone itself.	Permian	Paleozoic

Figure 4.14: Stratigraphy column of Bandar Utama Gua Musang.






LITHOLOGY COLUMN	
LITHOLOGY	DESCRIPTION
	Consists of some of secondary quartz, quartz (80% - 90%) in anhedral crystal system. Have massive structure, phaneric texture and coarse mineral.
	Bandar Utama Gua Musang granite consists of alkali feldspar mineral (60% - 70%) with anhedral crystal, quartz mineral (20% - 30%), biotite mineral (2% - 5%) and chlorite mineral (2% - 3%).
	Mainly consists of quartz mineral (90% - 100%) in anhedral crystal shape. Have granoblastic texture with <math><1/64 - >2\text{ mm}</math> in grain size.
	Consists of silica clay (85% - 90%), oxide clay (5% -8%) and quartz mineral (2% - 3%). Have slaty cleavage and blastopellite in texture. The grain size of minerals was around <math><1/256 - 1/8\text{ mm}</math>.
	Mainly consists up to 90% -100% of calcite mineral with anhedral crystal system. Have porphyroblastic texture and <math><1/256 - 1\text{ mm}</math> in its grain size.

Figure 4.15 (a): Lithology column of Bandar Utama Gua Musang.

COMPARISON OF GEOLOGICAL MAP OF JMG, PREVIOUS RESEARCHER MAP AND UPDATED MAP

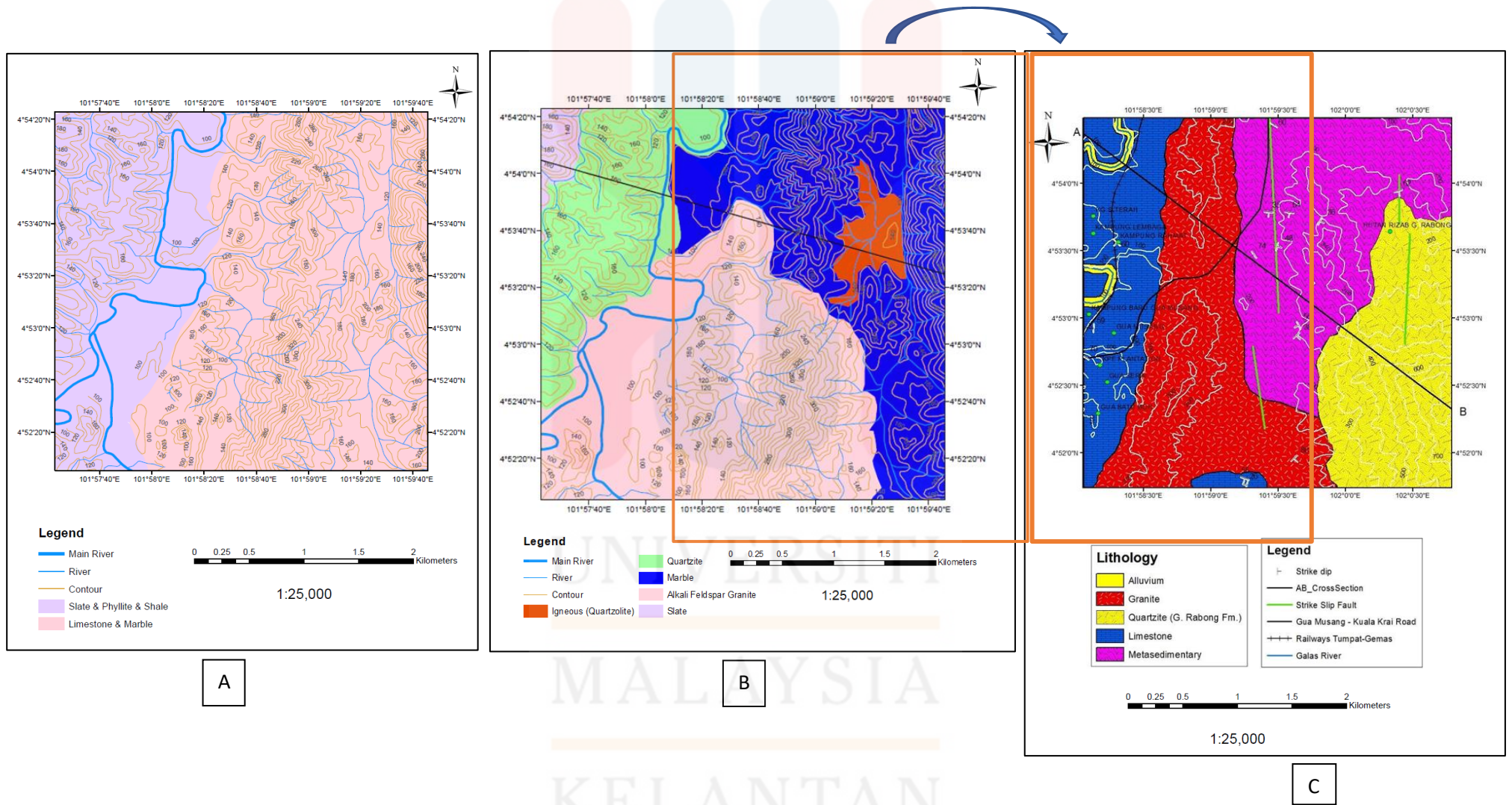


Figure 4. 15 (b): Comparison between geological map from JMG (A), my map/ updated (B), and previous senior/ researcher map, 60% overlapped (C).

4.3.2 Unit Explanation

Each unit described in section 4.3.1 will be further addressed in this subtopic along with a study of its petrography.

a) Marble/ Limestone

Limestone was discovered in the research area, which is shown on the map in the southern region. However, the limestone has undergone metamorphism process with the increases of temperature and pressure then form marble. The karst was big in scale and the most dominance. Based on formation of the limestone karst, it has been classified as the oldest formation in Bandar Utama Gua Musang which is in Permian age. Even so, there still have some limestone outcrop that form in the area. The Gua Musang cave and another cave (Gua Serai) which are situated across the main road from a Buddhist temple, both were significant limestone karsts or hills that have been discovered. Stalactite, stalagmite, and pillar cave structures were discovered. Galas River, the settlements (in the western study area), and KPF Plantation are all locations where additional limestone outcrops can be found.

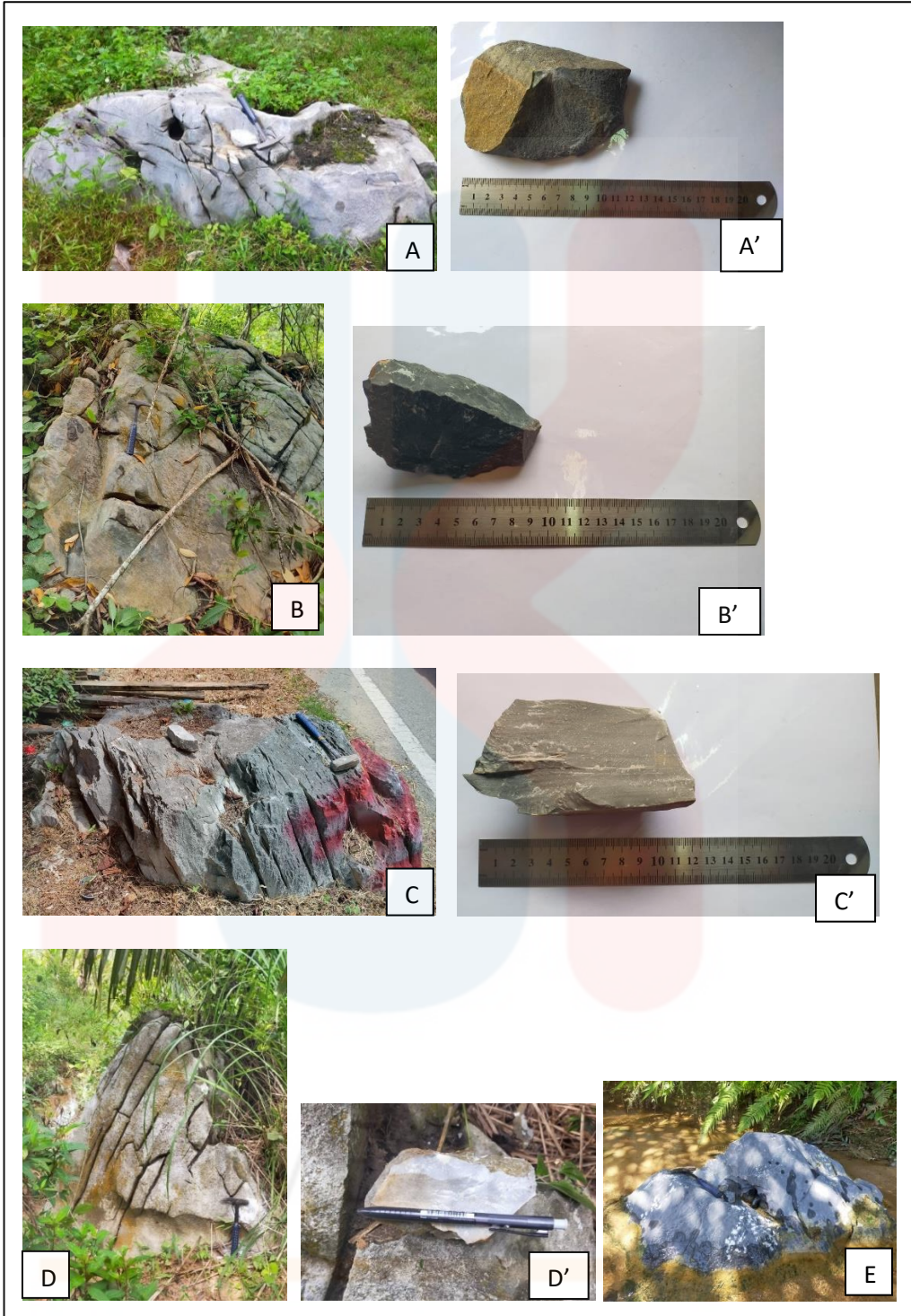




Figure 4.16: Outcrop marble/ limestone findings and sample taken. (A) The thin section analysis of the sample could be seen in the table 4.3.1 below. (B) – (E) The marble/limestone outcrop that found in the study area. (B') – (E') The rock sample taken.

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Table 4.3.1: Description marble (TH 001).

Sample code: TH 001		Location: KPF Plantation, Gua Musang.
Coordinate: N 04° 51' 47.5" / E 101° 59' 14.7"		
Classification: IUGS Classification		
Elevation: 90 m		
Rock Name: Marble		
Colour: Dark Grey		
Texture: Medium to coarse grain, granulose (non-foliated), crystalloblastic (granoblastic) texture, greatly sorted.		
Thin Section Analysis		
Minerals	%	Description
Calcite (Calc)	100	White to brownish, have a cleavage but not very clear - no cleavage appears. Anhedral crystal shape.
Description From the thin section below, the grains composed of crystals of calcite locked together like pieces of a jigsaw puzzle. The limestone undergoes metamorphism process and form into marble.		
Image		
<u>PPL</u>	<u>XPL</u>	
		
Magnificent: 10x/0.25P		

b) Slate

The slate rock that found has a fine-grained in grain size and foliated as shown in Figure 4.17. In the slate facies, there is minor carbonaceous and tuffaceous shale that were also found. Foliation can be described as either parallel arrangements of platy minerals or alternating layers of different mineral composition. During metamorphism, directed stresses typically cause foliation to occur, either in the compressional mode (perpendicular) or as shear (parallel).

Slate rock was coming from shale. Shale is a sedimentary rock that mostly comprises of clays. Similar to the metamorphism process, high heat and pressure can cause the clay flakes to recrystallize into very thin crystals of mica minerals, resulting in slate rock (muddy smell and microcrystalline texture). As pressure and temperature rise, the metamorphism process and recrystallization will proceed. Phyllite, schist, and subsequently gneiss will all eventually form from the slate in this situation (crystalline texture). This indicates that there is a possibility that phyllite, schist, and maybe gneiss was formed in the research area.

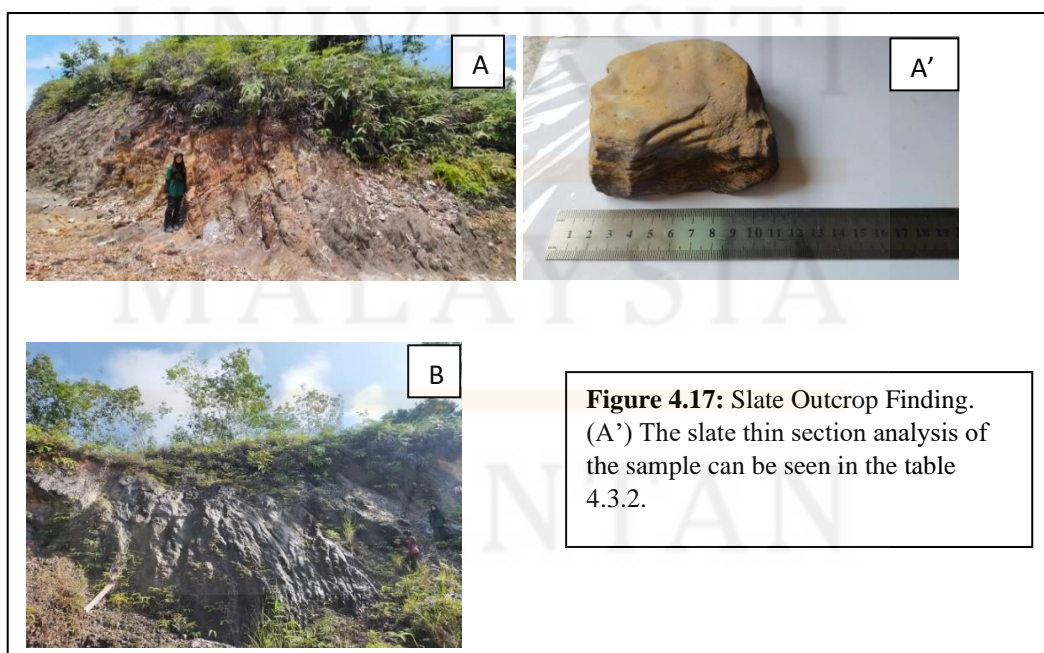
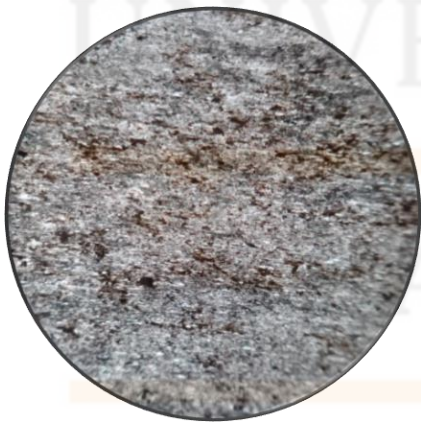



Table 4.3.2: Description Slate (TH 003)

Sample code: TH 003		Location: Jelawang Road – Gua Musang.
Coordinate: N 04° 53' 005" / E 101° 57' 15.051"		
Classification: IUGS Classification		
Elevation: 144 m		
Rock Name: Slate		
Colour: Dark grey with a bit orange (clay)		
Texture: Very fine to fine grained, has blastopellite texture, the foliation structure (slaty cleavage), grain size <math><1/256 - 1/8\text{ mm}</math>, well sorted.		
Thin Section Analysis		
Minerals	%	Description
Silica Clay	90	Colourless to brown in PPL, interference colour (dark grey to black) in XPL, no twinning.
Oxide Clay	5	Brown both in PPL and XPL, composed of mix silicate material and iron oxide in micron scale.
Quartz	5	Colourless in PPL, low relief, no pleochroism, anhedral, no cleavage, grey to white in XPL, no twinning.
<p>Description Based on the rock/ sample observations, the crystals not visible to the naked eye. The rock was brittle. While, based on thin section analysis, it has the slaty cleavage (fine foliation along which it breaks to leave smooth, flat surfaces). Dark slates usually owe their colour to carbonaceous material or to finely divided iron sulfide. Slate turns into phyllite as the metamorphic grade increases due to larger muscovite grains.</p>		
Image		
<u>PPL</u>	<u>XPL</u>	
		
Magnificent: 10x/0.25P		

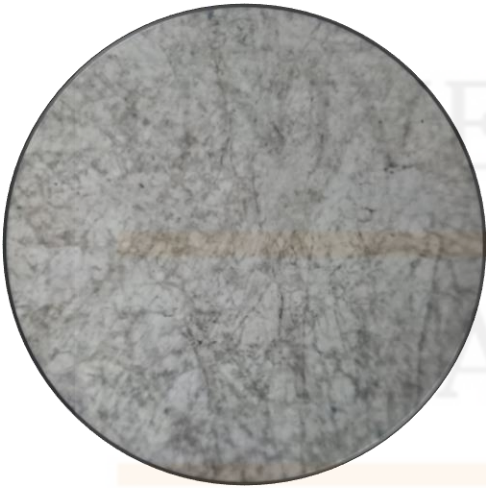
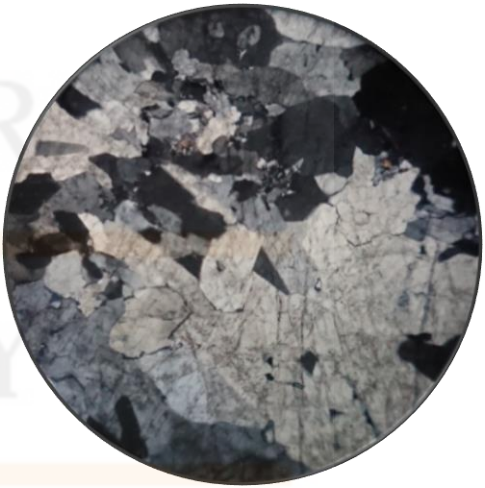
c) Quartzite

This unit is under the Gunung Rabong Formation which is younger than Gua Musang Formation. This rock unit were found at the North-Western part of the map of study area. All the thin section analysis in this unit is shown in Table 4.3.3.



Figure 4.18: Quartzite outcrop finding, and the sample quartzite taken.

Table 4.3.3: Description quartzite (TH 008).

Sample code: TH 008		Location: Palm Oil Plantation.
Coordinate: N 04° 52' 42.8" / E 102° 00' 23.6"		
Classification: IUGS Classification		
Elevation: 370 m		
Rock Name: Quartzite		
Colour: White		
Texture: Coarse grained, granoblastic texture with grains size <math><1/256 - 1/8\text{ mm}</math>.		
Thin Section Analysis		
Minerals	%	Description
Quartz (Qtz)	90	Colorless in PPL, light grey or greyish white to white interference color, no pleochroism, low relief, no twinning, anhedral, no cleavage.
Feldspar (Fs)	10	In PPL, Feldspar mineral is colorless and in XPL the color has a range white to brown.
Description The hand specimen is medium to coarse grained in size with white colour (quartz mineral clearly seen). Based on thin section analysis, the crystals are anhedral, non- foliated (granulose) and medium sorted. The grains are compact and has high hardness.		
Image		
<u>PPL</u> 	<u>XPL</u> 	
Magnificent: 10x/0.25P		

d) Granite

Granite formations were discovered near Bandar Utama Gua Musang, the KPF Plantation, and the main route between Gua Musang and Kuala Krai. Alkali feldspar granite is a type of granitic rock rich in the mineral orthoclase, also referred to as alkali feldspar. The orthoclase mineral, which has a color range of white to medium pink, is what gives granite its pink hue, as seen in the hand specimens in Figures 4.19 and Figure 4.20. In addition, the mineral compositions of pink granite are rich in quartz and biotite. When orthoclase or plagioclase feldspars have been subjected to hydrothermal alteration, the alteration mineral sericite is frequently found. This alteration mineral is typically connected to copper, tin, or other hydrothermal ore deposits. Tables 4.3.4 contain a thin section of alkali feldspar granite in great detail.

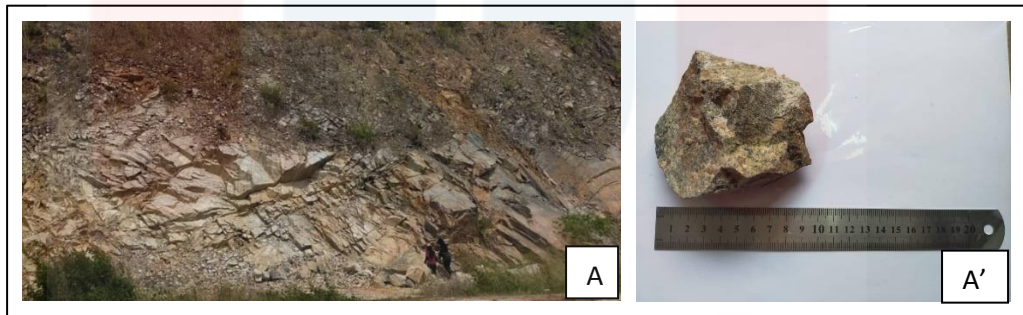


Figure 4.19: (A) Alkali feldspar Granite outcrop findings at Bandar Utama Gua Musang.

(A') Hand specimen, thin section analysis can be seen in table 4.3.4.

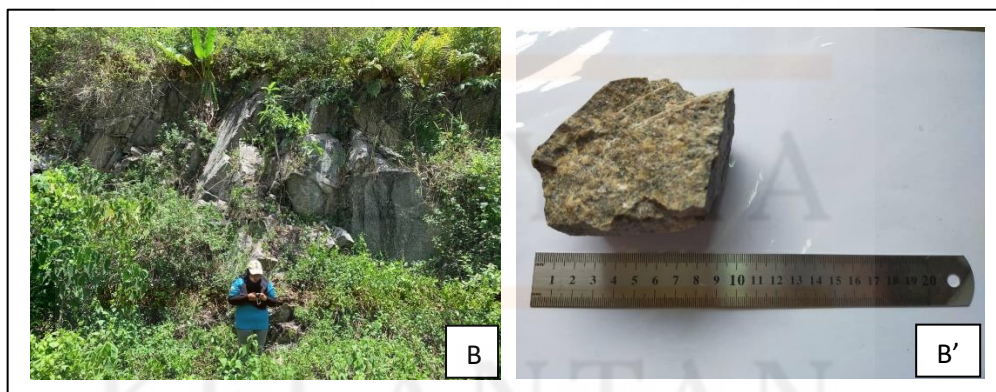
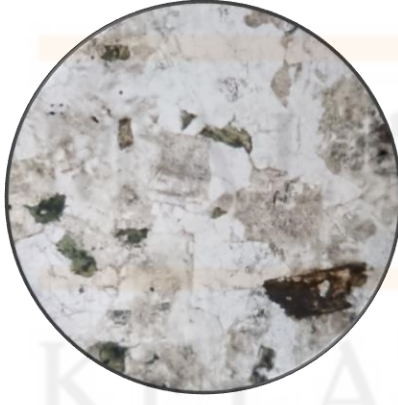
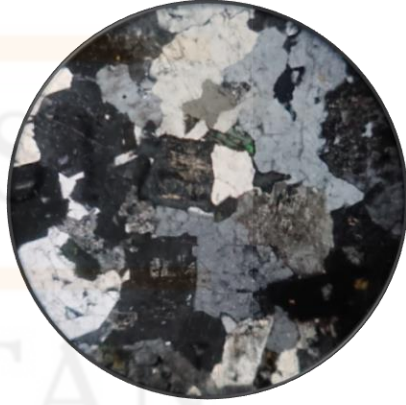


Figure 4.20: (B) Alkali feldspar Granite found along Gua Musang – Kuala Krai main road.

(B') Hand specimen taken.

Table 4.3.4: Description alkali feldspar granite (TH 006).

Sample code: TH 006		Location: Bandar Utama Gua Musang.
Coordinate: 4°53'31.47"N/ 101°58'48.15"E		
Classification: IUGS Classification		
Elevation: 121 m		
Rock Name: Alkali Feldspar Granite		
Colour: Greyish		
Texture: Phaneritic texture with massive structure, medium to coarse grained.		
Thin Section Analysis		
Minerals	%	Description
Sericite (ser)	64	Alteration from feldspar mineral, alkaline type. Colourless in PPL, low relief, no pleochroism, euhedral – anhedral, interference colour grey to white in XPL, no twinning.
Quartz (Qtz)	30	Colourless in PPL, low relief, no pleochroism, no cleavage, anhedral, interference colour grey to white in XPL, no twinning.
Biotite (Bt)	4	Brown to greenish in PPL, medium relief, high pleochroism, subhedral – euhedral, one direction cleavage. Interference colour is green to orange in XPL.
Chlorite (Chl)	2	Green in PPL, low to medium relief, low to medium pleochroism, anhedral – subhedral. Interference colour grey to dark green in XPL, no twinning.
Description The hand specimen is slightly weathered; however, the mineral still can be seen clearly with naked eyes. Based on the domination of sericite mineral in the thin section analysis, the rock name alkali feldspar granite was decided.		
Image		
<u>PPL</u>	<u>XPL</u>	
		
Magnificent: 10x/0.25P		

e) Quartzolite

Quartzolite or silexite is a rare type of rock. Based on thin section analysis, it consists of some of secondary quartz, quartz (80% - 90%) in anhedral crystal system and have massive structure, phaneric texture and coarse mineral. More than 90% of the felsic minerals in quartzolite, an intrusive igneous rock, are found in quartz. In addition to dykes, sills, and veins, quartzolite is a form of extremely rare rock.

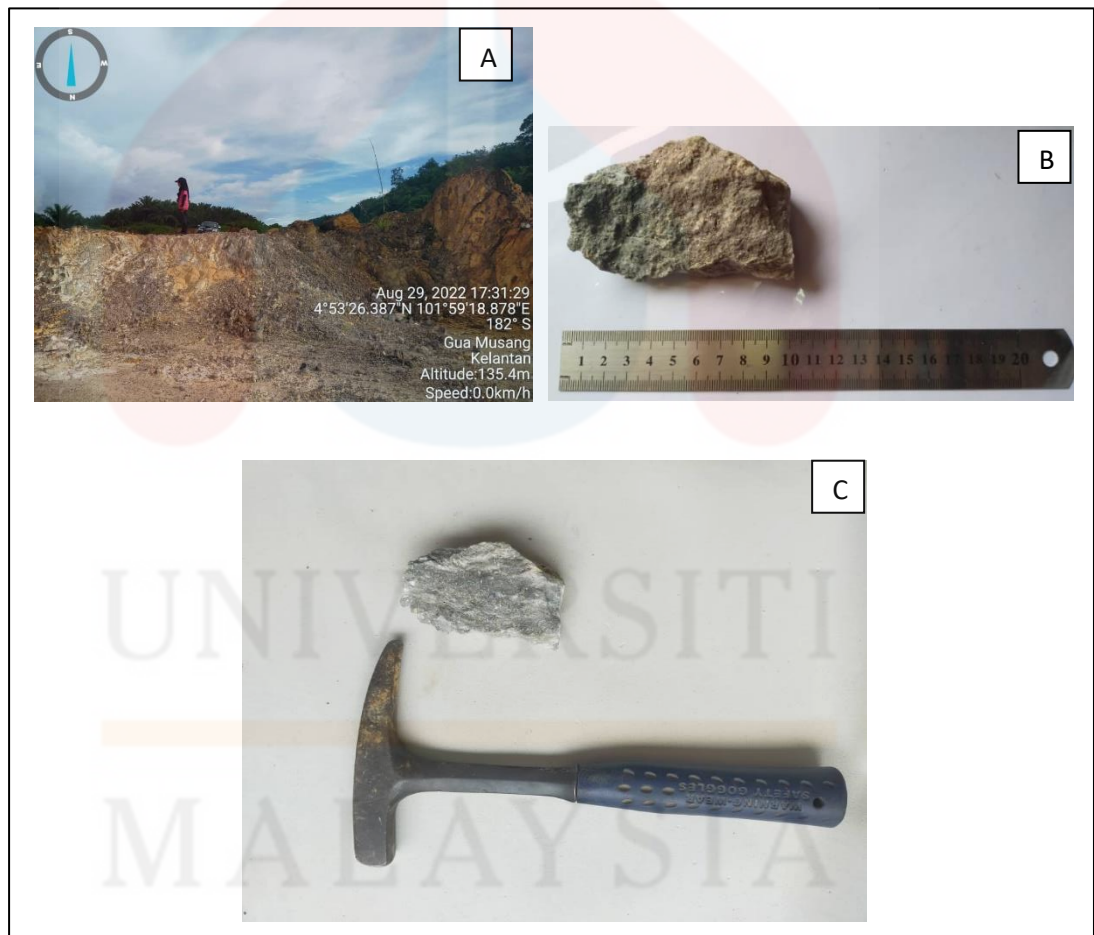
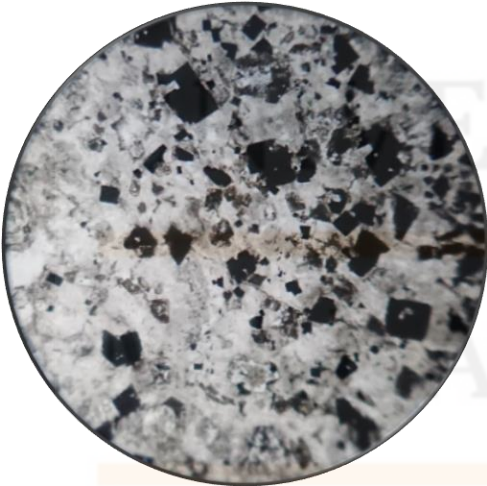
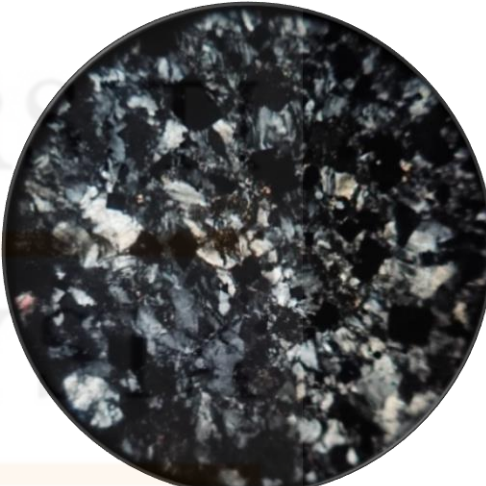


Figure 4.21: (A) Quartzolite dike or sills intrusion in clay. (B) Hand specimen of quartzolite. (C)

The other side (shining) with hammer scale.

Table 4.3.5: Description Quartzolite (TH 007).

Sample code: TH 007		Location: Palm Plantation, Gua Musang.
Coordinate: 4°53'27.29"N/ 101°59'16.51"E		
Classification: IUGS Classification		
Elevation: 122 m		
Rock Name: Quartzolite		
Colour: Light grey		
Texture: Phaneritic texture, massive structure, mineral grain size medium to coarse grained.		
Thin Section Analysis		
Minerals	%	Description
Quartz (Qtz)	70	Colourless in PPL, low relief, no pleochroism, anhedral, no cleavage. Interference colour grey to white in XPL, no twinning.
Opaque Mineral	30	Black in PPL, low relief, no pleochroism, euhedral – anhedral. Interference colour black, no twinning.
Description It is an igneous rock that composed essentially quartz, occurring in dikes, sills or veins during observation. Composed mainly primary quartz. This reason makes the rock name is quartzolite, which are extremely rare type of rock.		
Image		
<u>PPL</u>	<u>XPL</u>	
		
Magnificent: 10x/0.25P		

f) Iron Ore Mineral

Iron ore mineral also found in a big quantity near the KPF Palm Plantation, that form on the clay formation. However, it could not be counted into lithology section because it just a mineral that form on the Earth's surface.



Figure 4.22: (A) The iron ore mineral that form in large quantities through the oxidation process.

(B) The iron ore with scale.

4.4 Structural Geology

This section discusses all of the structural geology that may be found in the research region, including as joints, faults, folds, and contacts, along with their mechanisms. This section is crucial to geologists because structural geology can reveal information about the tectonic history of the studied area, associated historical conditions, and the events that led to the deformation of the rock. Due to the forces that were applied to the rock, it changed shape, location, and volume as it deformed.

The lineament analysis in the study area is carried out as indicated in Figure 4.23 before locating the regional structures in the area. The lineament analysis is carried out to locate faults that are a part of the regional structure in the research area. Figure 4.23 depicts a lineament with two significant faults: sinistral strike slip faults in the map's centre and dextral strike slip faults in the eastern portion.

Lineaments can be seen in aerial photographs or satellite images. In a topographic map, any linear features, such as a river or hill, are considered lineaments. This suggests the existence of a structure that was active in a faulting-related area and was able to convert these traits into a straight-line shape.

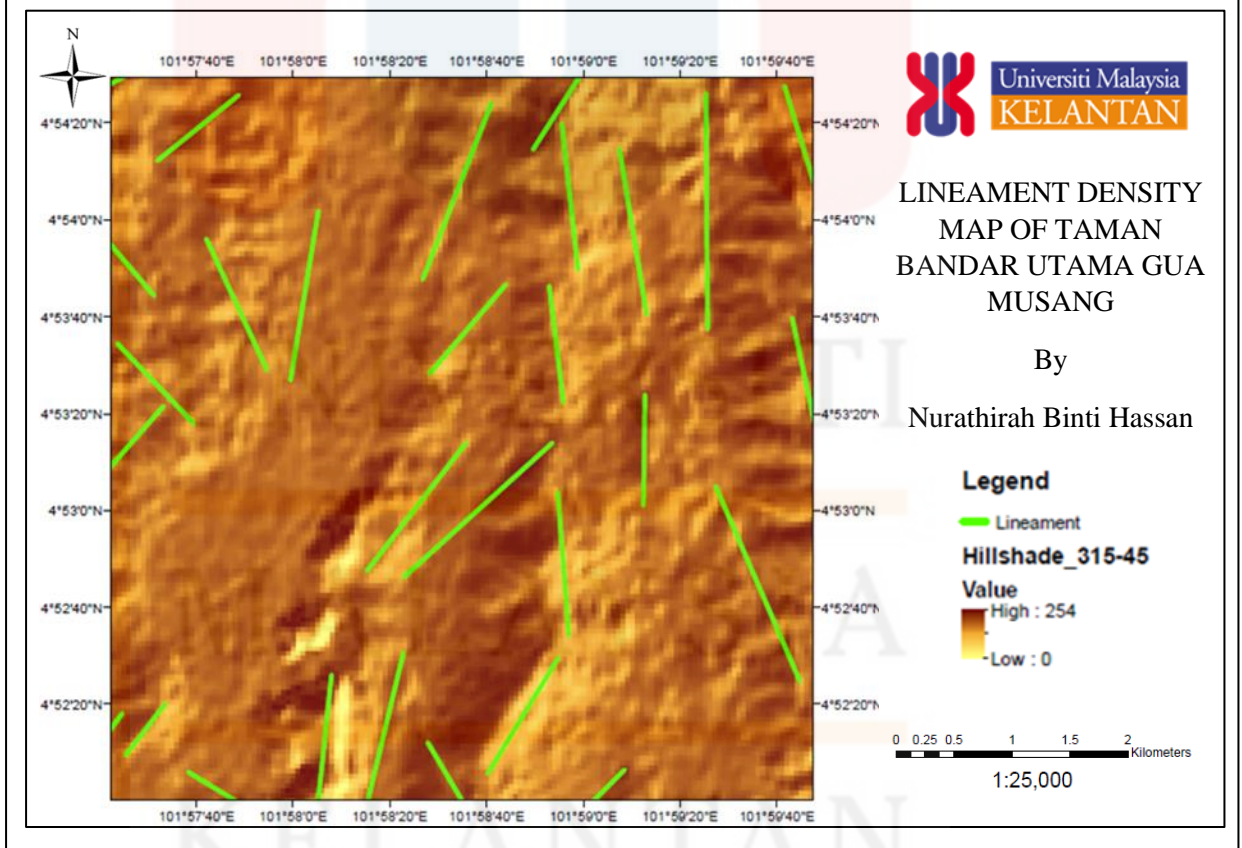
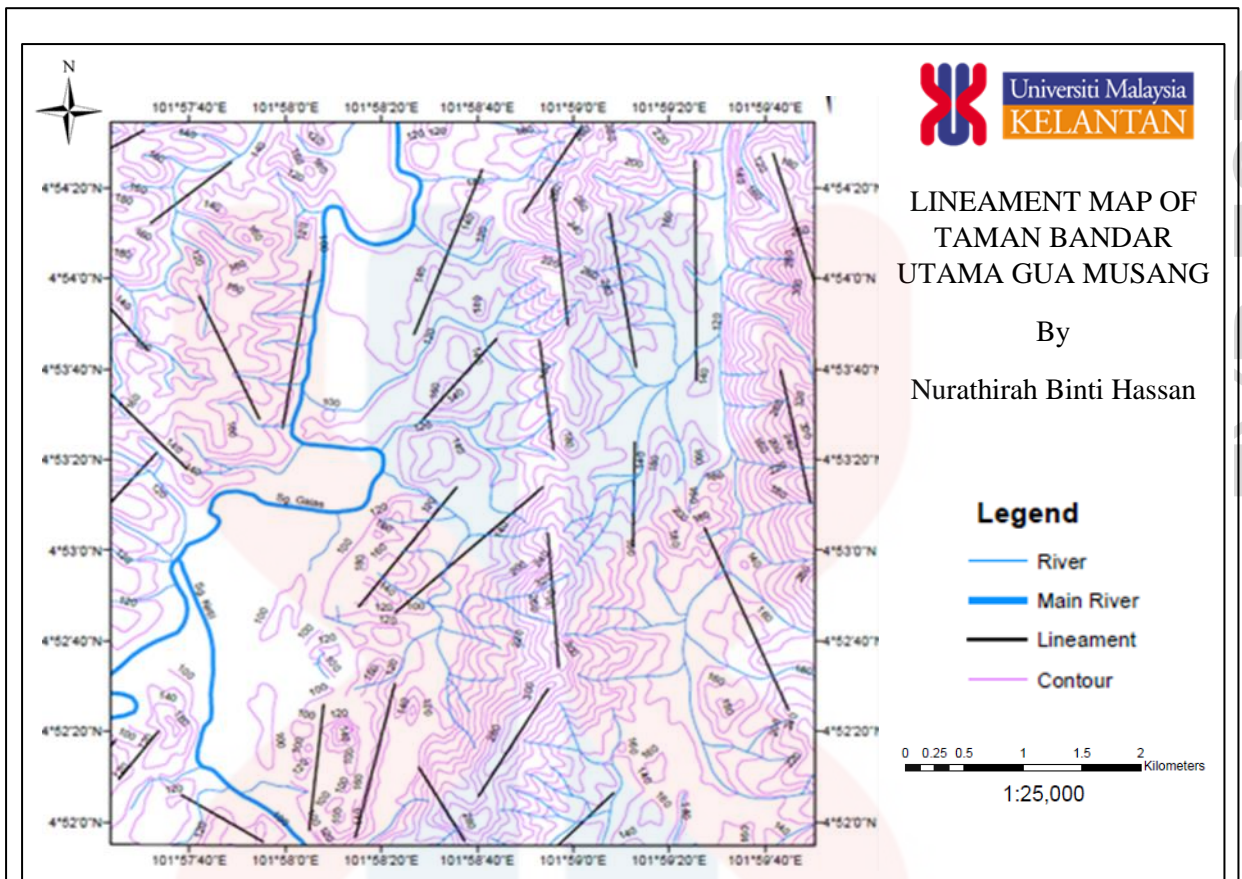


Figure 4.23: Lineament Map of Taman Bandar Utama Gua Musang.

4.4.2 Joint

A joint is a surface split or crack in the rock where there is no movement or displacement of the rock (Parul, n. d). When the strength of brittle rock is exceeded, there will be a break or fracture on the rock's surface. Joints typically come in sets rather than individually. The joints in each set will be parallel or sub-parallel to one another. The key elements that cause a joint to form are the contraction of the rock as a result of cooling or during rock consolidation, as well as tensile or compressional forces that are applied to the rock.

Additionally, the joint that formed in slate rock is categorized as a shear joint (Figure 4.24) since these joints are frequently connected to folded and deformed rocks. According to the Figure 4.24, the slate rock beds have been bent, crumpled, and tilted about 90 degrees. Shear joints are seen as crisscrossing or intersecting at a high angle (Shambavi, n.d). It often results from shear stress action at a closely spaced intersection joint during folding and faulting stages.

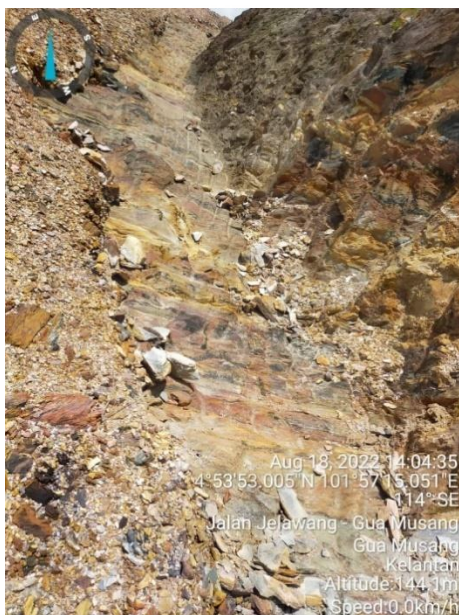


Figure 4.24: Shear joint at slate rock.



Figure 4.25: Outcrop with joint analysis.

4.4.3 Fold

The compressional force that was pressing on the rock and causing it to deform into a bending shape or curved shape without breaking it is what produced folding. A fold is made up of a hinge, which is where two limbs with various orientations are joined. Isoclinal folds and minor synclines are the forms of folding that were discovered in the research region. The terminology for faults, which includes the axial plane, limb, and hinge line, is shown in Figure 4.26.

Isoclinal fold (Figure 4.28) are symmetry with same angle of limbs and are parallel to each other. The interlimb angle of the isoclinal fold is between 0° to 10° . Limb on the left side of the isoclinal fold has 54° of dip angle reading whereas the limb on the right side of the isoclinal fold has 62° of dip angle reading. Thus, the interlimb angle is 8° reflecting that the fold is an isoclinal fold.

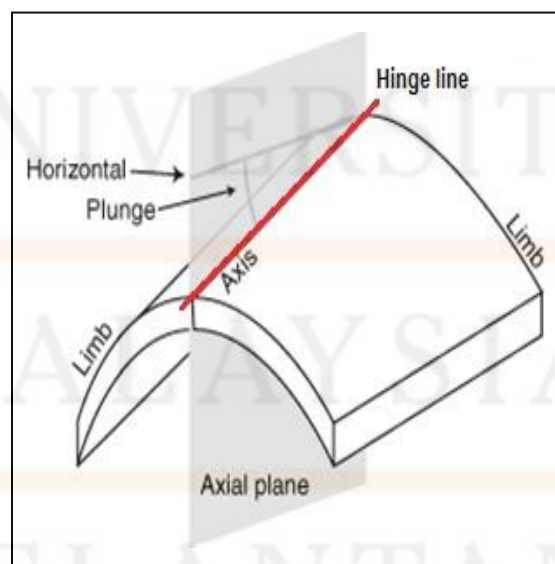


Figure 4.26: Fold terminology.



Figure 4.27: Folding found in palm plantation.



Figure 4.28: Folding found within the iron ore deposits area.

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4.4.4 Foliation

The repeating layering of metamorphic rock is known as foliation. This happens as a result of pressure exerted on flat or elongate minerals inside rocks, causing them to align. Foliation, a platy or sheet-like structure, is the result. Figure 4.29 illustrates how interlaminated tuffaceous and carbonaceous shale have foliated.



Figure 4.29: Foliation of slate rock.



Figure 4.30: Foliation near the iron ore deposits area.

4.4.5 Limestone Karst features

Many karst formations may be spotted in Bandar Utama Gua Musang. The karst landforms are what give rise to cave-like features. The cave contains a number of features, including stalactites, stalagmites, pillars, and cave windows, as depicted in Figure 4.31. While stalagmite is a rock structure that forms on the cave floor or ground, stalactite is a rock formation that hangs from the cave ceiling. A stalactite and stalagmite will join to form a column known as a pillar as they continue to form. One of the cave's structures, the cave window, is where visitors typically enter the cave.

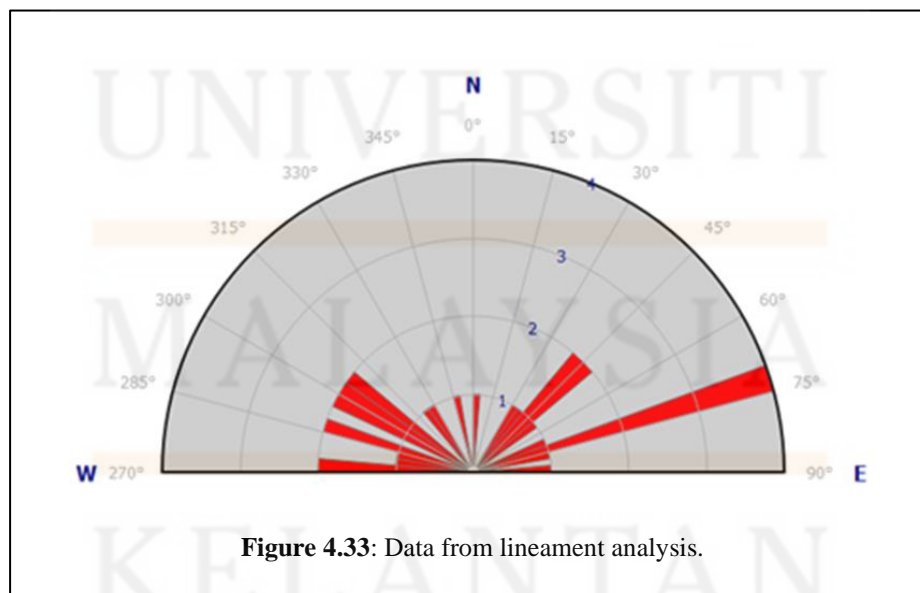


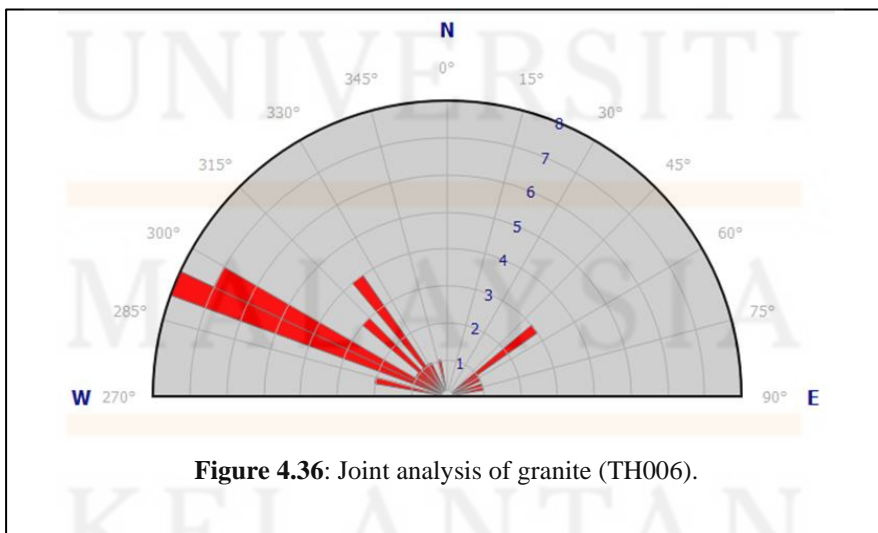
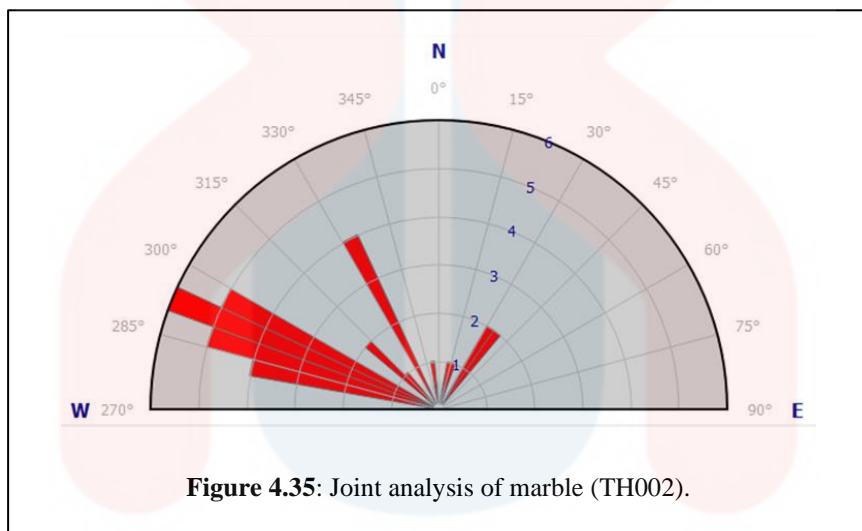
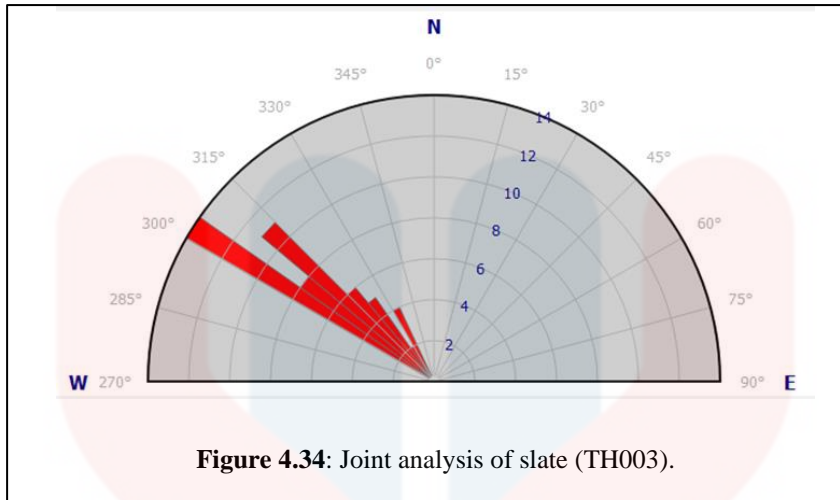
Figure 4.31 & Figure 4.32: Karst Features.

4.5 Mechanisms of Structure

It is crucial to perform the joint analysis in order to comprehend how the structure interacts with the rock that led to their deformation. Finding the main principal stress is aided by the combined analysis. According to the joint analysis in Figure 4.34, the major principal stress is from the North-South (N-S) direction, whereas the major principal stress is from the East-West (E-W) direction in Figure 4.35. According to Figure 4.34 and Figure 4.35, the main principle of stress is thought to be coming from the east-west direction. While reading the data in the field, the figure can contain an error. The strike slip fault at the study region is caused by this stress.

The studied region has both sinistral and dextral strike slip faults. Based on the fault's motions, this sinistral and dextral strike slip fault is categorised. The rock goes left lateral in dextral and sinistral directions, respectively.





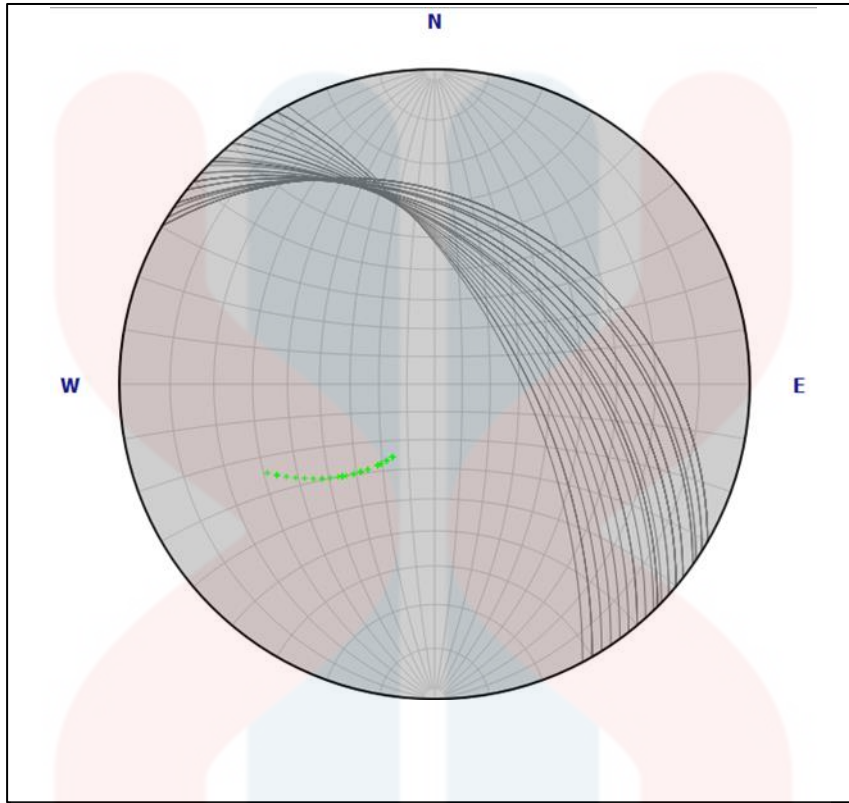


Figure 4.37: Stereonet projection of slate.

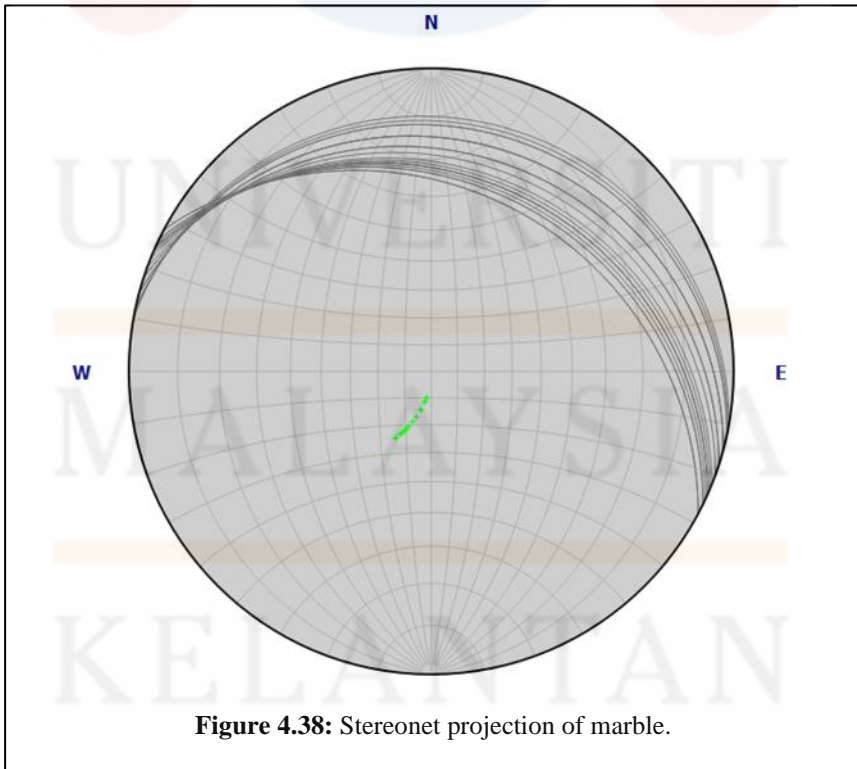


Figure 4.38: Stereonet projection of marble.

4.6 Historical Geology

The Gua Musang Formation and the Gunung Rabong Formation are the two formations that make up the study area. Gunung Rabong is underlain by the Gua Musang Formation, which indicates that Gunung Rabong Formation is younger than the Gua Musang Formation, as noted by Abdullah (2009) and Yin (1965). Marble, slate, quartzite, and granite are the four types of rock that may be found in the Gua Musang Formation. Meta-sediment makes up the Gunung Rabong Formation.

The slate unit discovered in the field is foliated, hard, and dark grey in color. Shale is present beneath the Gua Musang Formation, claims (Peng, 2009). This unit is therefore a part of the shale protolith. Shale transforms into slate as a result of low-grade regional metamorphism. Minor tuffaceous shale interlaminated with carbonaceous shale was detected in this slate unit to strengthen it.

CHAPTER 5

LIMESTONE KARSTS GEOHERITAGE VALUE MAP

5.1 Introduction

The geoheritage importance of nine limestone karsts in Gua Musang, Kelantan, was examined in this chapter. The research area's geodiversity prospects are identified using geological and geoheritage mapping. The primary components of the geoheritage resources in the studied region include rocks, minerals, soils, landforms or landscapes, and geological events. The focus of this study, however, is largely on the distinctive karst features, lovely landscapes, and landforms.

Geoheritage value essentially consists of the aesthetic, cultural and historical, scientific or educational, recreational, and economic values. The evaluation of the study area's heritage value is based on the quantitative geoheritage mapping in the limestone karst region and observation of the drone image capture. This methodology is used to evaluate the potential of the research area's geoheritage resources and might be suggested as a geosite for geotourism purposes.

5.2 Field Observation

During field observation, the karst landform and features was captured by drone at high and low elevation's view. This was due to the high elevation of the karst landform that needs a suitable technology to be view surrounding the karsts. With drone images, the special karst features can be seen clearly and widely. The geoheritage value was also determined in the field during the observation.

1) Gua Musang

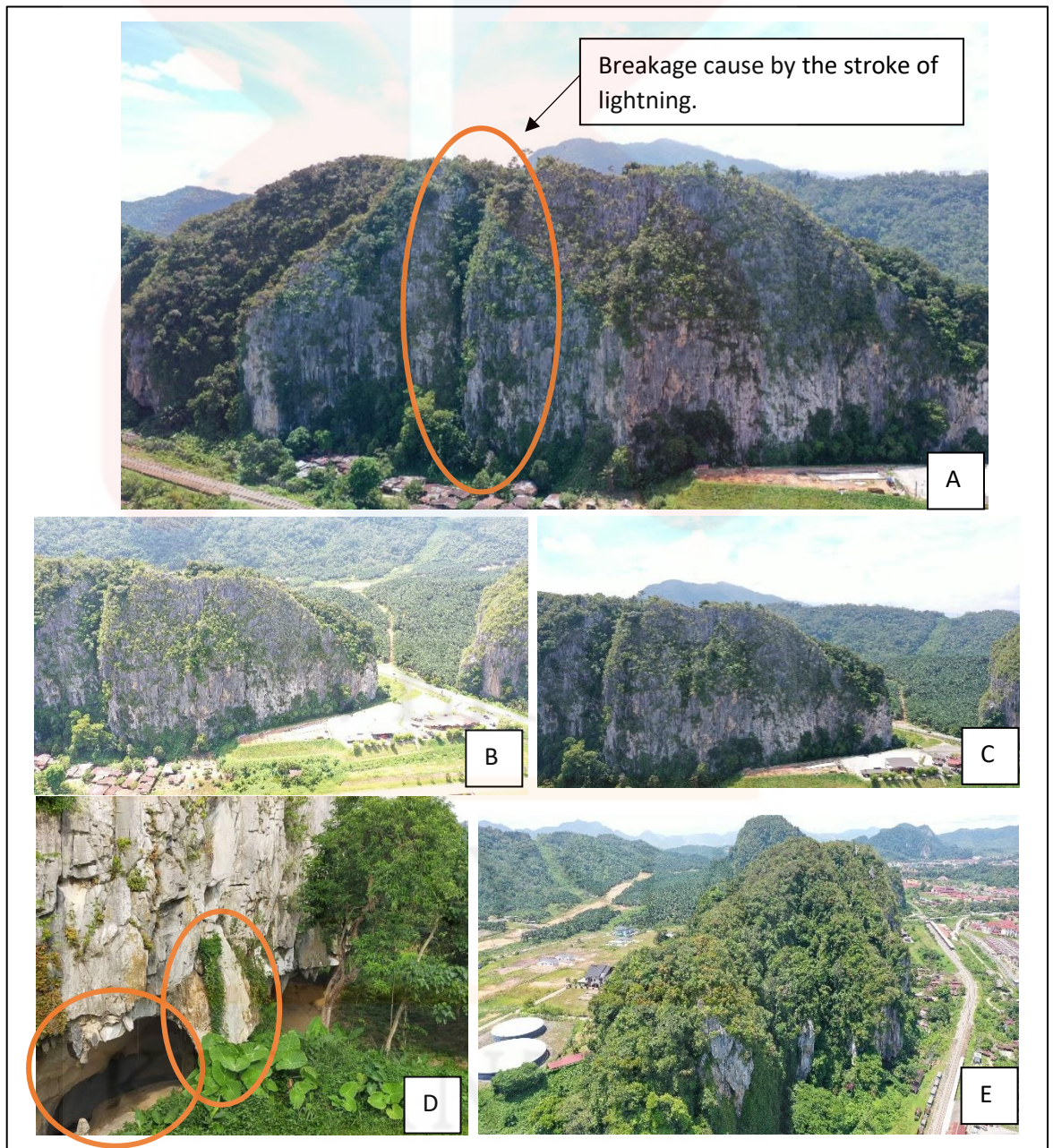


Figure 5.1: The drone image of Gua Musang's view and features.

Gua Musang located at latitude 4°52'53.24"N and longitude 101°58'12.12"E. Gua Musang is 180 m in high and covers 0.1951 km². It is popular recreational area famous for its large cave that uniquely is entered by squeezing through a narrow crack in the rock face. Then, at the far end of the cave, a scramble up a cliff face gives access to the summit with a panoramic view over the town and surrounding countryside.

Before the 1960s, botanical exploration of Gua Musang was sporadic because it was accessible only from the railway line with just two botanical visits in the decade 1920 – 1929. Among the karst hills in Peninsular Malaysia, Gua Musang is one of the three most biodiverse hills with 223 species recorded and it is one of the three hills with the highest number of rare species (Kiew et al., 2017). The total number of species collected from Gua Musang is far higher than that collected from Gua Batu Boh (96 species), although the latter covers a larger area. This is because for plant biodiversity, the variety of microhabitats rather than size determines species richness (Kiew et al., 2019). Gua Musang already have many facilities that covers recreational activities, mosque, restaurant and shop or mini market, thus the idea to conserve Gua Musang karst was a concrete proposes.

2) Gua Serai

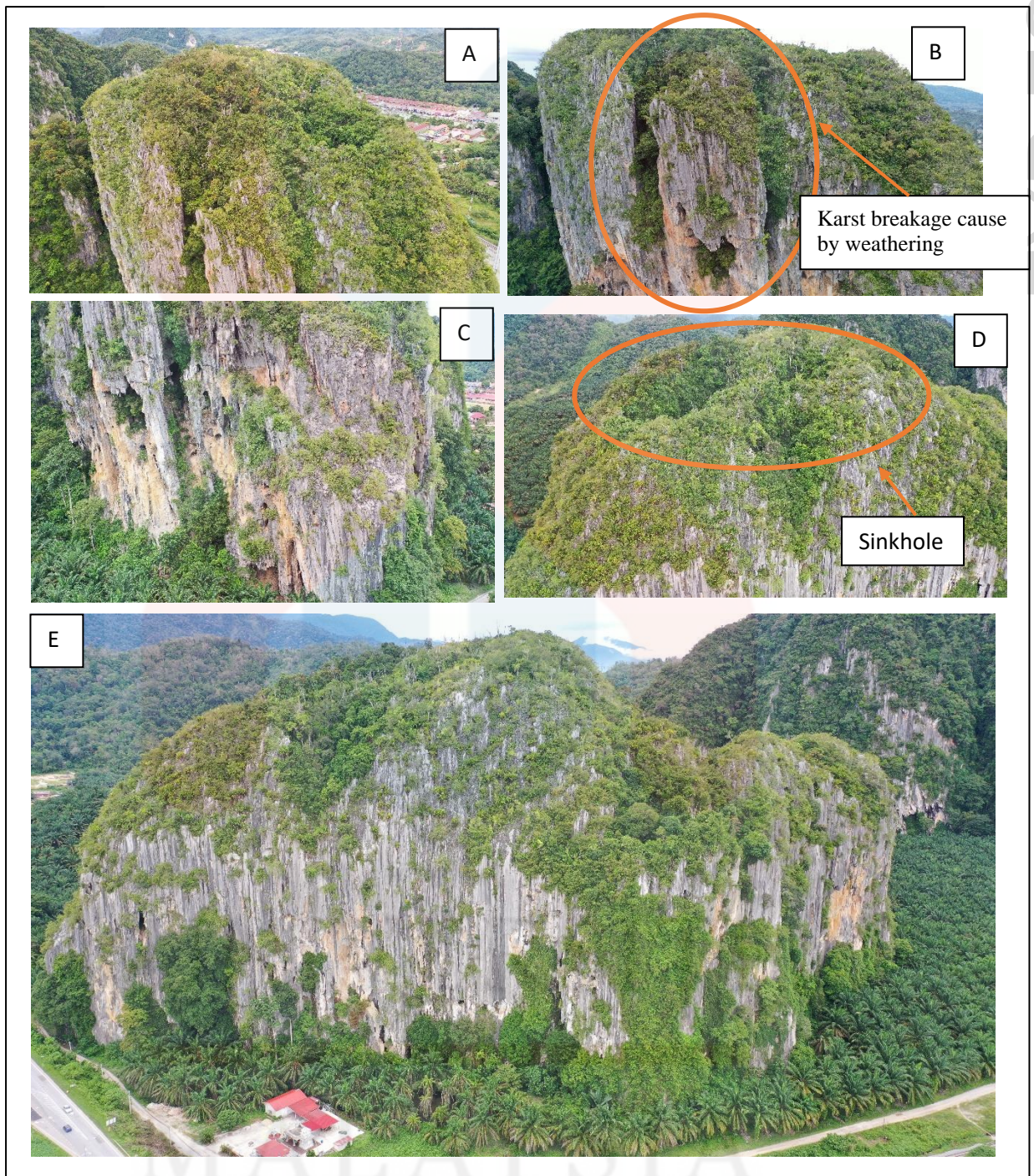


Figure 5.2: Drone image of Gua Serai's view and features.

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The estimate terrain elevation above sea level is 229 metres (751 feet) (refer to website). The latitude is 4° 52' 35" north and longitude are 101° 58' 3" east. Gua Serai also situated nearby to the railway station Gua Musang. Gua Serai is one of the smallest hills that covering an area of 0.0754 km². Gua Serai was surrounded by oil palm plantation that make it a bit hard for people to access the karst.

3) Gua Batu Boh



Figure 5.3: Drone image of Gua Batu Boh's view and features.

Gua Batu Boh is one of the largest limestone karst hills that covering an area of 0.0754 km² (Liew et al., 2016). It is surrounded by the oil palm plantation. Gua Batu Boh located at latitude 4°52'9.67"N and longitude 101°58'0.53"E. There are many habitats that live in Gua Batu Boh and its surrounding due to the geodiversity and biodiversity form there. The karst features such as crack, or hole make the suitable places for habitat to survive there. For example, bird that build a nest and monkey. A troop of monkey even has been spotted there during the field observation. It suitable for the monkey to make habitat there because of the humid place inside the cave and the plant species that are spread that enable the monkey to hang and swinging (as in Figure 5.3 (B)). A Buddhist temple has been located there that connected to people's religion and their belief (refer Figure 5.3 (D)).

4) Batu Papan

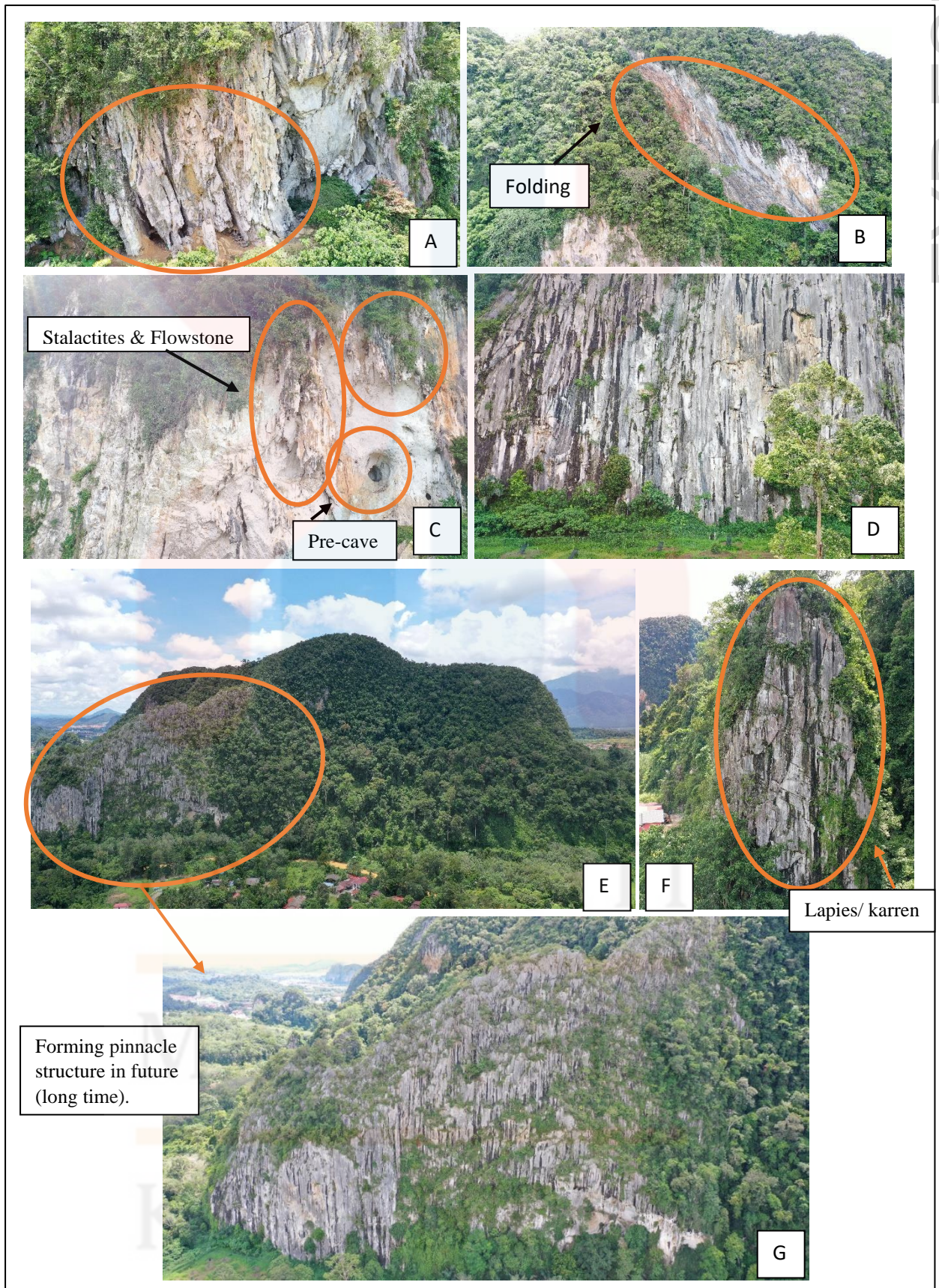
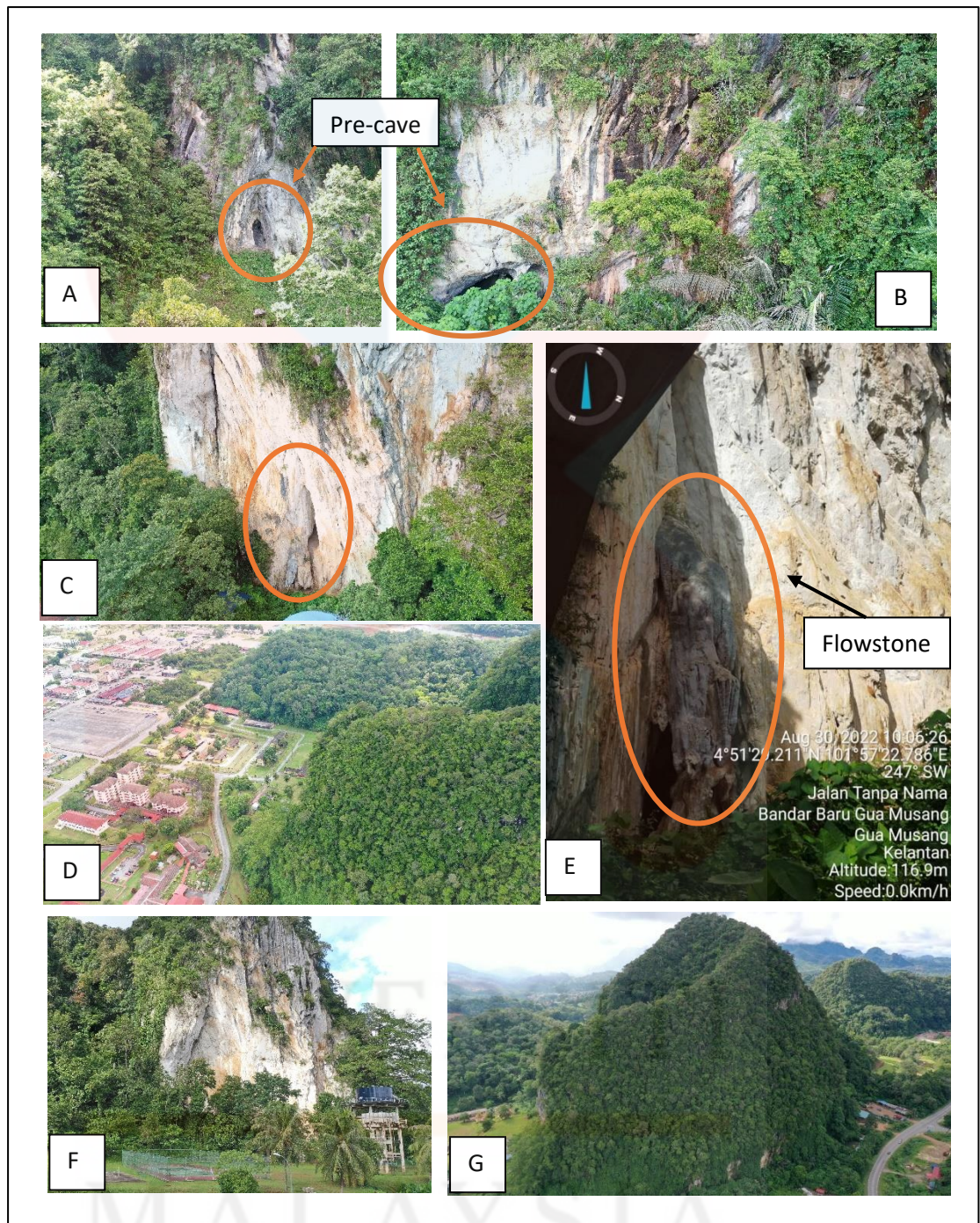


Figure 5.4: Drone image of Gua Batu Papan's view and features.

Bukit Batu Papan located at latitude $4^{\circ}50'44.17''\text{N}$ and longitude $101^{\circ}57'5.01''\text{E}$. Batu Papan are one of the largest karsts covering 0.78 km^2 . The elevation above sea level is 113 metres. Kampung Batu Papan is the near village of Bukit Batu Papan and may be name are from the karst name. Bukit Batu Papan was easy access because not surrounded with heavy forest or palm oil plantation. Many karst features were found which are the folding formation, pre-cave (hole), stalactite, stalagmite, lapies or karren and structure that forming pinnacle in hundred or million years forward.

5) Batu Neng



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Batu Neng is located at latitude 4°51'17.11"N and longitude 101°57'26.81"E. Batu Neng covers 0.41 km². Batu Neng located near the Gua Musang Hospital. The Batu Neng has high accessibility because of the surrounding mostly road, no heavy forest and oil palm plantation. There are many pre-cave (hole that possible or nearly to form cave due to the weathering process) as picture A in Figure 5.5. The recreational activities also can be done at Batu Neng since it easy to access and the karst is not too weathered if compared to Batu Machang. There are many beautiful karst features such as big flowstone (picture E in figure 5.5) and the formation of karst itself that has the dome-like shaped (picture D in figure 5.5).

6) Batu Machang

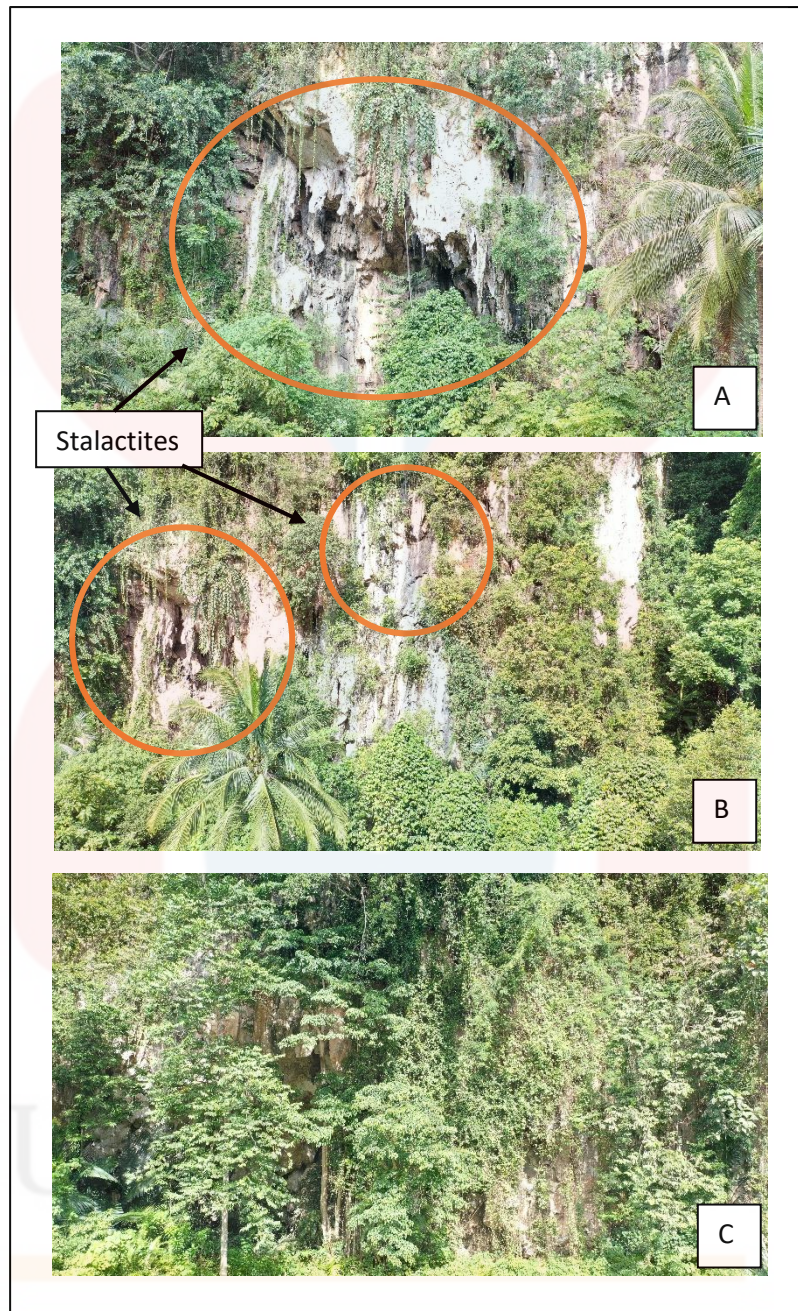


Figure 5.6: Drone image of Batu Machang's view and features.

Bukit Batu Machang located at latitude $4^{\circ}50'54.46''\text{N}$ and longitude $101^{\circ}57'29.30''\text{E}$. Bukit Batu Machang covers 0.39 km^2 in areas. Batu Machang was highly covered with vegetation and hard to access. Batu Machang also was highly weathered, thus the any recreational activities and any building or shop for economic purposes are not really proposed. It can be conserved as the scientific and educational value of the karst formation hold.

7) Gua Madu

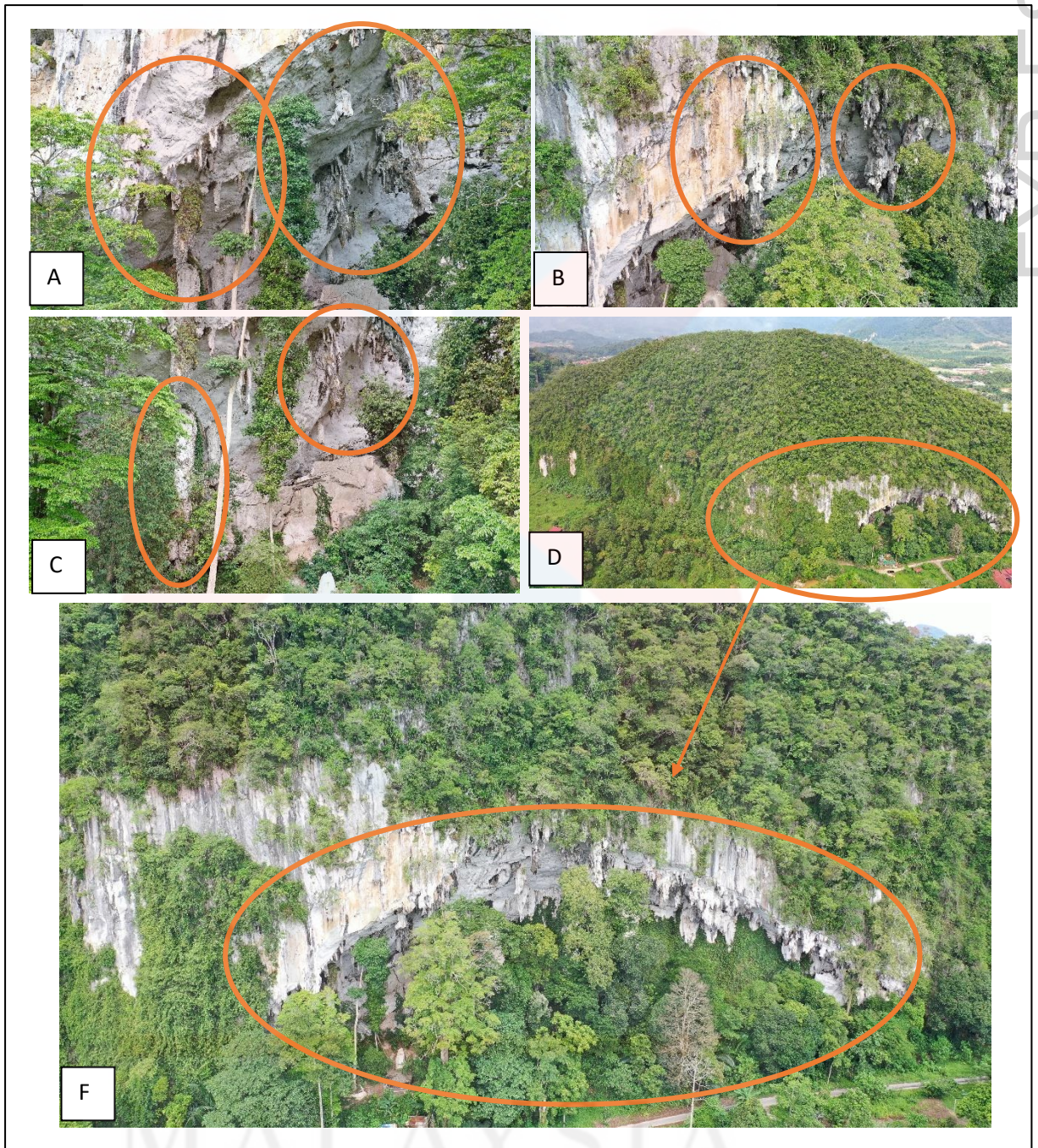


Figure 5.7: Drone image of Gua Madu's view and features.

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Gua Madu was located at latitude 4°50'14.61"N and longitude 101°57'7.98"E. Gua Madu covering 0.5 km² in area. Gua Madu was near with Galas River. Gua Madu has the cultural value of story of the honeybee that are produce in the cave. Gua Madu also known as the communist hideout in the long past years according to folklore and local's belief. Gua Madu has the aesthetic value that has the unique beautiful 'curtains' of the karst features in a big scale (picture F in Figure 5.7). The stalactite, stalagmite, cave, sinkhole, pillar or column and drapes or straw are the other of karst features that observed at Gua Madu.

8) Etnobotany 1

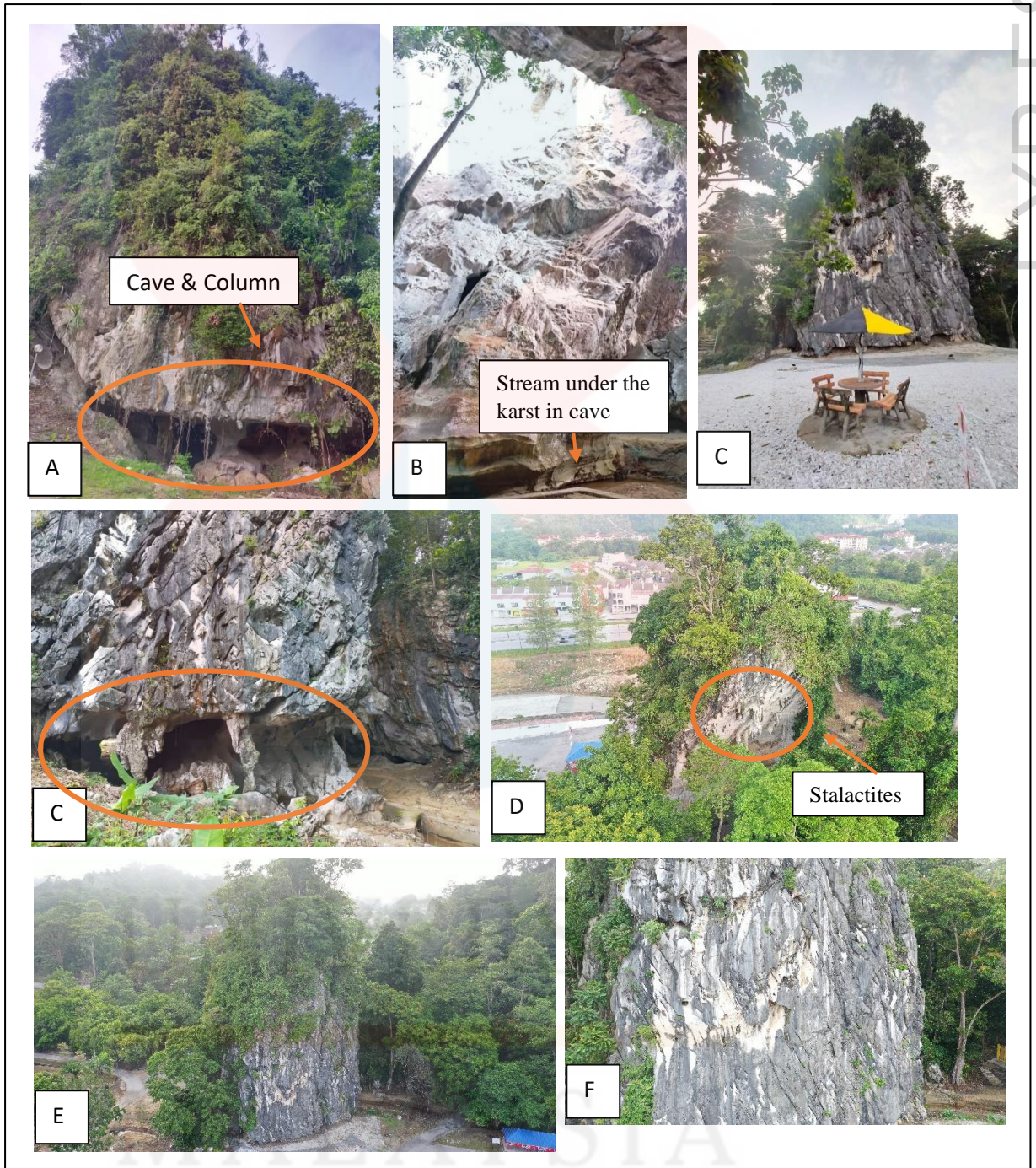


Figure 5.8: Drone image of karst Etnobotany 1's view and features.

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Etnobotany 1 karst was located at latitude $4^{\circ}50'15.95''\text{N}$ and longitude $101^{\circ}57'47.16''\text{E}$. It covers 1993 m^2 , the smallest limestone karst in Gua Musang. The karst was located inside of the Gua Musang Etnobotany Park, thus the name of the karst was discovered from it. Gua Musang Etnobotany Park was least popular in people's attractions and information. It was built as a forest research and recreation centre to help preserve the forest and its products, especially herbal goods. The National Service Training Program centre also was built in the area. There are also the herb garden and gallery, incubator centres for business, facilities, chalets, animal farm (livestock centre for Cassowary birds and Javan deer) and the recreational activities such as rock climbing and camping.

9) Etnobotany 2

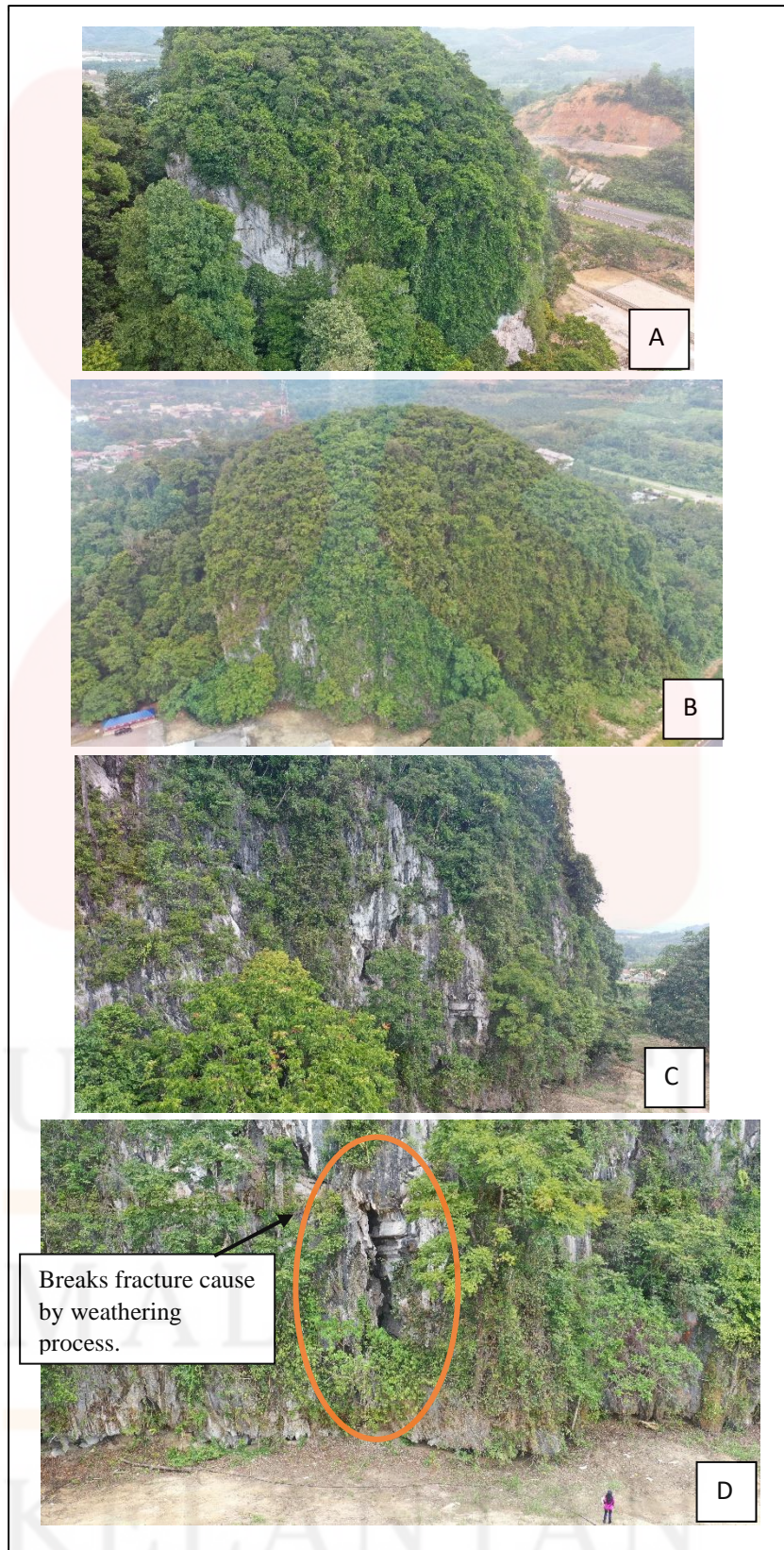


Figure 5.9: Drone image of karst Etnobotany 2's view and features.

Etnobotany 2 karst located at latitude $4^{\circ}50'8.82''\text{N}$ and longitude $101^{\circ}57'46.35''\text{E}$. It covers $71\,610\text{ m}^2/0.1\text{ km}^2$ in area. The information for Etnobotany2 karst also same as in Etnobotany 1 because both was located inside of the Gua Musang Etnobotany Park. It opens for people and visitors, but the Etnobotany 2 karst was more weathered compared to Etnobotany 1 karst. The karst also has high vegetation that cover the karsts. Many breaks fracture found and even in large scale due to the weathering process. The karst features also cannot be seen much in Etnobotany 2.

5.3 Geoheritage Value Classification Analysis

"Geoheritage" is a broad term that refers to geologic features or sites that have significant scientific, educational, cultural, or aesthetic value, according to the Geological Society of America (GSA, 2012). The heritage value will be determined using quantitative methods, with a range of (0-5). The quantitative approach is related to the need to assess the geological sites numerically (valuing) or to score the sites (Kubalikova 2013). For this study, this approach was conducted by assessing the potential geoheritage features based on their geodiversity and geoheritage values. Table 5.3.1 shows the examples of the scores obtained for each site in respect to geodiversity and geoheritage values in Jeli.

There are six classes of values which were simply established for this purpose, 0 (none) 1 (very bad) 2 (bad), 3 (fair), 4 (good) and 5 (very good). Meanwhile, table 5.3.2 shows the scores of numerical assessments of geoheritage value for selected nine limestones in the Gua Musang town. Thus, ArcGIS procedures and a drone-generated image will be used to construct the geoheritage-geotourism ranking value mapping.

No.	Geological feature	Scientific (and educational) value	Aesthetic value	Recreational value	Cultural value	Historical value	Economic value	Functional value	Total
1.	Gunung Reng	5	5	5	0	3	3	0	21
2.	Jeli Hot Spring	5	3	4	0	0	0	3	15
3.	Pergau Lake	3	4	5	0	0	4	4	20
4.	Gold deposits in Kg. Kalai	5	3	2	0	3	5	0	18
5.	Lata Janggut	5	4	5	0	0	0	0	14
6.	Sungai Rual	5	4	4	5	0	0	0	18
7.	Lata Renyok	5	5	4	0	0	0	5	19
8.	Lata Chenai	5	4	4	0	0	0	0	13
9.	Setir Cave complex	5	4	3	0	0	4	0	16

Note: 0 = none; 1 = very bad; 2 = bad; 3 = fair; 4 = good; 5 = very good

Table 5.3.1: Example of the numerical assessment of geoheritage value/ resources for ranking in Jeli districts, Kelantan, Malaysia (Dony Adriansyah et.al, 2015).

For the nine selected karsts in Gua Musang town, it includes Gua Musang karsts formation (GM), Gua Serai (GS), Gua Batu Boh (GBB), Batu Papan (BP), Etnobotany 1 (ET1), Etnobotany 2 (ET2), Batu Neng (BN), Gua Madu (GMD) and Batu Machang (BM). Geoheritage score value will be determined by the quantitative assessment through ranking.

Geoheritage/Weightage Value	Description	Score (Kubalikova, 2013)									
		Limestone Karsts in Gua Musang									
		GM	BP	GS	GBB	ET1	ET2	BN	GMD	BM	
Scientific/ Educational -Integrity -Rarity -Diversity -Scientific knowledge -Visibility of features -Exemplarity, pedagogical use -Existing educational products -Actual use of a site for educational purposes	-Stalactite, formation that hangs from the ceiling of a cave, produce by precipitation of minerals from water dripping. -Stalagmite, upward-growing mineral deposits, precipitated from water dripping onto the floor of a cave. -Pinnacle, tower, spire, needle, isolated from other rocks -Curtain/Drapes, curtain-shaped dripstones from cave ceiling -Cave, formed by water action by various method -Pillar/Column, fusion stalactites, and stalagmites. -Flowstone, calcium carbonate in water that flows along wall, calcite layers deposited. -Sinkhole/Doline, various sinkholes become doline. -Polje, depression come from water overlaying. -Karst window/Fenster, geomorphic features, underground river. -Springs, stream under karsts. -Straws, features like stalactites but sharper and thinner. -Lapies/Karren, weathered limestones surface, pitted, cause by solution along joints. -Habitat, flora and fauna.	5	5	5	5	5	2	4	5	4	

Aesthetic Value -number of colours, structure of the space, viewpoints	-Shape of limestones karst, cone, or tower -Old Railway Station in Gua Musang, old train. -Attractive Karst Landscape, high elevation, best scenery. -Karsts Features, varieties, unique	4	3	2	4	3	2	5	5	2
Recreational Value -recreational activities for geotourism purposes	-Rock Climbing, high elevation, great features -Cave Exploration, extreme activities with narrow route, attract people with uniqueness of the karst features -Hiking, hiking trails to cave entrance. -Camping, jogging, enjoy beautiful scenery.	5	3	3	4	5	4	3	5	0
Cultural/Historical Value -History, Folklore	-Cave name origin, exp: "Civet Cat Cave" -Local folklore, bolt lighting struck/ religion believe, Cave god, shaman conducted animal sacrifices in front cave, temple. -Local folklore in bee nests found on the cave ceiling, entrance only known by villagers. -Cave as communist hide out	5	0	0	0	0	0	0	5	0
Economical Value -Accessibility -Presence of tourist infrastructure -Local products	-Accessibility to the karst. -Infrastructure, café, toilet, chair -Tool provide and facilities. -Honeybee selling, products from cave.	5	3	3	3	5	2	3	4	1
Conservation Value -Actual threats and risks -Potential threats and risks -Current status of a site -Legislative problem	-The higher the value, the lower the risks, because score 5 for very good, and 1 is very bad, which is very risky condition.	5	3	3	5	4	4	4	5	1
Total		29	17	16	21	22	14	20	29	8

Table 5.3.2: Geoheritage Value Analysis for Nine Selected Limestone Karsts (Kubalikova, 2013).

5.4 Results.

From the numerical assessment that was done in Table 5.3.2, the geoheritage value was digitize and mapped by using the ArcGis software. For the digitization, the section or the classification area was being compared with the Google Earth view, the drone image and the geoheritage value score that was analysed. Hence, the location and the area of the features can be mapped. Each classification was shown as coloured zone that represent the geoheritage values (Table 5.3.3). However, the colour may slightly different due to the transparency effect.

No.	Geoheritage Value	Colour
1.	Recreational Value	Yellow
2.	Conservation Value	Reddish orange
3.	Economical Value	Purple
4.	Aesthetic Value	Pink
5.	Scientific and Educational Value	Turquoise
6.	Cultural Value	Green

Table 5.3.3: Geoheritage Value Classification.

5.4.1. Gua Musang

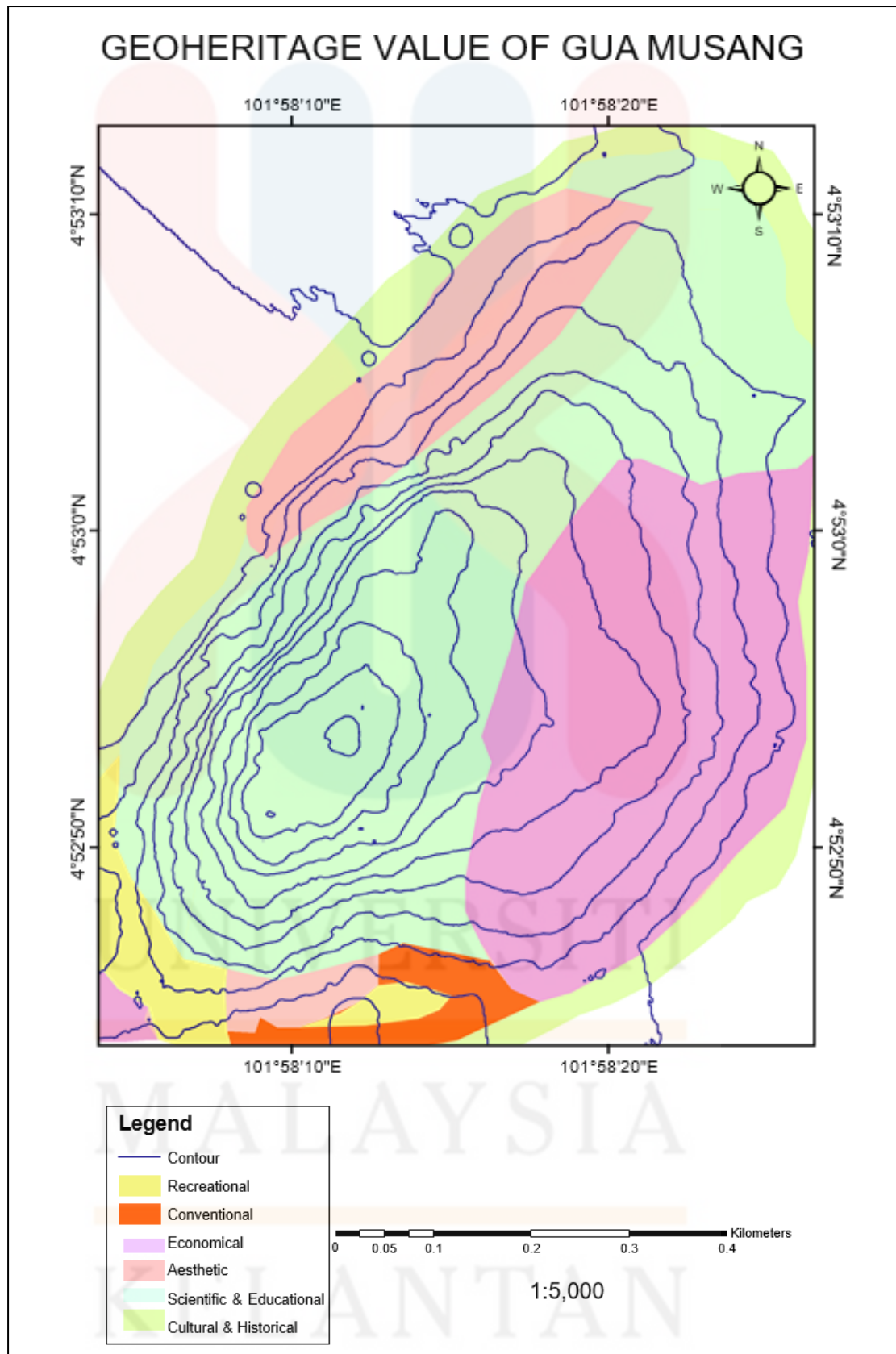


Figure 5.10: Geoheritage Value Map of Gua Musang.

5.4.2. Gua Serai

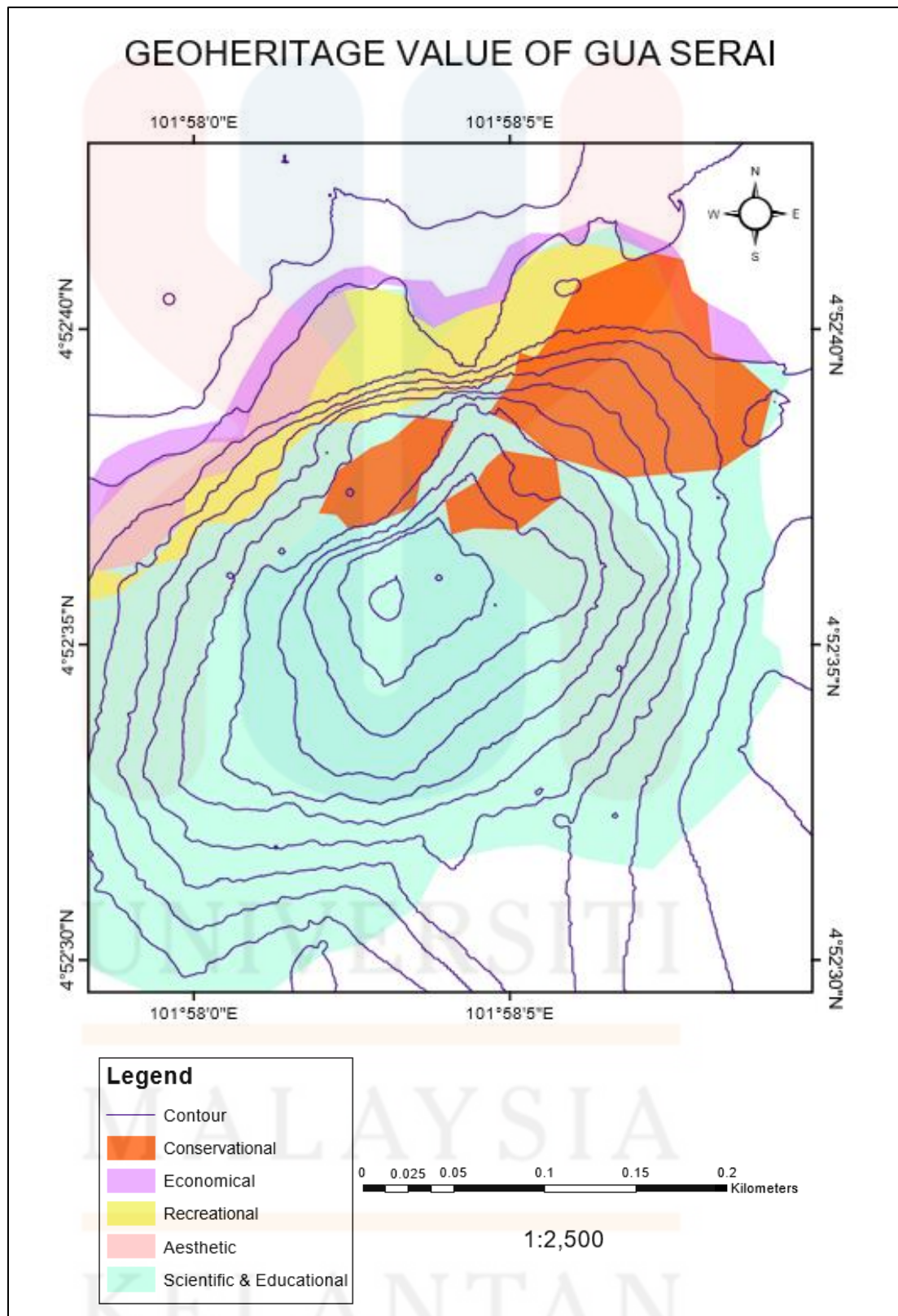


Figure 5.11: Geoheritage Value Map of Gua Serai.

5.4.3. Gua Batu Boh

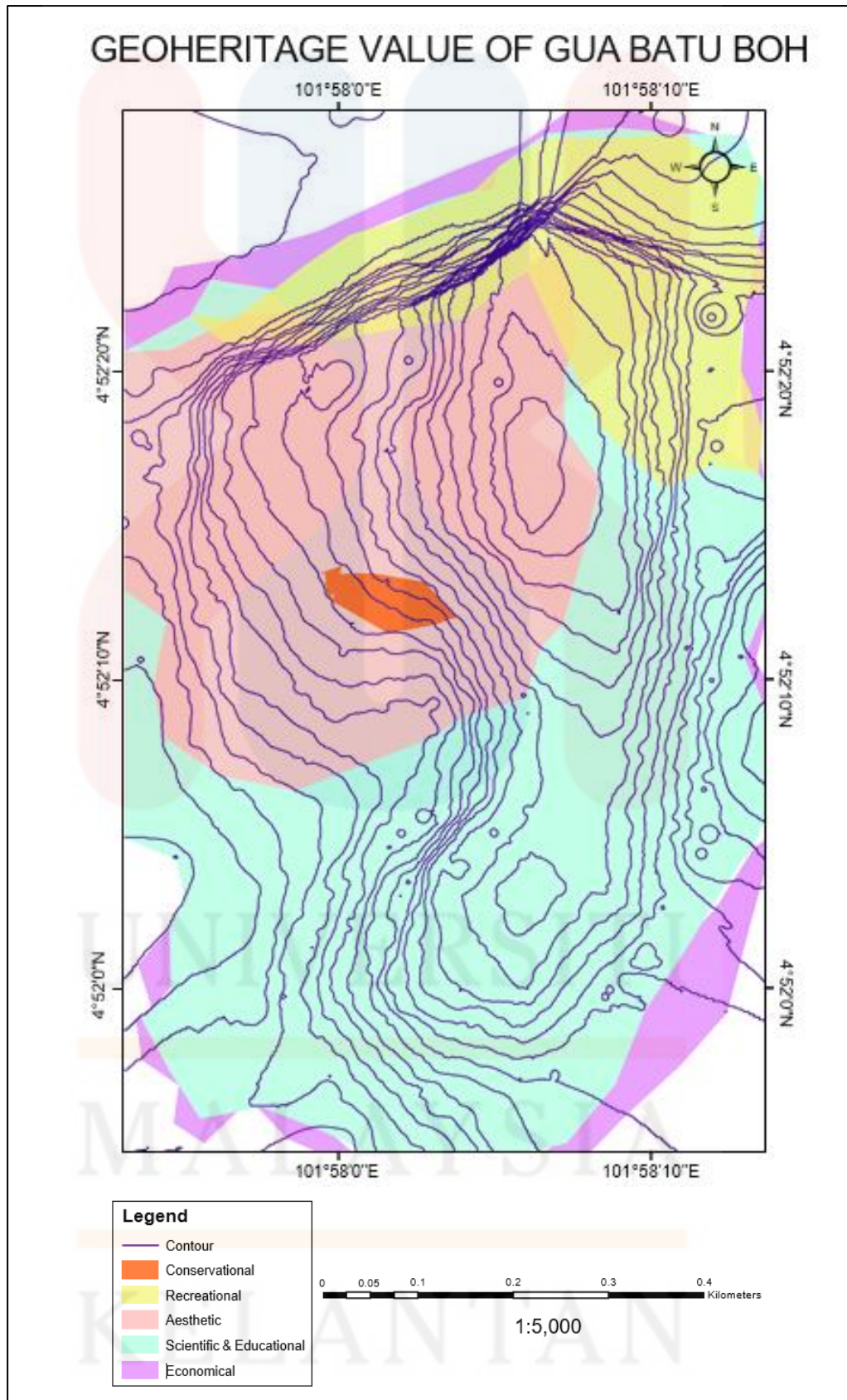


Figure 5.12: Geoheritage Value Map of Gua Batu Boh.

5.4.4. Bukit Batu Papan

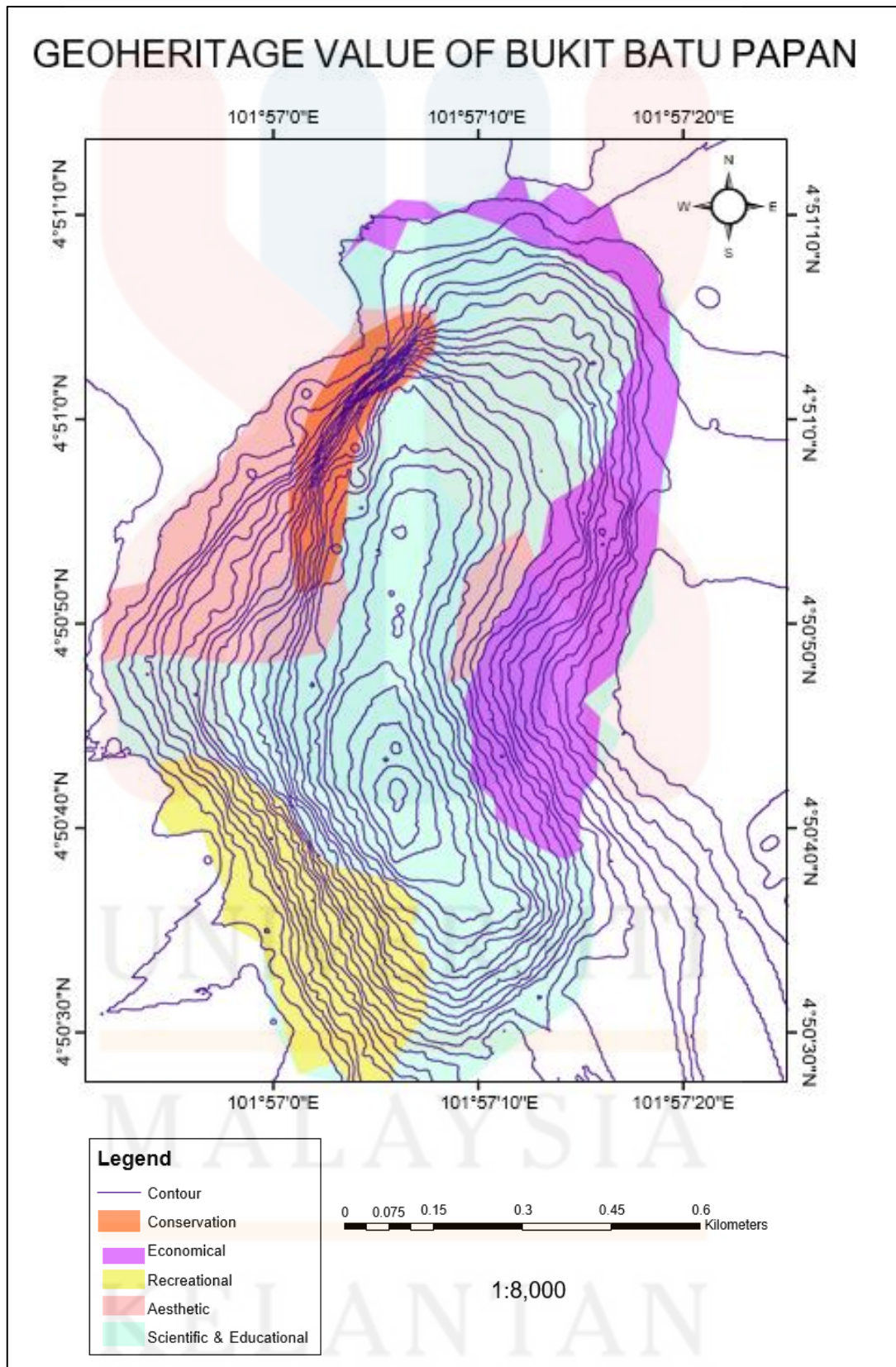


Figure 5.13: Geoheritage Value Map of Bukit Batu Papan.

5.4.5. Batu Neng

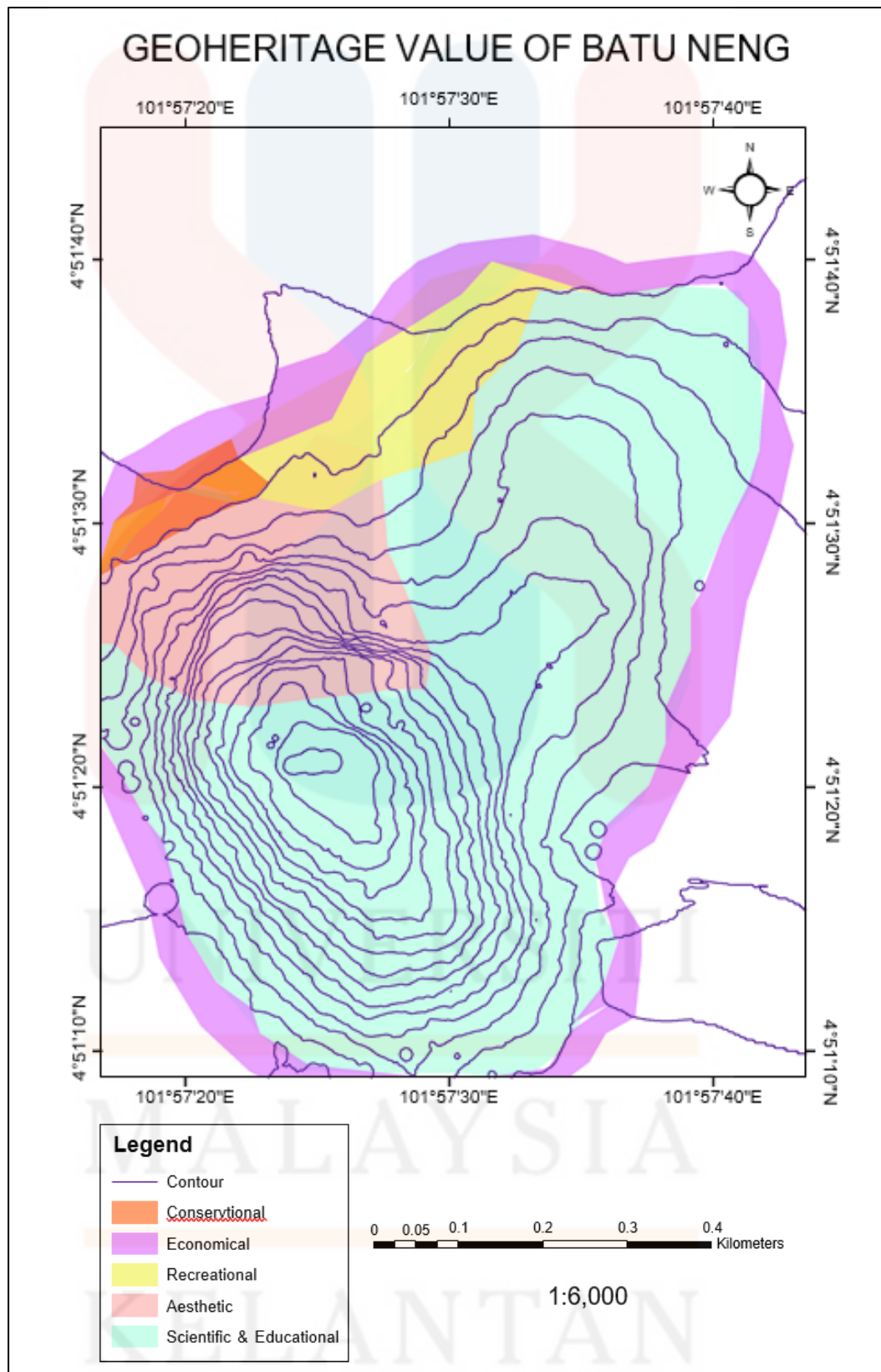


Figure: 5.14: Geoheritage Value Map of Batu Neng.

5.4.6. Gua Madu

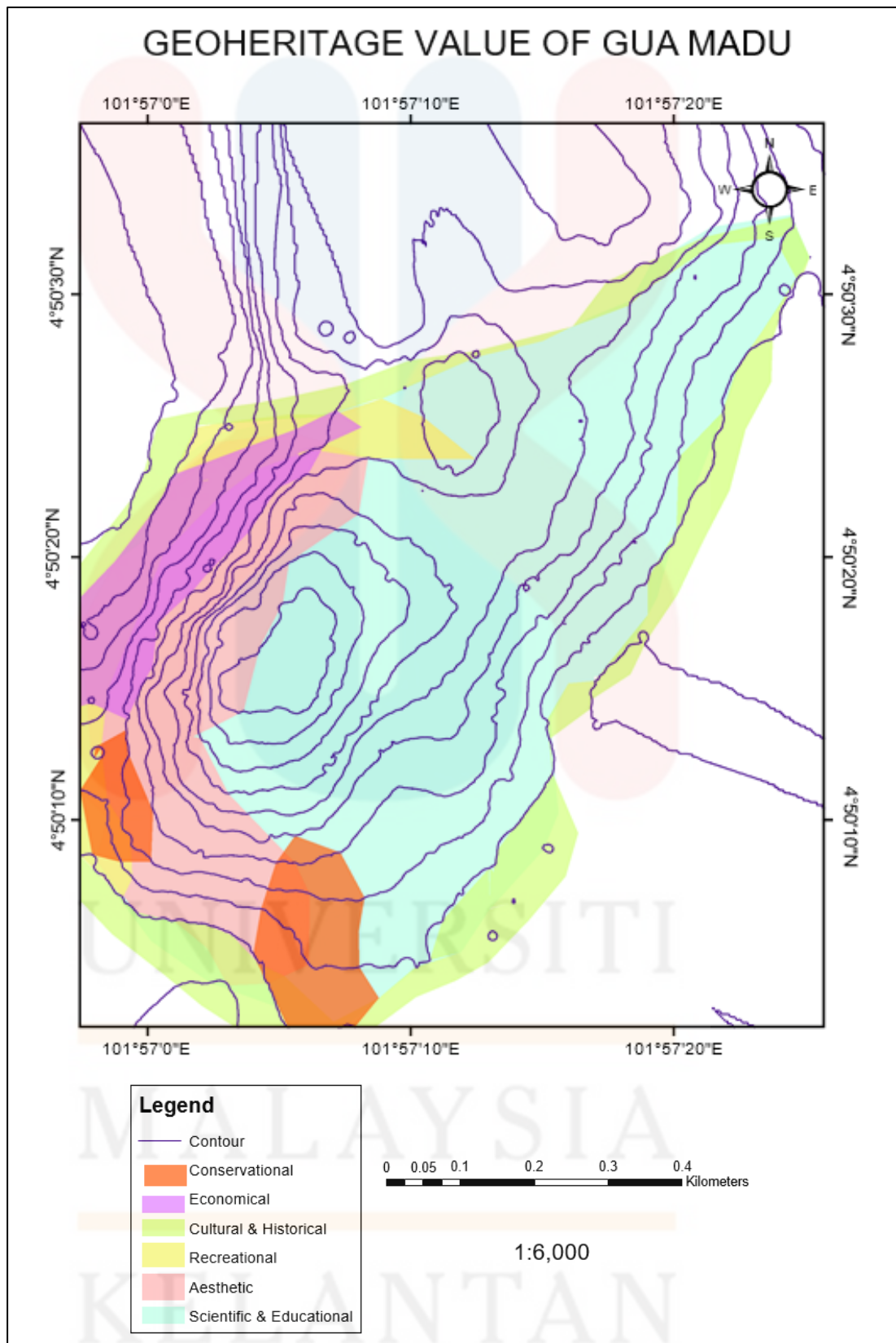


Figure 5.15: Geoheritage Value Map of Gua Madu.

5.4.7. Batu Machang

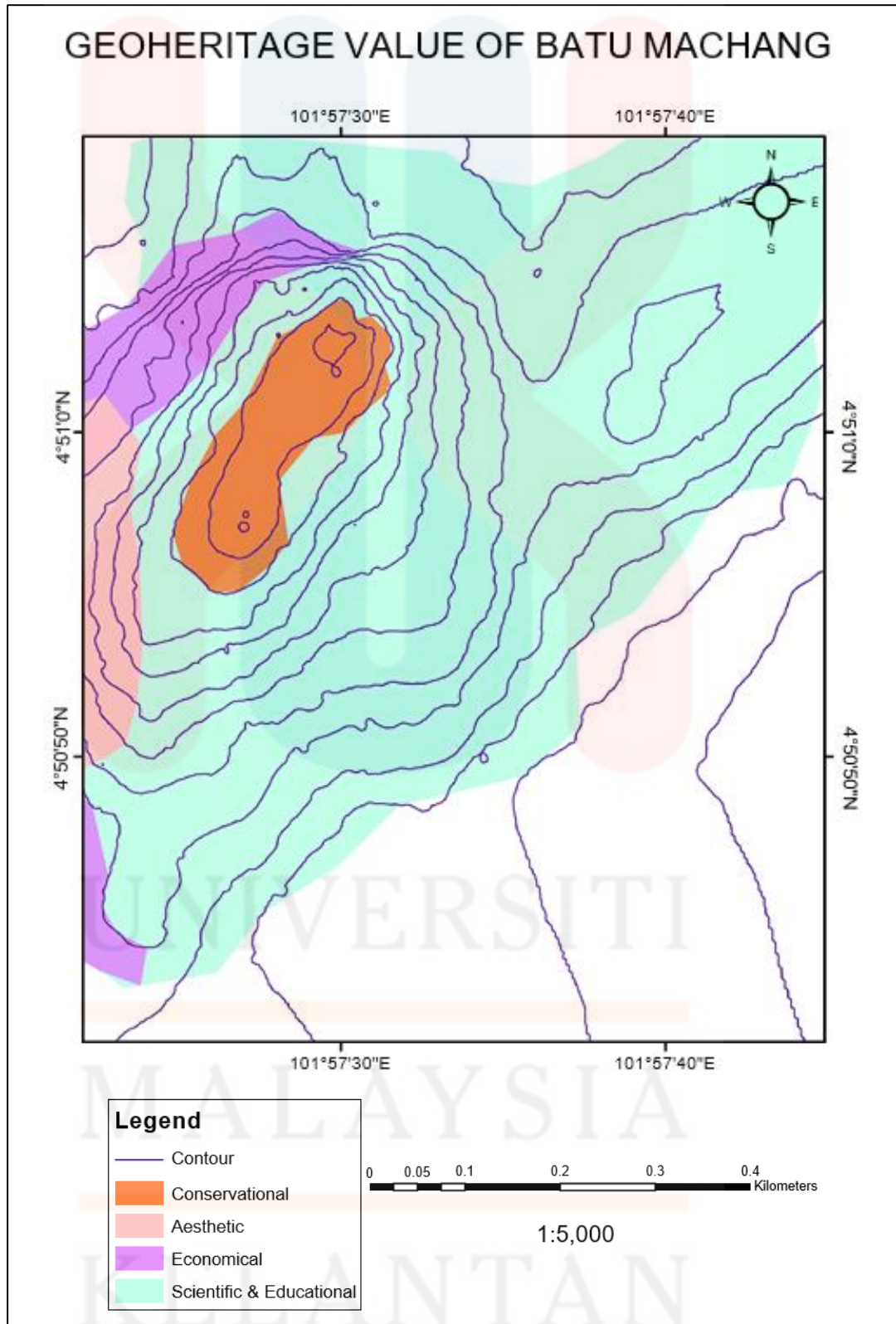


Figure 5.16: Geoheritage Value Map of Batu Machang.

5.4.8. Etnobotany 1

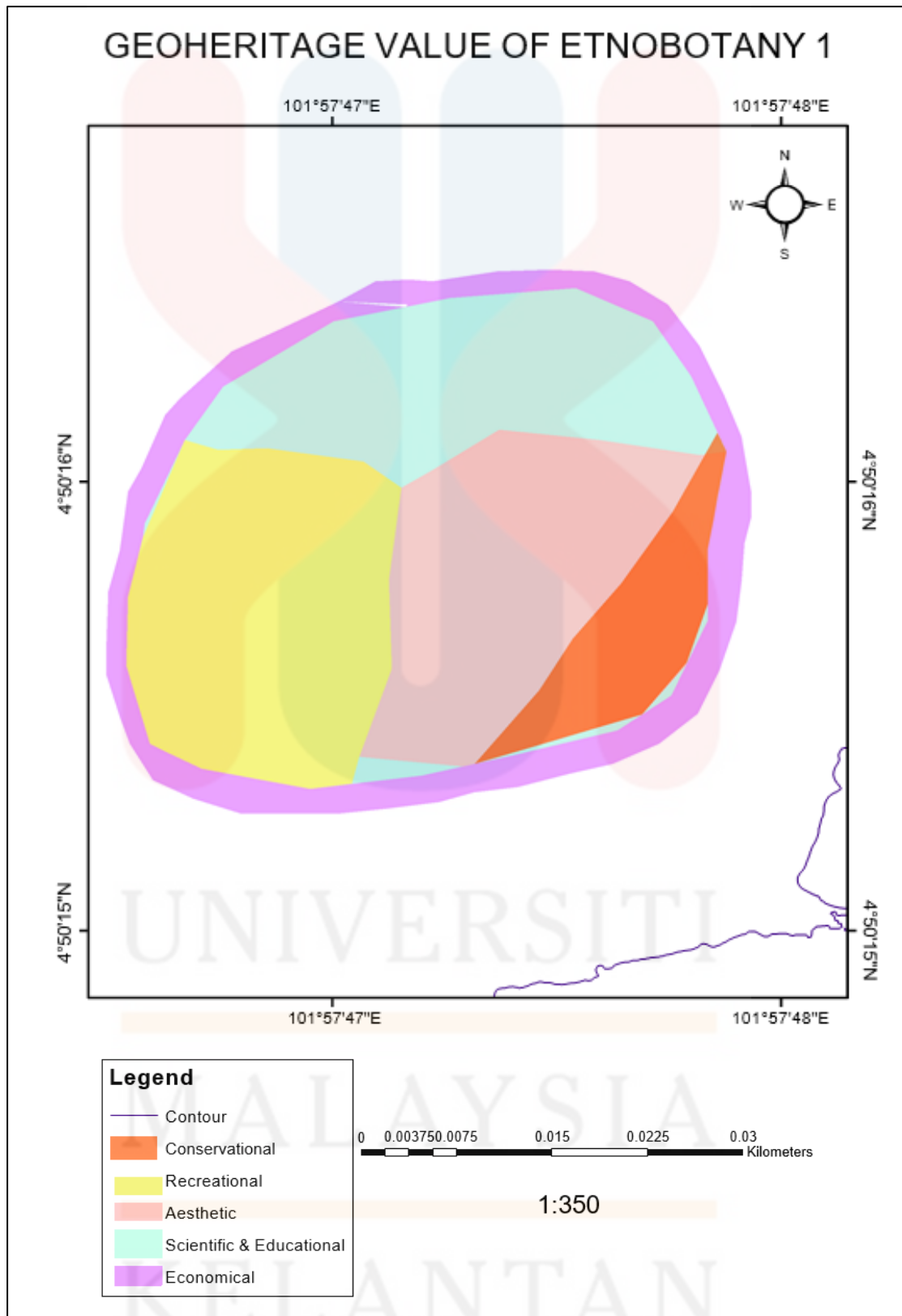


Figure 5.17: Geoheritage Value Map of Etnobotany 1.

5.4.9. Etnobotany 2

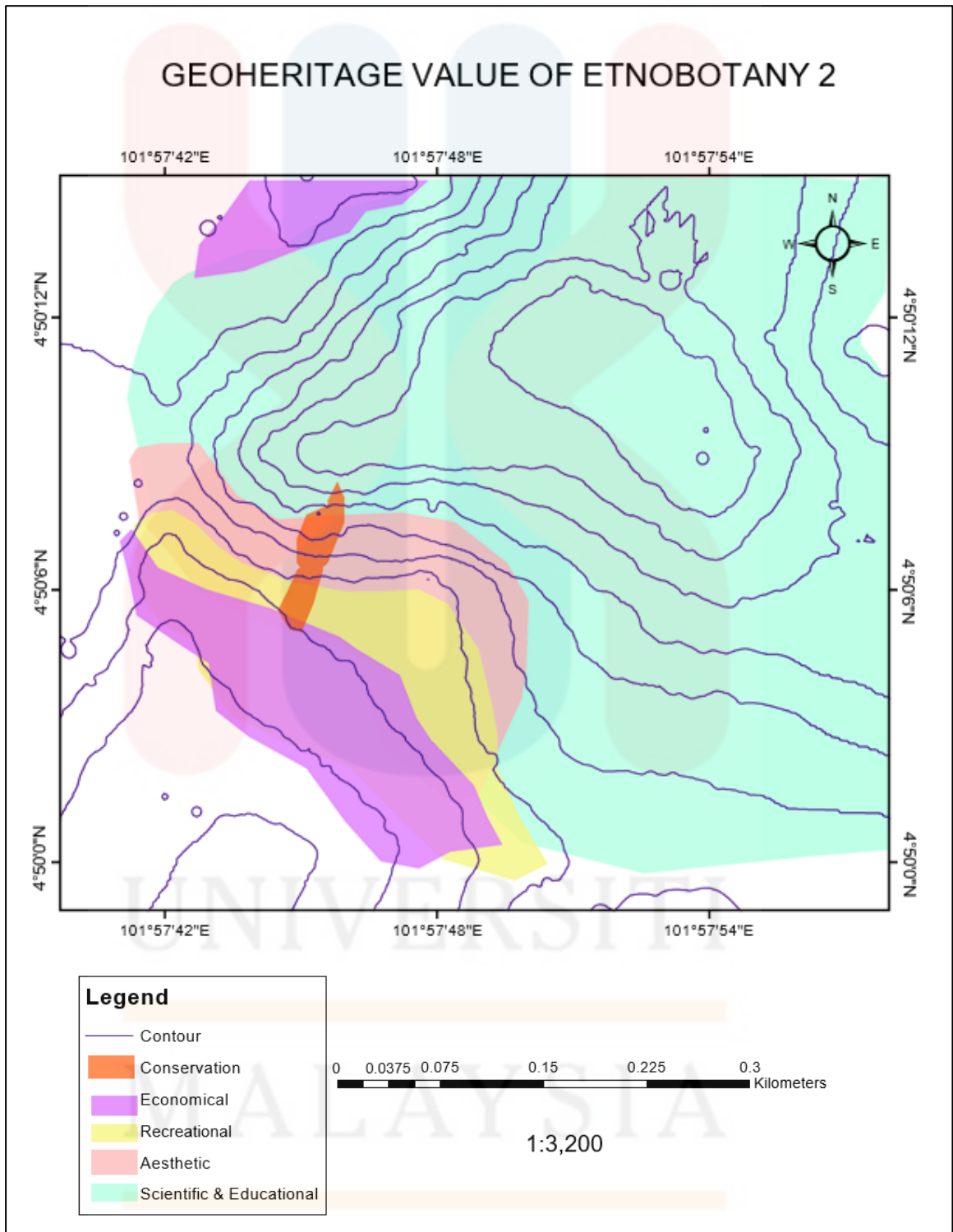


Figure 5.18: Geoheritage Value Map of Etnobotany 2.

5.4.10 Geoheritage Value for Limestone Karst Mapping

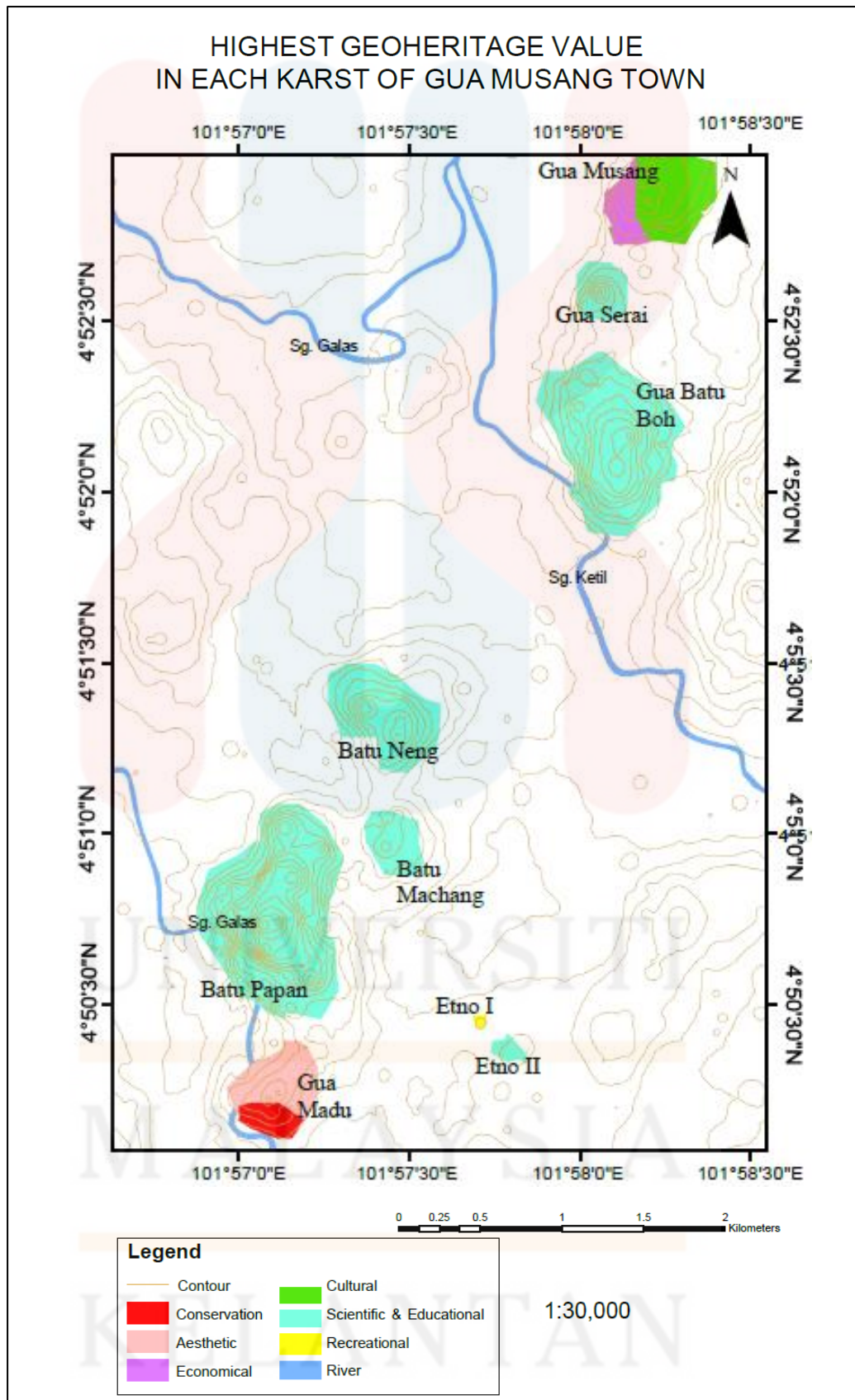


Figure 5.19: Highest Geoheritage Value in each of selected Karst in Gua Musang town.

5.5 Discussion and Interpretation.

Limestone Karst	Suitability Geoheritage Value			
	The highest Geoheritage Value	>66%	Second highest Geoheritage Value	(66 – 33) %
Gua Musang	Cultural	90%	Economical and Scientific and Educational	66%
Gua Serai	Scientific and Educational	80%	-	-
Gua Batu Boh	Scientific and Educational	90%	Aesthetic	40%
Batu Neng	Scientific and Educational	80%	Aesthetic	35%
Batu Machang	Scientific and Educational	80%	-	-
Batu Papan	Scientific and Educational	80%	Aesthetic	40%
Gua Madu	Scientific and Educational	80%	Aesthetic and Cultural	48%
Etnobotany 1	Scientific and Educational	80%	Recreational	35%
Etnobotany 2	Scientific and Educational	80%	-	-

Table 5.5.1: Overall suitability geoheritage value for each limestone karst.

Table 5.5.1 was build based on the estimation of coverage area of the coloured section in the map and the score of quantitative assessment of geoheritage values in Table 5.3.2. Each coloured section has the specific geoheritage value (can be refers to Table 5.3.3). In Table 5.5.1, the highest and second/third highest of geoheritage value has been categorized with the coverage of $\frac{2}{3}$ and $\frac{1}{3}$ of the map. The parts of the coverage were converted into estimation of percentage to easy explained and discussed.

5.5.1 Gua Musang

For Gua Musang, the highest geoheritage value is the cultural value that covers 90% of the map. Due to many folklores and historical story of Gua Musang, the cultural value shows the most valuable value. One of the tales are regarding the naming of the city, which literally translates to “civet cat cave” in Malay. Firstly, people regularly locate civet cats in one of the caves on the fringes of the town. Due to that situation, Gua Musang is a name given to the area by the local people since then. Secondly, according to folklore, a group of shamans conducted animal sacrifices in front of the cave. A furious storm broke out one day, and a lightning bolt struck the peak of the hill here, splitting it in half. The shamans felt the Cave God was furious with them, and while they prayed, they spotted a large group of civet cats, which gave the town its name. The breaks that cause from the lightning even could clearly see in the picture A in Figure 5.1.

Next, for the second and third highest geoheritage value will be scientific and educational value and economical value approximately about 66%. For the scientific and educational value, there are many karst features, and the geodiversity can be seen. The geodiversity will lead to biodiversity which they are many habitats and species live in Gua Musang. Many species of flora were found by the researcher and botanists as shown in Table 5.5.2 (table species). The karst features also can be observed in Gua Musang. The types of karst features can be divided into surface landforms and subsurface features. The surface landforms include sinkholes (dolines), areas of subsidence, sinking streams, springs, and cave entrances. At Gua Musang, the cave, springs, pillar, or column and lapies/ karren on the surface of the karst. The column is

the formation that join the stalactite (deposits that grow from the ceiling downward) and stalagmites (deposits that grow from the ground up) together.

For economic value, there are many facilities that are already build up and running at the Gua Musang area. There is a kiosk, shop, restaurant, mosque, and many other facilities, even the recreational activities which is the rock climbing and flying fox are provided there. There are facilities such as Muse Ecopark, KB Brewster Muse, Warong Muse, Keda Muse, and Inap Muse. There are all gives benefit to the economic sector people's there and for tourist facilities.

Family	Species	Gua Musang	Gua Serai	Gua Batu Boh
Annonaceae	<i>Polyalthia guamusangensis</i>	+		
Cyperaceae	<i>Carex speciosa</i>	+		
Myrsinaceae	<i>Ardisia biflora</i>	+		
Palmae	<i>Calamus elegans</i>	+		
Moraceae	<i>Bleekrodea malayana</i>	+		
Rubiaceae	<i>Ophiorrhiza longerepens</i>	+		+
Palmae	<i>Borassodendron machadonis</i>			+
Gesneriaceae	<i>Paraboea brachycarpa</i>			+
Gesneriaceae	<i>Microchirita sericea</i>		+	

Table 5.5.2: Distribution of rare species on Gua Musang, Gua Serai and Gua Batu Boh (Conservation Malaysia Bulletin, Forest Research Institute Malaysia, FRIM, 2019).

5.5.2 Gua Serai

For Gua Serai, the highest geoheritage value is scientific and educational value that covers 80% of the Gua Serai Geoheritage Value Map. Although Gua Serai karst have covered with vegetation, but the scientific value of the karst has still there. Karst is associated with soluble rock types such as limestones, marble, and gypsum. In this case, there are marble that have been metamorphosed from limestone. In general, a typical karst landscape forms when much of the water falling on the surface interacts with and enters the subsurface through cracks, fractures, and holes that have been dissolved into the bedrock.

For Gua Serai there can be clearly seen the breaking part due to the weathering process in picture B in Figure 5.2. This is because, as rainwater seeps into the rock, it slowly erodes. Karst landscapes can be worn away from the top or dissolved from a weak point inside the rock. Karst topography refers to natural landscape that is largely the result of chemical weathering by water, resulting in caves, sinkholes, cliffs, and steep sided hill called towers. These features form when water picks up carbon dioxide from the atmosphere and ground to form carbonic acid. Meanwhile, biological weathering involves the weakening and disintegration of rocks and dissolution of minerals that caused by the activity of plants and even animals.

The surface landform that can observed by the drone image is the sinkhole from the upside view of Gua Serai. Sinkholes are holes or depressions that form when water washes sediment down into cracks and voids in karst bedrock Based on FRIM article, Gua Serai and Gua Musang both have the history of fire in the past years, however, after almost 50 years since the 1969 fire, the vegetation on the summit of Gua Serai has still not recovered.

5.5.3 Gua Batu Boh

For Gua Batu Boh, the highest geoheritage value is scientific and educational value that covered 90% of the Gua Batu Boh Geoheritage Value Map. Although there not so many karst features found here but the karst formation itself give the scientific and educational purposes to the people. When the trip or the visitors come, the scientific value of the formation limestone could be educating people to appreciate and enjoy the uniqueness of the limestone karsts formation and landscapes. Many habitats flora and fauna also has been observed there.

Next, the second highest geoheritage value observed in Gua Batu Boh is aesthetic value. The aesthetic value that covered 40% area of the map. The aesthetic value can be observed at the formation of the Gua Batu Boh karst that has the multilevel of formation as can be seen in picture G in Figure 5.3. Moreover, the karst was like cabbage look from the upper view of the drone image (pic E in Figure 5.3). The accessibility to economic value quiet low even the karsts could be access but the economic activities such as build a shop and other facilities are not suitable. Same goes with recreational activities, the potential for recreational activites to build there is not very suitable as the many habitats were dominant there. However, if the beauty of the karst landform has been used for background's photoshoot, it can be benefit for economic. The risk is rarely observed in Gua Batu Boh, that make the conservation is high and need to be conserve due its nature.

5.5.4 Batu Neng

For Batu Neng, the highest geoheritage value is scientific and educational value that covers 80% of the Batu Neng Geoheritage Value Map. Batu Neng karst are easy access and can be benefits to educate people with the uniqueness of the karst formation and features. They can be touching the limestone karst by hand and see the features like flowstone clearly. The flowstone occurs when water rich in calcium carbonate flows along the walls or floor of a cave, depositing layers of calcite. The formations can look smooth and glossy or create hanging ‘curtains’ and draperies. The pre-cave also observed there. The pre-cave is possible to form cave in long time process due to weathering.

Next, the second highest geoheritage value is the aesthetic value that covers up to 35% of the map. The aesthetic value can be seen at formation of the big flowstone around 1.5 m length. The flowstone forms very slowly, growing an average of only 1 inch every 100 years. Due to its longer time formation and uniqueness, it makes it valuable to be conserved because not all karst formation has same karst features. The formation of Batu Neng also has a dome-like shaped that observed from the drone image (picture D in Figure 5.5) which gives the special aesthetic value to the karst. The recreational activities also could be done in Batu Neng as we can see in picture F in Figure 5.5, there are the football or netball court for people to play there. For economic benefit, the facilities like shop or café can be build there because of the easy access of the Batu Neng and located at the centre of the town.

5.5.5 Batu Papan

For Bukit Batu Papan, the highest geoheritage value is the scientific and educational value that covered around 80% of the Batu Papan Geoheritage Value Map. The karst features and the karst formation itself hold the scientific value that can educate people. The karst formation found are the pre-cave, stalactite (grow down from the cave ceiling), stalagmite (grow up from the cave floor), karren (at surface), flowstone and pinnacle. The geodiversity also will lead to biodiversity where flora and fauna could be live there. Second highest geoheritage value is the aesthetic value which covered around 40% of the map. The karst features like pinnacle are a long-time formation and unique to be found. The formation of the Bukit Batu Papan are all covered and rounded-like, but it continued with pinnacle structure at the end side as in picture E in Figure 5.4. The folding also is rare structure found in karst (refer picture B in Figure 5.4).

5.5.6 Batu Machang

For Bukit Batu Machang, the highest geoheritage value is the scientific and educational value that covered up to 80% of the Batu Machang Geoheritage Value Map. Even though the karst was highly weathered and covered with vegetation, the scientific and educational still exists. It is valuable to educate people about the karst features and formation in the meantime and futures. The recreational activities and building or shop for economic purposes are not suitable to be proposed. It is because of the high risk of rock fall or sinkholes to be happen due to the weathering process. Then, the accessibility of the karst also was low, so it hard for people or visitors to come. However, the karst features still had been observed in Batu Machang. There is the pre-cave (the holes that are possible to form a cave), stalactite, stalagmite and pillar or column (formation that joins the stalactite and stalagmite together).

5.5.7 Gua Madu

For Gua Madu, the highest geoheritage value is the scientific and educational value that covered about 80% of the Gua Madu Geoheritage Value Map. Gua Madu are covered with vegetation, but we can still discover the karst landform, formation, and features. The karst features observed was stalactite, stalagmite, sinkhole at the upper part, column and drapes or straw. The cave also formed below the cave, there are the track that used for hiking to the Gua Madu cave entrance.

Next, for the second and third highest geoheritage value are aesthetic value and cultural value that covers about 48% of the map when mix both values together. The aesthetic value can be observed at the big beautiful ‘curtain’ shaped karst features at Gua Madu. It is a unique feature that rarely be found. It has many stalactites formation at the upper part of the ‘curtain’ (refer picture F in Figure 5.7). It gives Gua Madu the added special value that need to be protected and conserved.

Meanwhile, for the cultural, from the folklore and local belief, Gua Madu’s cave was a hideout place for communist in the past years. They also claim that the honeybee was produce in the ceiling of the cave and only local people knows the exact location of the honeybee production. The fruit stall also was built along the track to the cave. This benefits the economics of people there direct or indirectly. Gua Madu has a high possibility for tourist to access as it was not surrounded with heavy vegetation. Recreational value like cave exploration also can be done and there is the guider will be guiding the tourist.

5.5.8 Etnobotany 1

For Etnobotany 1 karst, the highest geoheritage value observed was scientific and educational value that covered about 80% of the Etnobotany 1 Geoheritage Value Map. The scientific value refers to the karst features that was found. The karst features found was spring, cave, pillar, or column, lapies or karren, stalactites, stalagmite, and flowstone. All the karst features hold the scientific information that can be used to educate people. The geodiversity there lead to biodiversity, flora, and fauna such as bird. Next, the second highest geoheritage value was recreational value that covered about 35% of the map. Due to many facilities provided at the Etnobotany Park, the recreational activities were highly recommended to attract the tourist attention. The rock climbing and camping can be done at the Etnobotany 1 karst. It has a large area for the recreational activities, located near the city and open to the public make it strategically for the activities to be done. The economic value also can be observed if there are stall open near the karst. Even though there was a cave and spring, the karst approximately has low risk for rock fall and can be conserved for future generation.

5.5.9 Etnobotany 2

For Etnobotany 2, the highest geoheritage value is the scientific and educational value that covered up to 80% of the Etnobotany 2 Geoheritage Value Map. The karst was highly covered with vegetation and a bit high weathered. The break or fracture in a large scale can clearly be seen in picture D in Figure 5.9. However, the scientific and educational value still can be observed as the formation was there. The geodiversity and biodiversity there also will be the attraction for the tourist. The accessibility was quite good because it located at the Gua Musang town and in the Etnobotany Park that open for public. It is possible for the economic sector to be done there because of the accessibility and the large are provided for the tourist. The stall, shop, restaurant, or café can be constructed as it can be benefit for the economic purpose while enjoying the beauty of the karst landscapes and nature. The karst features cannot be seen much in Etnobotany 2 and has low percentage of aesthetic value, but the recreational activities still can be done here such as rock climbing.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

In conclusion, this study intends to update the geological map of the research area as well as to assess the potential and heritage value ranking map of Bandar Utama Gua Musang. A geological mapping was completed in the mapping study area. Quartzite, marble, slate, and alkali feldspar granite were the lithologies discovered in the study area, according to field mapping and laboratory research. Additionally, structural geology including joints was present and has been measured and documented.

An updated geological map on the 1:25000 scale has been generated. Comparison was made between geological map of JMG, previous researcher by Lilly Azleena in 2019 and the updated map of the study area. The JMG's geological map does not show the granite, quartzite and quartzolite in their data. Mainly composed of limestone/ marble, phyllite, slate, shale and volcanic rock. Meanwhile, if the updated one was compared to previous researcher, it just overlapped around 60% of the study area, and the difference of the lithologies was metasedimentary rock, quartzolite and a bit alluvium. The covering of the lithologies was a bit different maybe because of tectonic movement and formation of a new rock.

Furthermore, 9 limestone karsts were found in the Bandar Baru Gua Musang area, which made up the majority of the specified area. Based on Limestone Karsts Geoheritage Map produced, Etnobotany 1 shows the highest percentage of area suitable for recreational value, Gua Batu Boh and Gua Batu Papan shows the highest percentage of area suitable for scientific and educational because both of the karsts was biggest in size and formation, Gua Musang shows the highest percentage of area suitable for economic value, Gua Madu shows the highest percentage of area suitable for conservation value and aesthetic value, then Gua Musang shows the highest percentage of area for cultural and historical value.

Mostly the highest rank value identified at the selected karsts was scientific and educational value. Then followed by aesthetic, cultural, economic, conservational and recreational value. Thus, based on the score of the Gua Madu and Gua Musang are the highest score which means it tends to be conserve more compared to other karsts because of its value that it hold.

6.2 Recommendation

Karst's topography and features is remarkable and has a distinct aesthetic appeal. If properly maintained, some regions of Gua Musang's karst zone would be more attractive. The cave formed by the limestone in the research region should be protected and maintained. Some research locations also have a geo-heritage value connected to scientific, educational, artistic, cultural, and financial significance. The other method that can be used in this study could be the M-GAM method. It used for geosite and geomorphosite assessment that also in score value from 0 to 1. Then other method could qualitative method that describes all the places with the identification of level (local, national, international).

It is important to consider the significance of geological research, which includes geo-heritage and geoconservation, since these topics are often related on a geological level. The geological heritage must be protected and developed because it is an element of the natural heritage. Geoconservation is a technique for protecting the earth's geology from physical harm and formation events while also highlighting the various types of earth's geology. Geologically rich study areas necessitate physical development monitoring and conservation.

Rapid development and plantation development should be linked in their planning. Heritage value is threatened by human activities like land usage, forestry, mine for limestone, excavation, construction, and agriculture. Rapid development necessitates careful planning or management in order to preserve natural formations like karst and prevent geological processes that have destroyed heritage value. Then, it is the responsibility of geologists or educational institutions to convey to the community the need of safeguarding geological resources.

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