GEOLOGY AND GEOHERITAGE STUDY OF SUBONG AREA, GUA MUSANG, KELANTAN USING GEODIVERSITY ASSESSMENT

by

NUR ANTHASHA BILLAH BINTI MOHD NOOR

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

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APPROVAL

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

Signature :

Name of Supervisor : DR. NURSUFIAH BTE SULAIMAN

Date :

DECLARATION

I declare that this thesis entitled "**GEOLOGY AND GEOHERITAGE STUDY OF SUBONG AREA, GUA MUSANG, KELANTAN USING GEODIVERSITY ASSESSMENT**" 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.

Signature :

Name : NUR ANTHASHA BILLAH BINTI MOHD NOOR

Date :

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GEOLOGY AND GEOHERITAGE STUDY OF SUBONG AREA, GUA MUSANG, KELANTAN USING GEODIVERSITY ASSESSMENT

ABSTRACT

This research focussed on the geology and geoheritage study using geodiversity assessment method in Subong area, Gua Musang. The research was done in a study area of 25 km^2 within the longitude of 101°53'05.50"E to 101°55'50.50"E and latitude 4°54'42.07"N to 4°57'24.04"N. The objectives of this research are to: i) generate a detailed geological map of study area with scale of 1:25000 and ii) assess the geodiversity in the study area for geoheritage potential. Geology of the study area is conducted by mapping interpretation method using DEM SRTM, satellite imagery, topography map and TIN map. The geology of study area consists of metasedimentary rock unit, limestone, granite and alluvium deposits. Geoheritage study is conducted by using geodiversity assessment method. Four geological elements which are lithology, geomorphology, hydrology and mineral are quantified and indexed to produce total geodiversity index map. The total geodiversity index is quantified based on the sum up of four partial indices and classified into five classes using natural breaks Jenks classification method in ArcGIS. Geodiversity index map is presented on map of study area with 100 square grid cells. The total geodiversity index value ranges from 2 to 11. This value indicates the existence of a complex geological system in the study area. Thus, the geodiversity elements in the study area may possess its own geoheritage potential in which it has the potential to be further classified as a geosites based on the uniqueness of geological elements in the area.

GEOLOGI DAN KAJIAN GEOWARISAN KAWASAN SUBONG, GUA MUSANG, KELANTAN MENGGUNAKAN PENILAIAN GEODIVERSITI

ABSTRAK

Kajian ini memfokuskan kepada geologi dan kajian geowarisan menggunakan penilaian geodiversiti di kawasan Subong, Gua Musang. Kajian ini dijalankan di kawasan kajian seluas 25 km^2 dalam lingkungan longitud 101°53'05.50"E sehingga 101°55'50.50"E dan latitud 4°54'42.07"N sehingga 4°57'24.04"N. Objektif penyelidikan ini dijalankan adalah untuk: i) menghasilkan peta geologi kawasan kajian yang terperinci dalam skala 1:25000 dan ii) menilai geodiversiti kawasan kajian untuk potensi geowarisan. Kajian geologi dijalankan menggunakan kaedah interpretasi peta menggunakan *DEM SRTM*, imej satelit, peta topografi dan peta *TIN*. Geologi kawasan kajian terdiri daripada batuan metasedimen, batu kapur, granit dan endapan aluvium. Kajian geowarisan dijalankan menggunakan kaedah penilaian geodiversiti. Empat elemen geologi iaitu litologi, geomorfologi, hidrologi dan mineral dikuantifikasi dan diindeks bagi menghasilkan peta indeks geodiversiti. Indeks geodiversiti dikira berdasarkan jumlah keseluruhan keempat-empat indeks dan diklasifikasi kepada lima kelas menggunakan kaedah klasifikasi di dalam perisian ArcGIS iaitu *natural breaks* oleh Jenks. Peta indeks geodiversiti kawasan kajian terdiri daripada 100 grid. Hasil jumlah keseluruhan indeks geodiversiti bernilai antara 2 ke 11. Julat nilai indeks geodiversiti tersebut menandakan kawasan kajian mempunyai sistem geologi yang kompleks. Elemen geodiversiti di kawasan kajian cenderung untuk mempunyai potensi geowarisan yang tersendiri dan dengan kajian yang lebih lanjut, ianya berkemungkinan boleh diklasifikasikan sebagai geotapak berdasarkan keunikan elemen geologi di kawasan tersebut.

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LIST OF ABBREVIATIONS

Km	Kilometre
E	East
N	North
m	Metre
KESEDAR	Lembaga Kemajuan Kelantan Selatan
FELDA	Federal Land Development Authority
PKINK	Perbadanan Kemajuan Iktisad Negeri Kelantan
GIS	Geographic Information System
DEM	Digital Elevation Model
STRM	Shuttle Radar Topography Mission
USGS	United States Geological Survey
TIN	Triangular Irregular Network
$CaCO_3$	Calcium carbonate

LIST OF SYMBOLS

%	Percentage
σ	Stress
′	Minutes
″	Seconds
°	Degree

CHAPTER 1

INTRODUCTION

1.1 General Background

Geology is a study that investigates Earth materials, history and processes which acted upon it throughout hundreds to billions of years. Geology encompasses the study of evidence on Earth and the effects of previous processes that took place throughout the extensive geological time scale (Earle, 2018). The processes and history are hidden within geological features such as structural geology, lithology, stratigraphy, petrology and geomorphology. Meanwhile, geoheritage is a term derived from the phrase geological heritage which is a geology subdivision that focuses on geological elements in an area that exhibits several values such as scientific, educational, aesthetic, recreational and cultural values (Nazaruddin et al., 2016). Geoheritage highlights the unique, rare and representable geological features in an area with scientific, educational, aesthetic, recreational, cultural and functional values that are important to be conserved and recognised as geosites. According to Erikstad (2013), geosite is defined as a locality that contains diverse abiotic elements; for example rocks, landforms and fossils represent the intrinsic interest that allow people to understand Earth history.

Geodiversity with unique values is the key to assess geoheritage and establish a geological site or geosite which is important to be conserved. Geodiversity is defined as the natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features that assemblage systems and processes (Sharples, 2002). During previous decades, nature conservation debate had always been focusing only on biodiversity (Erikstad, 2013). Nature conservation should not be focusing solely on biodiversity because biotic and abiotic elements are interrelated and depending on each other. Besides, abiotic elements also have their own influences on the environment and ecosystem. Thus, it has been a great achievement for geological heritage management when geodiversity was introduced and finally be recognised worldwide in conserving nature (Erikstad, 2013). Work by Brocx and Semeniuk (2007) states that geoheritage and geoconservation are important concepts that focus on preserving Earth science features in an area. When a geosite is being proposed for geoconservation project, the preserved geodiversity in that area can be further developed for geotourism purposes.

Hence, this study is conducted to understand the whole geological processes, Earth history and to assess the geodiversity in the area. General geology study of the area is carried out through mapping interpretation of a 5 km x 5 km (25 km^2) study area by using secondary data obtained from previous researcher and related agencies. This work is conducted to produce a detailed geological map of the study area with scale 1:25000. Geoheritage study is done by using geodiversity assessment method where the occurrence and spatial distribution of geological elements in the study area were assessed and presented in the form of geodiversity index map.

1.2 Study Area

1.2.1 Location

The research is conducted in Subong area at Gua Musang district of Kelantan state. Gua Musang is the largest district located in southern Kelantan, Malaysia. The study area is bounded within the longitude of 101°53'05.50"E to 101°55'50.50"E and latitude 4°54'42.07"N to 4°57'24.04"N. Based on Google Earth satellite view, the study area is situated in the region of Gua Musang Formation and batolith of Central Belt granitoid also known as the Eastern Province granite as shown in Figure 1.1. Based on Figure 1.2, the area consists of high hills with an elevation of 580 m and lowlands with the lowest elevation of 120 m.

Figure 1.1: Satellite image of the study area shown as a red square with points A,B,C and D which is located nearby Gua Musang Town. (Source: Google Earth, 2020)

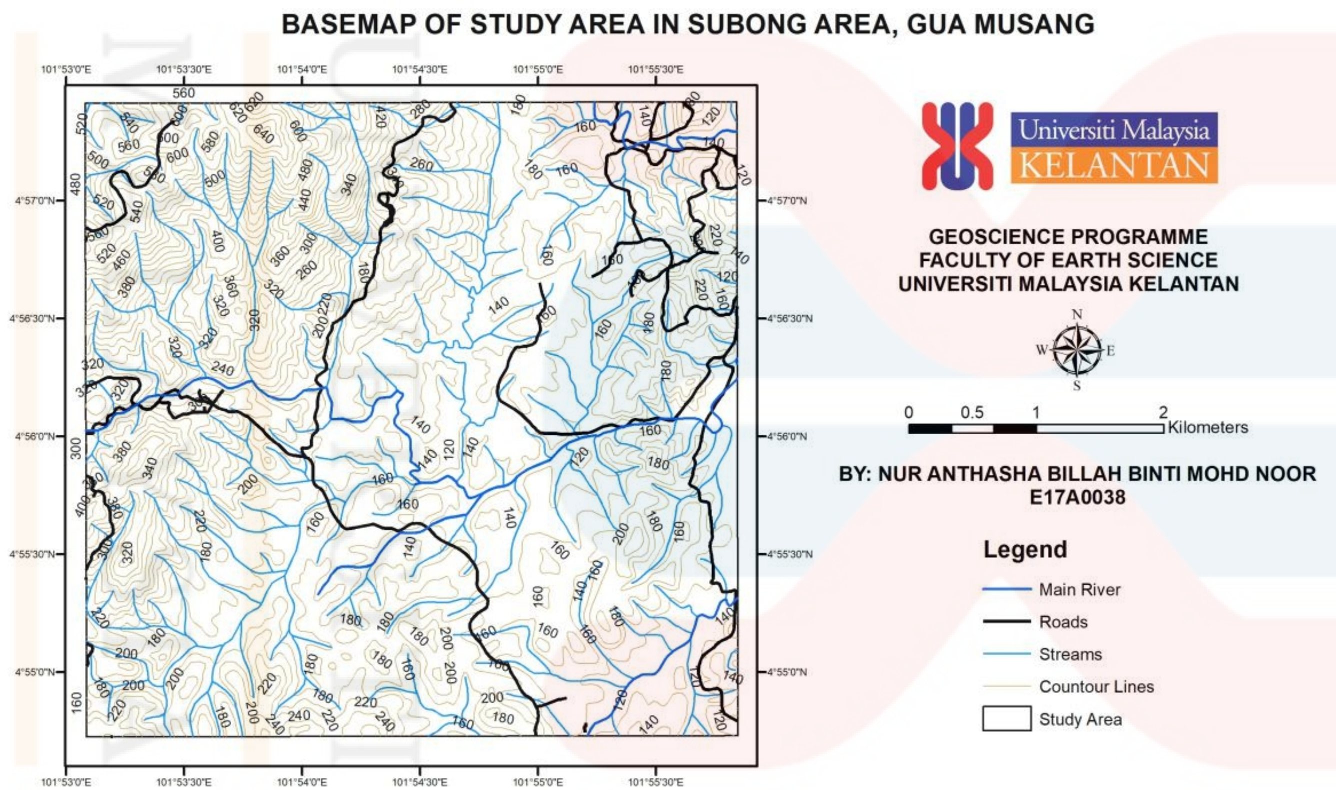


Figure 1.2: Basemap of the study area.

1.2.2 Road Connection

Gua Musang town is accessible through Kuala Lumpur - Gua Musang Highway, Kota Bharu - Gua Musang Highway and Gua Musang - Cameron Highland Street. Jeli is connected to Gua Musang through Sungai Sam - Dabong - Jeli Street, Gua Musang Street and Jelawang - Gua Musang Street. Meanwhile,the study area is accessible through Jalan Gua Musang from Gua Musang town.

1.2.3 Demography

The total population of Kelantan has been increasing since the year 2017 to 2019 which is around 1.9 million people in 2019. Table 1.1 shows the population of Kelantan from 2017 to 2019 in each district in Kelantan. Generally, every district showed an increase of population throughout those years. The highest population is in Kota Bharu with a total population of 608,600 people in 2019. Meanwhile, Jeli is the least populated district with only 51,900 people by the year 2019. Although Gua Musang is the largest district in Kelantan with a total area of 7,980 km^2, the population in 2019 only consists of 116,200 people compared to Kota Bharu with only 115.6 km^2 total area. The difference is about 492,400 people. Gua Musang has gone through rate of increase of population by 1.98% in 2019.

Table 1.1: Total population of every district in Kelantan from 2017 to 2019.

(Source: Jabatan Perangkaan Malaysia, 2020)

District	Year		
	2017	2018	2019
Tumpat	183,600	187,300	190,900
Kota Bharu	585,300	596,900	608,900
Bachok	159,300	162,500	165,800
Pasir Mas	227,300	231,800	236,400
Tanah Merah	146,300	149,200	152,200
Machang	111,400	113,600	115,900
Jeli	49,800	50,800	51,900
Kuala Krai	132,600	135,200	137,800
Gua Musang	111,500	113,900	116,200

1.2.4 Landuse

Landuse is the environment and natural habitat modification into the area of settlement and semi-natural habitats. Usually, landuse modification is done for development planning through urbanisation, agricultural activities, residential area. Gua Musang landuse is influenced by town planning development. It involves landuse of residential areas in villages, urbanisation around Gua Musang town, oil palm and rubber tree plantation, reserve forest and mining area. Meanwhile, landuse in the study area consist of the rubber tree and oil palm plantation managed by Lembaga Kemajuan Kelantan Selatan, KESEDAR.

1.2.5 Social Economic

The most significant social economic activities in Gua Musang is driven by plantation and harvesting of oil palm and rubber trees. This plantation is managed by two agencies which are the Lembaga Kemajuan Kelantan Selatan, KESEDAR and Federal Land Development Authority, FELDA. The study area which is located in Ladang Subong is a part of the Ladang Sungai Terah area under the management of KESEDAR. The rubber trees plantation in Ladang Subong started in 1973 with 2,993 hectares wide by the Perbadanan Kemajuan Iktisad Negeri Kelantan (PKINK) under the supervision of Kelantan State Government (Perbadanan Kemajuan Iktisad Negeri Kelantan, 2012). Ladang Sungai Terah has been the main contributor to the development in southern Kelantan since 1990. The previous rubber trees plantation is replaced by oil palm plantation in certain areas to increase production and incomes (Perbadanan Kemajuan Iktisad Negeri Kelantan, 2012). These plantation activities have opened up countless job opportunities to the local communities to work in the plantation, administration office and production factories.

1.3 Problem Statement

Geological maps of Gua Musang that can be obtained based on literature are outdated and in a small scale. Thus, it is crucial to produce an updated and detailed of a large scale geological map of the study area as Earth is dynamic and may change from time to time. It is important to provide new geological data and information which will benefit any particular persons or agencies in the geology field to have a better understanding of its geological processes, histories and new processes that happened in the study area. Gua Musang is one of many districts in Kelantan that is enriched and blessed with a variety of remarkable geological features. Until the recent years, there is no approach made by researchers to conduct research specifically in geoheritage field in the study area. Thus, the study on geoheritage needs to be conducted to fill the void. Furthermore, the area is expected to have abundance of geological elements. Therefore, the geological elements need to be assessed using geodiversity assessment method to show their occurrence and spatial distribution in the study area. Thus, further action can be taken for example for further research in geoheritage field, to develop the area as a geosite and for geodiversity conservation work.

1.4 Objectives

The main objectives of this research:

1. To generate a detailed geological map of study area with scale of 1:25 000.
2. To assess the geodiversity in the study area for geoheritage potential.

1.5 Scope of Study

This study focused on two parts which are the geological interpretation and analysis and geodiversity assessment of 5 km x 5 km box of study area in Subong area, Gua Musang. Both works involve the generation of maps which are the geological map and geodiversity index maps with scale of 1:25000. The work is done by using hardware such as laptop and ArcGIS software. Geological study of the study area is done by data processing, interpretation and analysis of secondary spatial data to examine its structural geology, lithostratigraphy and geomorphology.

Meanwhile, historical geology in the study area is carried out through literature review based on previous research.

Geodiversity assessment is carried out by indexing the occurrence of geological elements in the study area which are the lithology, geomorphology, minerals, hydrology and geodiversity. Map indices of each elements are produced by using secondary data obtained in form of raster and vector data. Quantification assessment of each partial indices are classified using Jenks natural breaks using geoprocessing in ArcGIS. Those four indices are summed up, overlaid and classified to produce geodiversity index map to determine the occurrence and spatial distribution of geological elements in the study area. Secondary data such as existing lithological map, Digital Elevation Model (DEM), Shuttle Radar Topography Mission (STRM) DEM, satellite imagery and mineral resources data of Subong are used to do interpretation and analysis.

1.6 Significance of Study

This study is important to provide a detailed geological information presented in a geological map of the study area for geology community to understand the history and processes that occurred in the study area. The information that are provided such as lithostratigraphy, structural geology and geomorphology plays role as a reference for the authorities, agencies or government to implement proper management and development planning in the study area. Besides, the importance of geodiversity assessment in the study area is to show the occurrence and spatial distribution of valuable geological elements in order to promote awareness to conserve geological resources in the study area not only to geology community but most importantly to the authorities and local community. Conserving valuable geological resources is as important as conserving biodiversity which contributes to a sustainable geodiversity and stable regional ecosystem. The overall result of geodiversity assessment shown in the form of geodiversity index map could act as a reference to carry out further geoheritage research, conservation work or proper development planning in the study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is one of the major part in researching in order to gather information and to know background knowledge of selected research topic. Literature review in this research was done to get the background information theoretically about general geology specifically on regional geology and tectonic setting, stratigraphy, structural and historical geology from the scale of Peninsular Malaysia to the study area. It also covers geoheritage subject based on terms available, conceptual, history and its development through times and across region.

2.2 Regional Geology and Tectonic Setting

Peninsular Malaysia is made up of three tectonic belts which is Western belt, Central belt and Eastern Belt due to the collision of Sibumasu and Indochina plate tectonic in Late Permian to Triassic period (Hutchinson & Tan, 2009) as shown in Figure 2.1. The collision of Sibumasu and Indochina plate tectonic has resulted in orogenesis process (Ooi, 1976). Besides, variation of stratigraphy and geological history in Peninsular Malaysia are also produced due to the tectonic event (Hutchinson & Tan, 2009).

The Bentong-Raub Suture is a line that separated Western Belt from Central Belt that represents the closure of Palaeo Tethys ocean due to the collision of Sibumasu and Indochina terranes (Hutchison & Tan, 2009). It is a North-South long line lineament extending from Thailand towards East of Malacca which also produced a trend of deformed rocks (Hutchison & Tan, 2009). There are two major fault within Peninsular Malaysia which are the Lebir Fault that borders the Eastern and Central Belts and Bentong-Raub line that borders the Central and Western Belts (Hutchinson & Tan, 2009) as in Figure 2.2.

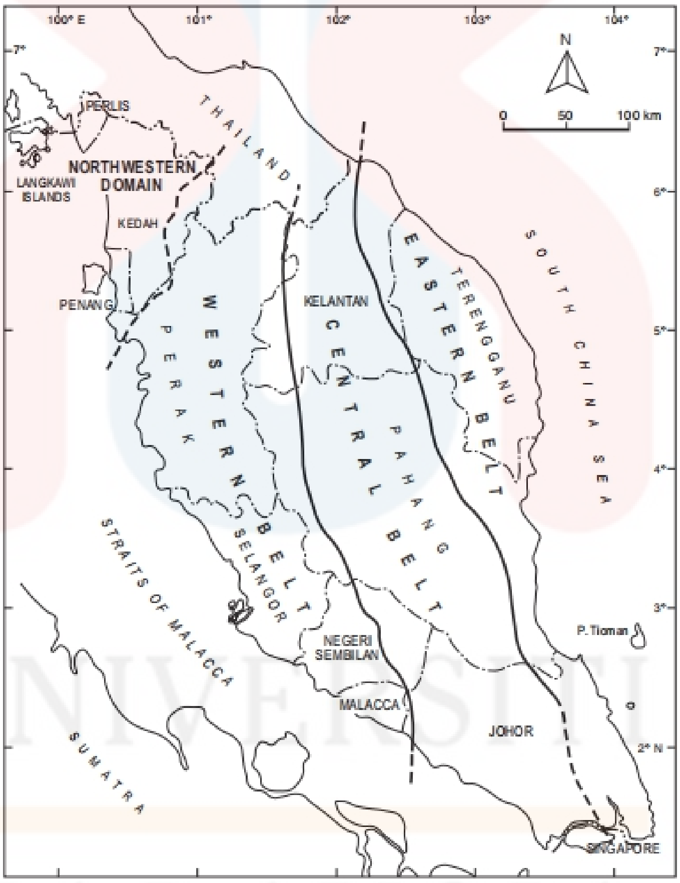


Figure 2.1: Map of Peninsular Malaysia showing Western, Central and Eastern Belts

(Source: Hutchison & Tan, 2009)

Figure 2.2: The Bentong-Raub Suture line and Lebir Fault line in Peninsular Malaysia

(Source: Hutchinson & Tan, 2009)

A large part of Kelantan is located in the Central Belt and Southern Kelantan is one of the region in Central Belt. The oldest rock unit in Kelantan occurred during Silurian-Ordovician Period and depositional process is continued with Carboniferous, Permian, Triassic, Cretaceous-Jurassic and Quarternary succession as shown in geological map of Kelantan in Figure 2.3. The study area, Subong, is situated nearby Gua Musang town that is made up of the Gua Musang Formation which deposited during Early Permian to Late Triassic. The formation consists of argillaceous and calcareous rocks interbedded with volcanic while arenaceous rocks are only in minor amount (Mohamed et al., 2016). It also consists of crystalline limestone with interbedded argillites and subordinate sandstones (Yee, 1983). Argillaceous rock units consist of shale, siltstone, mudstone, slate, and phyllite (Mohamed et al., 2016).

On the other hand, one third of the Peninsular Malaysia land is covered with granite that are distributed into three belts, the Western Belt, Central Belt and Eastern Belt (Hutchison & Tan, 2009) as shown in Figure 2.4. Granite rocks in Peninsular Malaysia are divided into Western Belt, Central Belt and Eastern Belt granite (Hussin, 2011). The distribution of granite rocks was further categorised into two granite province, the Main Range Province and the Eastern Province which were separated by Bentong-Raub Suture zone (Hutchison & Tan, 2009) as in Figure 2.5.

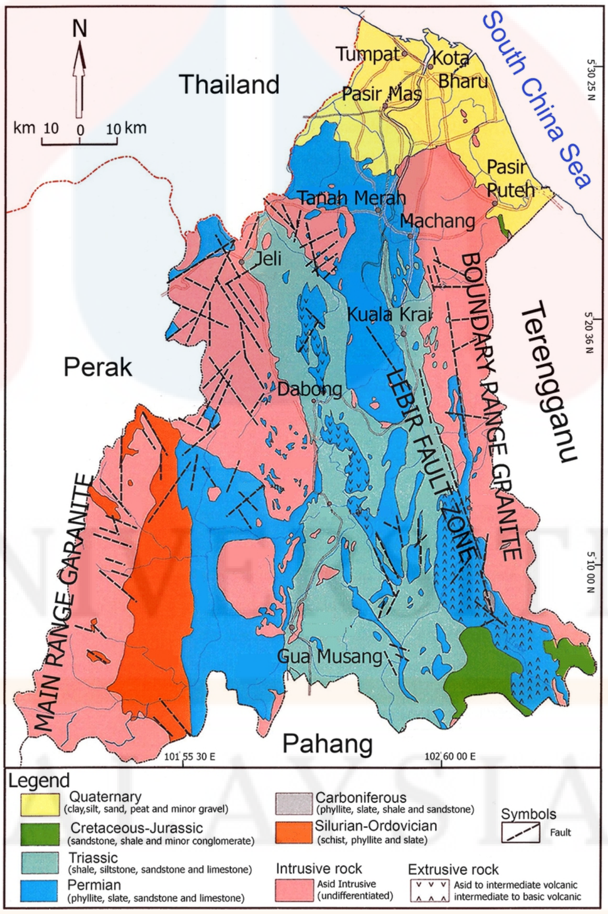


Figure 2.3: Geological map of Kelantan

(Source: Department of Minerals and Geoscience Malaysia, 2003)

The Eastern Province granite is made up of mainly I-type granite with mostly in forms of smaller batholiths of zone and unzoned plutons (Hutchison & Tan, 2009). These plutons developed from Permian to Triassic period which they intruded a sequence of mudstone, siltstone, sandstone, limestone and a thick sequence of intermediate to acid volcanic and volcaniclastic rocks (Hutchison & Tan, 2009). Eastern Province granite has a composition ranging from gabbro to monzogranite that are characterised by equigranular to weakly porphyritic texture (Ghani, 2008). The Eastern Province is dominated by hornblende and biotite as the common mafic phase which occur up to 1 cm size (Ghani, 2008).

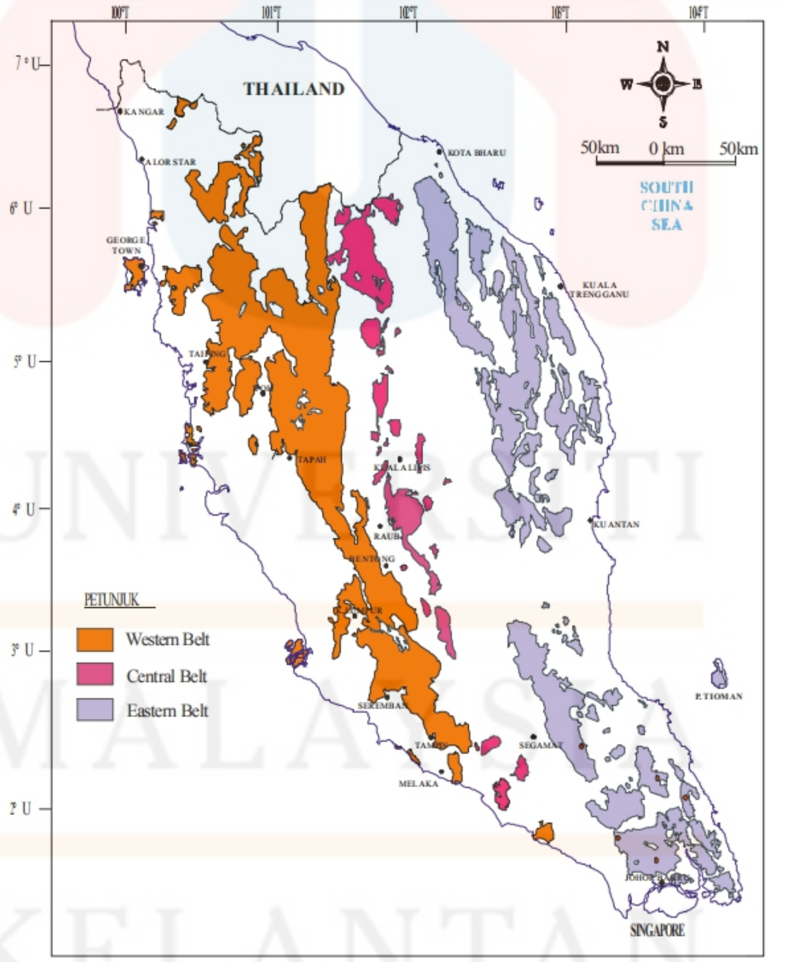


Figure 2.4: The distribution of granitoids in Peninsular Malaysia (Source: Hussin, 2011)

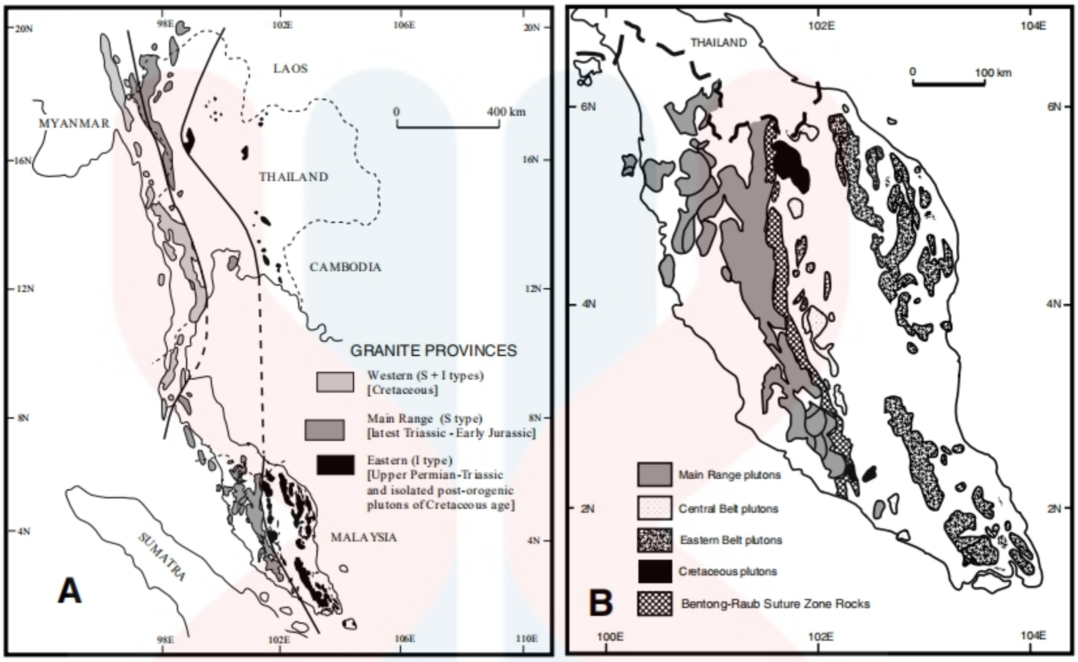


Figure 2.5: A. Granite Provinces of Southeast Asia. B. Granite in Peninsular Malaysia shown concerning the Bentong-Raub suture zone. (Source: Metcalfe, 2000)

2.3 Stratigraphy

Kelantan geological formation developed from Lower Paleozoic until the Quaternary Era has been categorised into three chronological types which are the Paleozoic, Mesozoic and Cenozoic (Hutchison & Tan, 2009). All three types are found in the Central Belt of Peninsular Malaysia (Hutchison & Tan, 2009) which can also be found in Southern Kelantan. Southern Kelantan is divided into four areas - Kuala Betis, Gua Musang, Aring and Gunung Gagau area. There are two types of formation called Gua Musang Formation and Aring Formation deposited during the Upper Paleozoic that covers a part of Southern Kelantan region (Hutchison & Tan, 2009).

The formations are dominant with argillaceous and volcanic facies which indicated shallow marine with active submarine volcanism as its depositional environment (Hutchison & Tan, 2009). Mesozoic formation dominated the central belt in the peninsular. It extends continuously from north (Gua Musang Formation) to south (Jurong Formation) (Hutchison & Tan, 2009). Meanwhile, Cenozoic formation that mostly from Quaternary Period deposition covers Northern part of Kelantan with deposition of unconsolidated to semi-consolidated sediments near river valley such as gravel, sand, silts and clay (Nur Shahirah binti Che Azlan, 2018).

Southern Kelantan consist of deposition during Permo-Triassic Period which consist of Gua Musang Formation, Gunung Rabong Formation, Aring Formation, Telong Formation, Koh Formation and Nilam Marble (Kamal Roslan Mohamed, n.d.). Gua Musang district encompasses of two formation; the Gua Musang Formation and Gunung Rabong Formation. All of the formations dominates the northern region of Peninsular Malaysia Central Belt. The stratigraphic sequence and correlation of all formations in Central Belt is as shown in Figure 2.6.

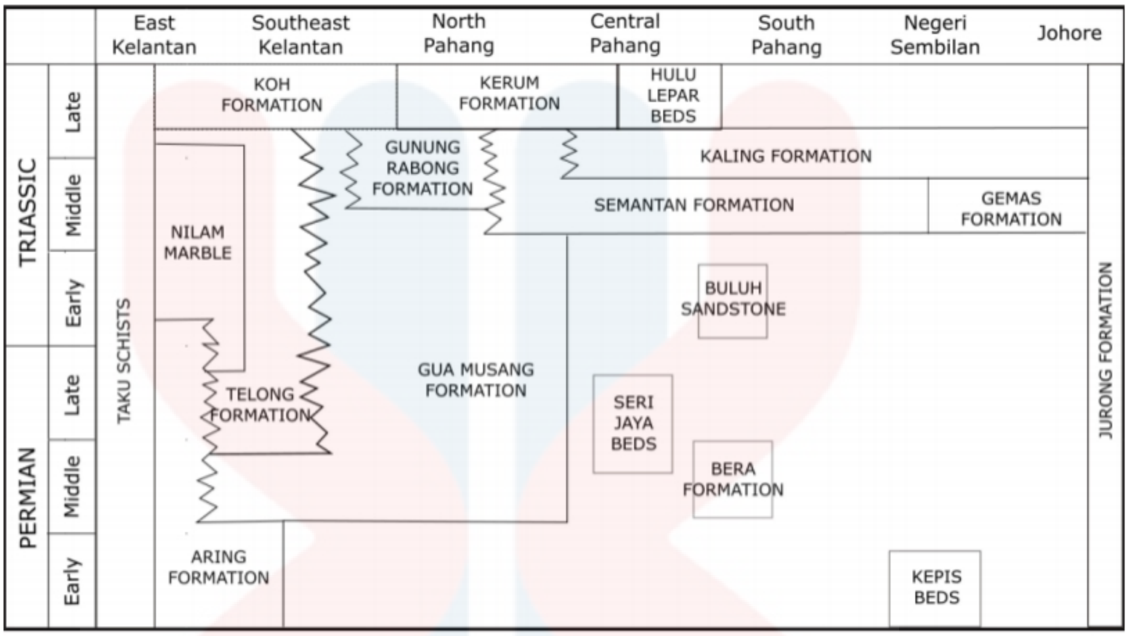


Figure 2.6: Stratigraphic correlation of formations in Central Belt of Peninsular Malaysia aged Permian to Triassic (Source: Mohamed et. al, 2016)

Newly proposed Gua Musang Group encompasses of the Gua Musang Formation, Aring Formation, Telong Formation and the Nilam Marble which are categorised based on their similarities and variation of lithological units, sedimentology and palaeontology (Mohamed et al., 2016). Those are based on deposition of argillite rock units, carbonate and volcanic on a shallow marine platform during Permian until Triassic Period. Generally the stratigraphy in Subong area is made up of slate deposited during Permian period, limestone deposition during Late Triassic followed by intrusion of granite during Cretaceous and most recent deposition of alluvium which took place in Quartenary until recent years (Nur Shahirah binti Che Azlan, 2018).

2.4 Structural Geology

The most significant geological structure in the peninsular is influenced by the occurrence of Bentong-Raub Suture which also affects other structures in Central Belt, which is situated adjacent to it. Bentong-Raub Suture is a North-South long line lineament extending from Thailand towards East of Malacca which also produced a trend of deformed rocks (Hutchison & Tan, 2009). It is a line that separates Western Belt from Central Belt that represents the closure of Palaeo Tethys ocean due to the collision of Sibumasu and Indochina terranes. In addition, the suture zone is a highly compressed crustal containing complex rocks with oceanic and continental shelf deposits such as ribbon-bedded cherts, argillites rock unit, turbidites, belt of melange and elongate serpentinites body (Hutchison & Tan, 2009). These rocks maybe associated to post-accretion strike-slip faulting in the Cretaceous (Hutchison & Tan, 2009).

There are numerous high angled faulting oriented parallel or sub-parallel to the suture line with North-Northwest orientation and strike slip motion (Hutchison & Tan, 2009). Oceanic sedimentary rocks consist of olistostrome (chaotic and heterogeneous) blocks are situated within melange and are sheared and in foliated argillaceous matrix (Hutchison & Tan, 2009). Apart from that, structural geology evidence consists of the characteristics of radiolarian chert which exist as clasts and olistostromal blocks where the clasts are in augen-shaped, in lenses, elongated parallel to the foliation orientation and show boudinage structure (Hutchison & Tan, 2009). Plus, wavy features can be observed around the clasts margins formed due to foliation of the sheared matrix that wraps around the clasts and tensional gashes structure are also visible (Hutchison & Tan, 2009). Radiolarian chert blocks and argillite are folded in orientation of fold axes trending northwards with sheared matrix foliation oriented parallel to its strike (Hutchison & Tan, 2009).

2.5 Historical Geology

According to sedimentological and palaeontological study, formations in Gua Musang area were deposited during Permian to Triassic period. The deposition took place in Central Belt which previously was the Paleo-Tethys Seaway and the depositional environment are warm and shallow marine environment (Mohamed et al., 2016). The depositional environment was proven due to the discovery of abundance of brachiopods and bivalves which are benthic organism that live on the sea floor. Meanwhile, warm and shallow marine platform is indicated by the dominance of argillite and the existence of extensive carbonate. The argillio-carbonate sedimentary continues to deposit as the subduction of Paleo-Tethys Ocean and Sibumasu terrane under the Indochina volcanic arc was going on (Mohamed et al., 2016). Presence of volcanic and pyroclastic deposition such as tuff and lapilli were supplied from the presence of Indochina volcanic arc nearby. The regional volcanism which is a high topographic created a shallow marine environment for limestone deposition (Mohamed et al., 2016). The chronology of tectonic evolution of Gua Musang is shown in Figure 2.7.

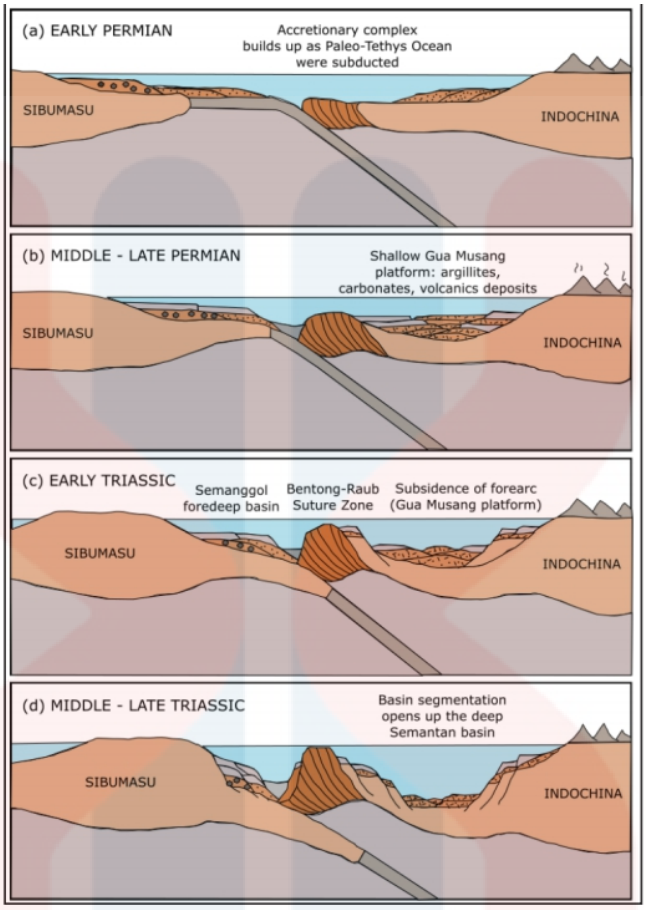


Figure 2.7: Illustration of geologic history of Gua Musang Group. The geologic history of the development of Gua Musang Group from Early Permian to Late Triassic. (a) Thick argillite and volcanic (known as Aring and Telong formations) were deposited adjacent to Indochina volcanic arc while the Paleo-Tethys Ocean was being subducted during Early Permian. (b) Thick argillites and volcanics created Gua Musang platform, a shallow marine environment suitable for carbonate development in Middle-Late Permian. Gua Musang formation begun in the east. Volcanism peaks while forearc basin started to subside. (c) Forearc basin undergone an intense subsidence in Gua Musang platform during Early Triassic, creating more accomodation space for carbonate-argillite-volcanis deposition. Closure of PaleoTethys Ocean as subduction of Sibumasu completely stopped when both Sibumasu and Indochina terrane collided. (d) Middle-Late Triassic: Oblique subduction of Sibumasu aided process of basin segmentation on the subsiding Gua Musang platform, thus creating the deep marine Semantan-Gemas basin. This basin was bounded by shallow marine platform as portrayed by the geometry of Central Belt as we observe today. Basin faulting and segmentation caused the presence of slump deposits and intraclasts in Pos Blau, Krau, Raub, and Kota Gelanggi. (Source: Mohamed et al., 2016)

Eastern Province granite plutons developed from Permian to Triassic Period due to the oceanic subduction. There are 18 isolated granitoid plutons extend from nothern Kelantan towards the south of peninsular in Segamat. The granite is generally undeformed and mainly of calc-alkaline I-type granitoids with some S-type (Metcalfe, 2000). Meanwhile, the Main Range granite ascended during Triassic to Early Jurassic Period due to the melting of continental crust in a syn- to post-collisional setting (Metcalfe, 2000). The Eastern Province plutons intruded a lithological sequence of mudstone, siltstone and sandstone, limestone and thick sequences of intermediate to acid volcanic and volcaniclastic rocks.

2.6 Geoheritage and Geodiversity

Geoheritage is another subdiscipline of geology that considered to be first introduced in United Kingdom (Brocx & Semeniuk, 2007). In addition, a systematic inventory-based geoconservation which is a part of the geoheritage planning and management was also first acknowledge in the region (Brocx & Semeniuk, 2007). Geoheritage in global literature are being correlated to sites of mineral, fossil locations, petrogenetic features that indicate petrogenesis, landforms and other geomorphological features locations that illustrate Earth history, and Earth processes that are operating until current day, and emphasis on some principles of geology (Brocx & Semeniuk, 2007). According to Nazaruddin (2016), geoheritage is associated with sites and features that is significant in showing and understanding the Earth history. This means geodiversity is the key factor in determining geoheritage significance.

Geodiversity is defined by Pereira (2013) as the natural variance of geological, geomorphological and soil as well as their aggregation, properties and interconnecting relationship. Geodiversity has several values that has been proposed by researchers which geodiversity is recognised for its scientific and educational value and its potential to benefits society with geological knowledge (Hjort et al., 2015). The importance of geodiversity conservation can be considered according to several values portrayed by the geodiversity itself which are the intrinsic, ecological and anthropocentric or geoheritage values (Sharples, 2002) or scientific, cultural, aesthetic, functional and economic values (de Paula Silva, Rodrigues & Pereira, 2014). Work by Kubaliková (2013) states that scientific and educational values is associated with understanding the process and the provenance of landforms and the whole Earth geological history. Cultural value is related with a region myth, history and folks story that is used to explain geological elements (Kubaliková, 2013). Aesthetic value is about the visual and non-visual appearance of a landscape, scenic view which can be a potential for geotourism (Kubaliková, 2013). Meanwhile economic and functional value refers to the usage of geological resources such as minerals, landforms for economical purpose (Kubaliková, 2013).

Wimbledon was the first researcher to propose the 'geosite' term in 1996 which defines as sites containing significant geodiversity. In Malaysia, similar concept was introduced by Ibrahim Komoo in 2004. The term geosite is defined as geological site with feature or landform with remarkable geodiversity component with high values (Nazaruddin et al., 2016). Malaysia started putting efforts in geoheritage conservation and developing geoheritage resources during the Third Malaysian Plan in 1976-1980. As the Third Malaysian Plan came out with a vision where protecting geological monuments and landscape is necessary. In 1996, Malaysian Geological

Heritage Group developed a systematic planning in promoting and conserving geoheritage. A lot more research were carried out to study and assess more geosites for development and conservation since then (Nazaruddin 2015). The significant of a geosite is partly determine by its scale and scope of geological characteristics in the sites. The scale is categorised from regional to very fine scale as in table (Brocx and Semeniuk, 2007).

Table 2.1: Scale and its sizes of geoheritage sites. (Source: Brocx and Semeniuk, 2007)

Scale	**Coverage Size**
Regional Scale (megascale)	100 km × 100 km
Large Scale (macroscale)	10 km × 10 km
Medium Scale (mesoscale)	1 km × 1 km
Small Scale (microscale)	10-100 m × 10-100 m
Fine Scale (leptoscale)	1 m × 1 m
Very Fine Scale	1 mm × 1 mm

In order to select a geosite, the geodiversity must be assessed. Geodiversity assessment purpose is not only focusing on conservation of fossils, rare rocks and minerals, landforms and landscapes but should also be highlighting on the management of mineral resources, non-renewable energy resources, and water resources that are essential for domestic utilisation (de Paula Silva, et al., 2014).

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

There were several materials used to complete the process of geological mapping interpretation and geodiversity assessment. In this research, methodology applied consist of qualitative and quantitative. Qualitative method consists of geological mapping interpretation. Quantitative method includes in geodiversity index mapping as well as in data processing, analysis and interpretation that also consists of process to produce geological map.

3.2 Materials

Materials involved are those needed to carry out procedures of methods applied in this research as follows:

Table 3.1: List of materials and functions.

Materials	Functions
Secondary Data	Spatial and attribute data obtained from agencies and previous researchers used in ArcGIS Software for processing, analysis, interpretation and producing maps of the study area. The secondary data needed are satellite image, DEM, STRM, lithological map and mineral resources data.
Laptop	Portable personal computer used to store files, secondary data, carry out processing and analysing using software and writings.
ArcGIS Software	Produce base map of study area, a complete geological map and geodiversity index map of study area to be presented as findings of research.

3.3 Methodology

3.3.1 Preliminary Research

This method was the first most important process in carrying out research which was done to obtain a deeper understanding of the research topic, methods and the study area. First thing done was gathering sources of reference about the research topic which are geology and geoheritage. References are in form of printed and electronic sources such as books, journals, articles, unpublished thesis and online publications. Literature survey was done by reviewing all related and reliable sources to get identify background information, scientific knowledge and critically analyse the theories involved and all the essential parts in completing a research in general geology and geoheritage field. Important information, facts, theories and methodology were extracted, added and cited in writing to support this research. Literature review on geoheritage field was mostly done on well-established sources and methods by geoheritage specialist.

3.3.2 Secondary Data Acquisition

Secondary data is existing data whether they are obtained from previous research findings or agencies, available in both digital and hard-copy formats. Implementation of this indirect methodology is as an initiatives to replace direct data collection method such as field studies. It uses some existing geological and geospatial data in form of satellite imagery (raster) and features data (vector). In order to generate geological maps, existing geospatial data in raster or vector form is required to interpret the lithology, structural geology and geomorphology and geodiversity distribution of the study area. The data were interpreted from DEM and SRTM obtained from the United States Geological Survey (USGS) open access website.

3.3.3 Data Processing, Analysis and Interpretation

Secondary data collected from agencies and previous researchers were processed, analysed and interpreted to represent the results of all the geological data and information. This method includes interpreting geospatial secondary data that are needed to produce maps. Lithology, geomorphology and structural geology of the study area were interpreted from the data obtained based on its photographic tone, texture, colour, size, pattern and shape of DEM data (Ray, 1960) using AcrGIS tools. Description of geology and geoheritage study based on geodiversity of the study area were emphasised according to the result of interpretation.

The interpretation of lithology was based on topography map of the study area and correlation with previous researches. Then, in order to determine lithological boundary, the boundary was interpreted from contour lines characteristics and digitised into polygon form. The interpretation results were compared to existing lithological map or geological map data.

Geomorphology of the study area was analysed by processing DEM SRTM and contour data of the study area in ArcGIS software using geoprocessing tools. Satellite imagery was used to locate and confirm the type of landform in the study area. Geomorphological units were classified according to elevation and topography using geoprocessing tools in ArcGIS by referring to Van Zuidam classification (1985). Structural geology was analysed by locating lineaments on topographical map and Triangular Irregular Network (TIN) map. Lineament data are helpful in interpreting the presence of geological structures in study area.

The results from processing and interpretation were represented in the form of a 1:25000 scale geological map, geodiversity index map and other related thematic map using ArcGIS software. The geological map represents map of study area with the distribution of rocks and their boundaries, faulting as a part of geological structures, the overall lithological cross section and stratigraphic column that shows the stratigraphic sequence of all lithology in the study area.

3.3.4 Geodiversity Assessment

There are two perspective in assessing geodiversity which are qualitative and quantitative approaches. However, this research used a quantitative approach which is the geodiversity assessment method. This method aims to show the variation and distribution of geological elements in study area numerically through geodiversity index map (Fernandez et al., 2020). The purpose of geodiversity indexing techniques is to represent geodiversity elements comprehensively by quantifying the range of abiotic elements occurrence in the study area (de Paula Silva et al., 2014). The results act as an evidence to support and show importance of conserving the ecosystem and geosystem of the area since map is easy to understand by enabling easy interpretation as a planning tool such as land-use and nature conservation planning (Pereira et al., 2013). Besides, the results of this research also can be used as a reference for further geoheritage study for instance, in evaluating geoheritage potential based on the occurrence of geodiversity elements in the study area.

Four different geodiversity elements indices were included in calculating the geodiversity index which are the lithology, geomorphology, hydrology and minerals (de Paula Silva et al., 2014). These four elements were included in quantification as all four geodiversity elements is significant in the study area. All four indices were processed through secondary data by using ArcGIS Software. Geodiversity index map is shown with map of study area being divided with grids of 500 m^2 size per cells resulting in a total of 100 square cells. The size of grid cells are designated to suit the scale of the study area map used in this method; 1:50000. The spatial data of each indices was analysed by counting the number of occurrences of each spatial attributes in each grid cells such as the number of lithology exist in a grid cell (Araujo & Pereira, 2018).

The lithology index was calculated according to the sum of lithological occurrences per square (Fernandez, et al., 2020). Geomorphology index was obtained by counting the number of geomorphological units in each cells such as fluvial, hills and ridges (Fernandez, et al., 2020). Quantification of minerals index was based on the occurrence of different minerals in the area consist of industrial minerals, precious metals or metallic minerals (de Paula Silva et al., 2014). The hydrology index was calculated by the sum of rivers hierarchy (Fernandez, et al., 2020). Each indexes were shown respectively in index maps with legends of classification scales (Fernandez, et al., 2020). Lastly, all of those individuals indices were overlaid together, using union tool in ArcGIS and classified into five classes of very low (1), low (2), medium (3), high (4) and very high (5) using natural breaks Jenks classification method (Fernandez, et al., 2020). Generally, geodiversity index is the sum up of all other four index. The flowchart is shown in Figure 3.1.

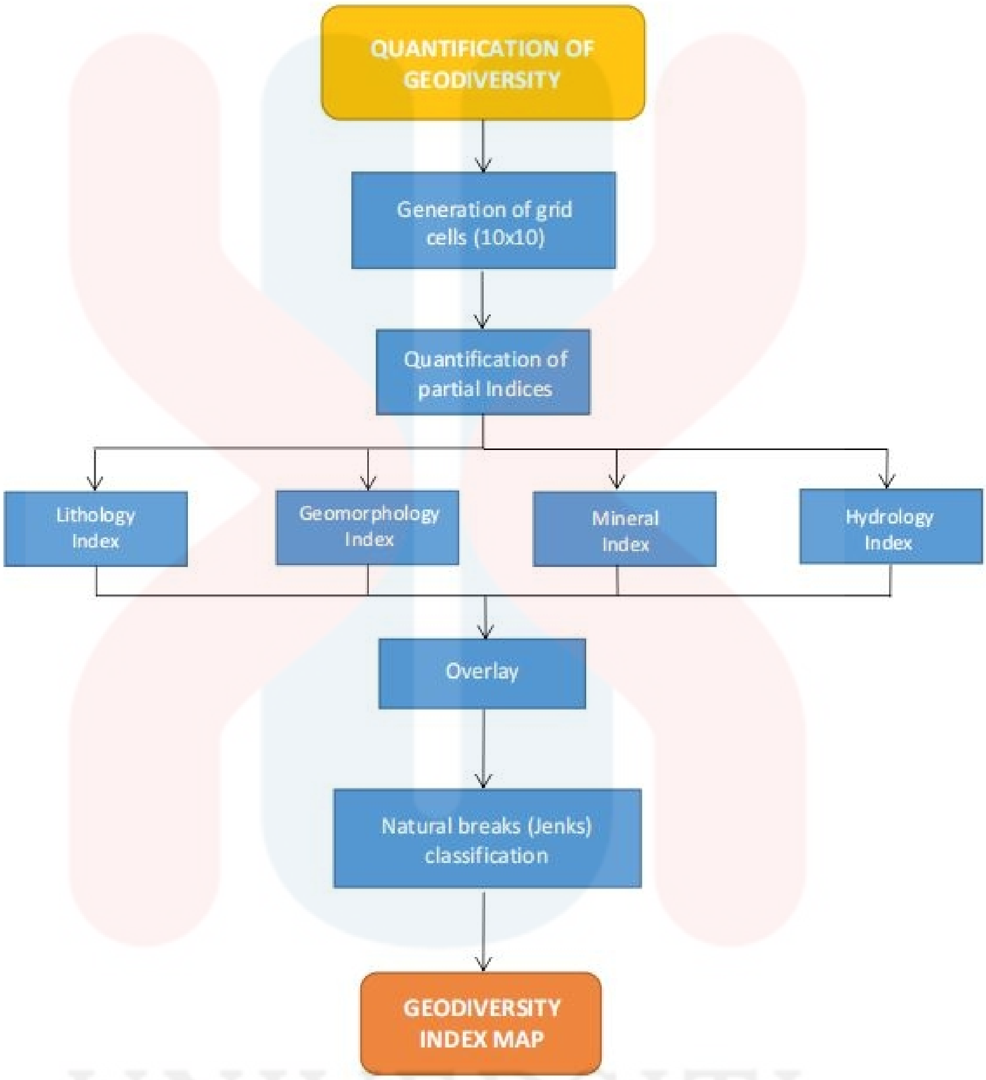
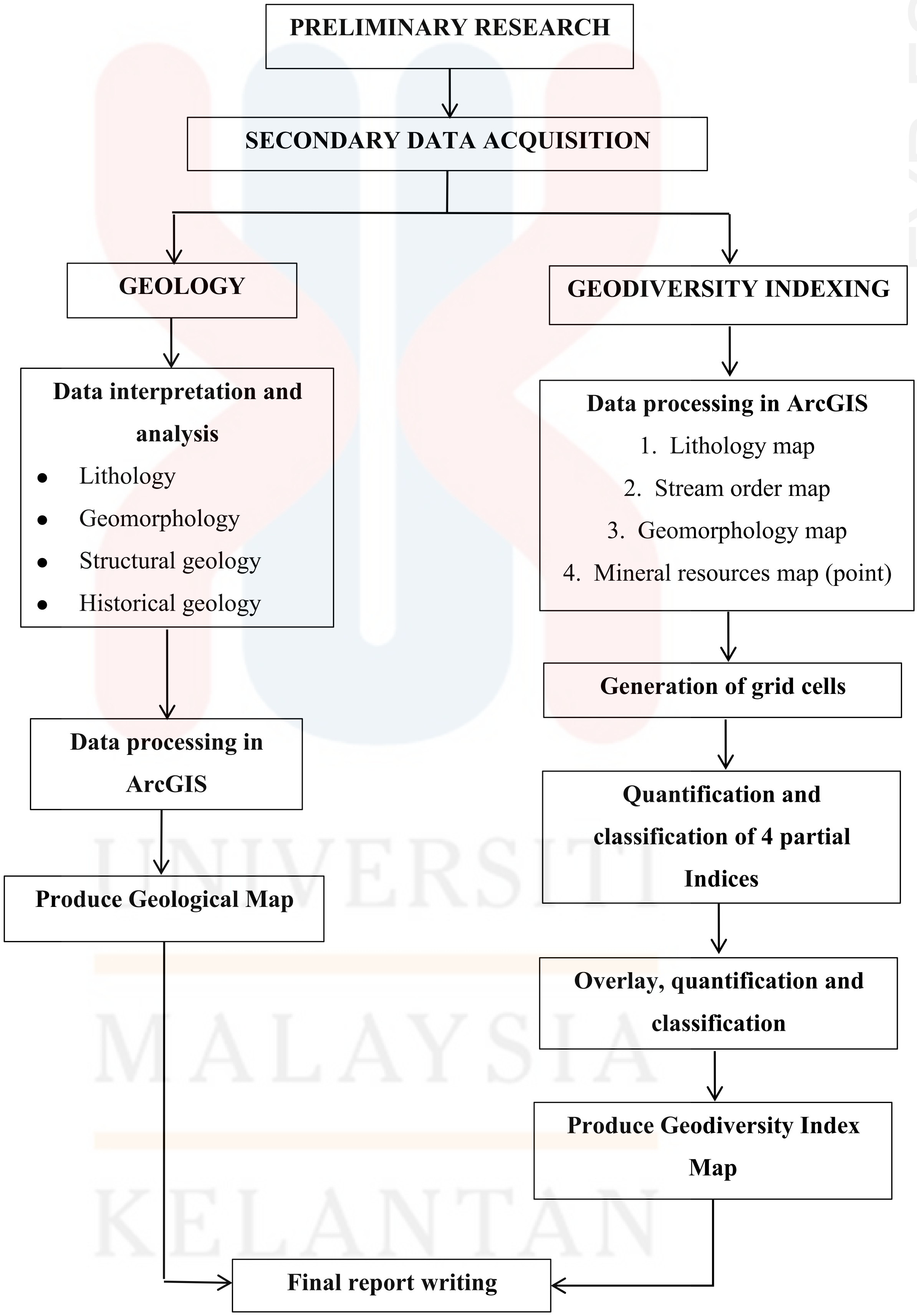


Figure 3.1: Flowchart of geodiversity assessment using geodiversity quantification.

3.3.5 Research Flowchart



CHAPTER 4

GENERAL GEOLOGY

4.1 Introduction

General geology in this study covers the general information about the location of the study area as well as discussing the findings on its geomorphology, lithostratigraphy, structural geology and historical geology. The information and findings about its geology were obtained based on spatial data analysis and interpretation of the study area from DEM SRTM data obtained from USGS. The data processed and interpreted were represented in its respective maps. Meanwhile, the overall geology of the study area is displayed in geological map with scale 1:25000 showing the distribution of rock units, rock boundaries, cross-section and the age relation of every rock unit in the study area.

4.1.1 Accessibility

The study area is located at north-west from Gua Musang town in Subong plantation area. The main access to the study area is from the southward direction of the study area through an unpaved road that is connected to Gua Musang Street. Meanwhile, the study area is also accessible from eastward direction through roads that are connected to Jelawang - Gua Musang Street. The accessibility of the study area consists of several paved and unpaved roads utilised by lorries and trucks to transport crops within the plantation area.

4.1.2 Settlement

The settlement in the study area is a dispersed settlement in which there are several scattered houses owned by plantation workers. The settlement is not dense as the area is covered almost entirely with oil palm and rubber tree plantation.

4.1.3 Forestry

Overall, the study area is covered by forestry as it is a highly vegetated area with the plantation of oil palm and rubber trees.

4.2 Geomorphology

Geomorphology is defined as the study of landforms of the Earth, its physical features and processes that shaped them. Processes that shaped landforms consist of exogenic processes that are controlled by the climatic changes and endogenic processes that occurred due to tectonic settings. The most commonly found landforms in Malaysia are mountain ranges, hills, river, fluvial and coastal. Landforms in Gua Musang area are dominant with hilly, fluvial and karst geomorphology.

4.2.1 Geomorphologic Classification

Geomorphology in the study area is mainly classified based on the elevation of contour using Van Zuidam classification (1985) as shown in Table 4.1.

Table 4.1: Classification of morphography based on elevation. (Source: Van Zuidam, 1985)

Elevation	Morphography
< 50 metre	Land
50 metre - 100 metre	Low land
100 metre - 200 metre	Low hill
200 - 500 metre	Hill
500 metre - 1500 metre	High hill
1500 metre - 3000 metre	Mountain
> 3000 metre	High mountain

The classification was made according to the relationship of elevation and morphography. The importance in classifying geomorphology based on contour elevation is to infer the landforms' morphogenetic which explains its origin and formation process. The contour elevation in the research area ranging from 96 m to 666 m. Thus, the elevation is classified into four classes which are low land (50 - 100 m), low hill (100 - 200 m), hill (200 - 500 m) and high hill (500 - 1000 m). The geomorphology in the study area consists of high hill, hill, low hill, low land and fluvial landforms as shown in Figure 4.2.

The study area is dominant with an elevation range of a low land, 50 - 100 m. Meanwhile, hilly geomorphology presents from south-west to north-west of the study area. The hilly landforms in the study area formed due to endogenic process which is a part of the Central Belt pluton granitic body intrusion occurred during Triassic Period also known as Ulu Lalat granite. The physical of hilly landforms appears like a massive granitic dome if viewed from terrain map as shown in Figure 4.1.

Areas of low hill is dominated by metasedimentary rock unit inferred to be phyllite, slate or shale. Fluvial landforms exist at northeast, southeast and across the centre of the study area. They are made up of main rivers, Sungai Keneroh, Sungai Kampai and Sungai Rawang that formed due to continuous episodes of erosion, transportation and deposition throughout time. It started with sheet erosion which occurred on the surface followed by rill erosion and gully erosion that resulted in formation of valley with flowing water called as river.

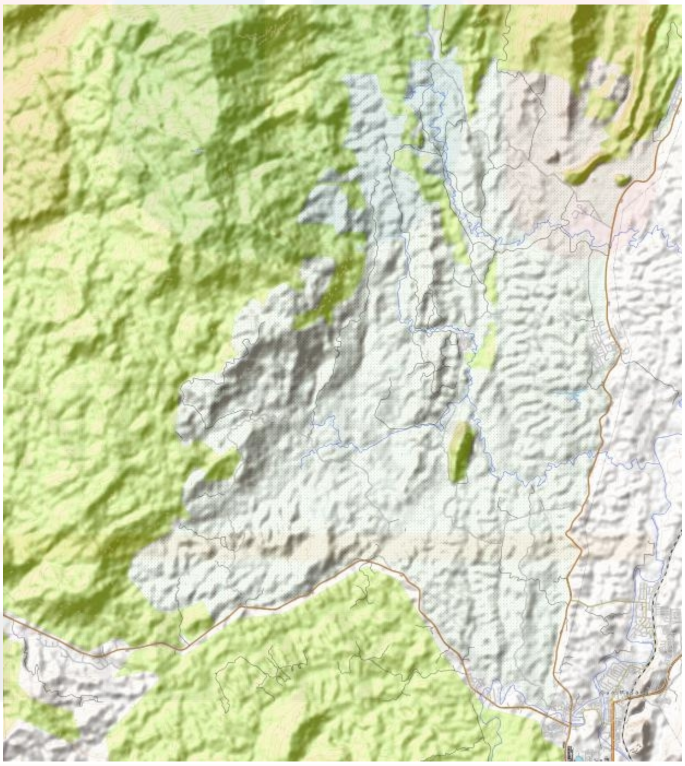


Figure 4.1: The shape of massive granitic dome of Ulu Lalat area on google terrain map (Google map, 2020)

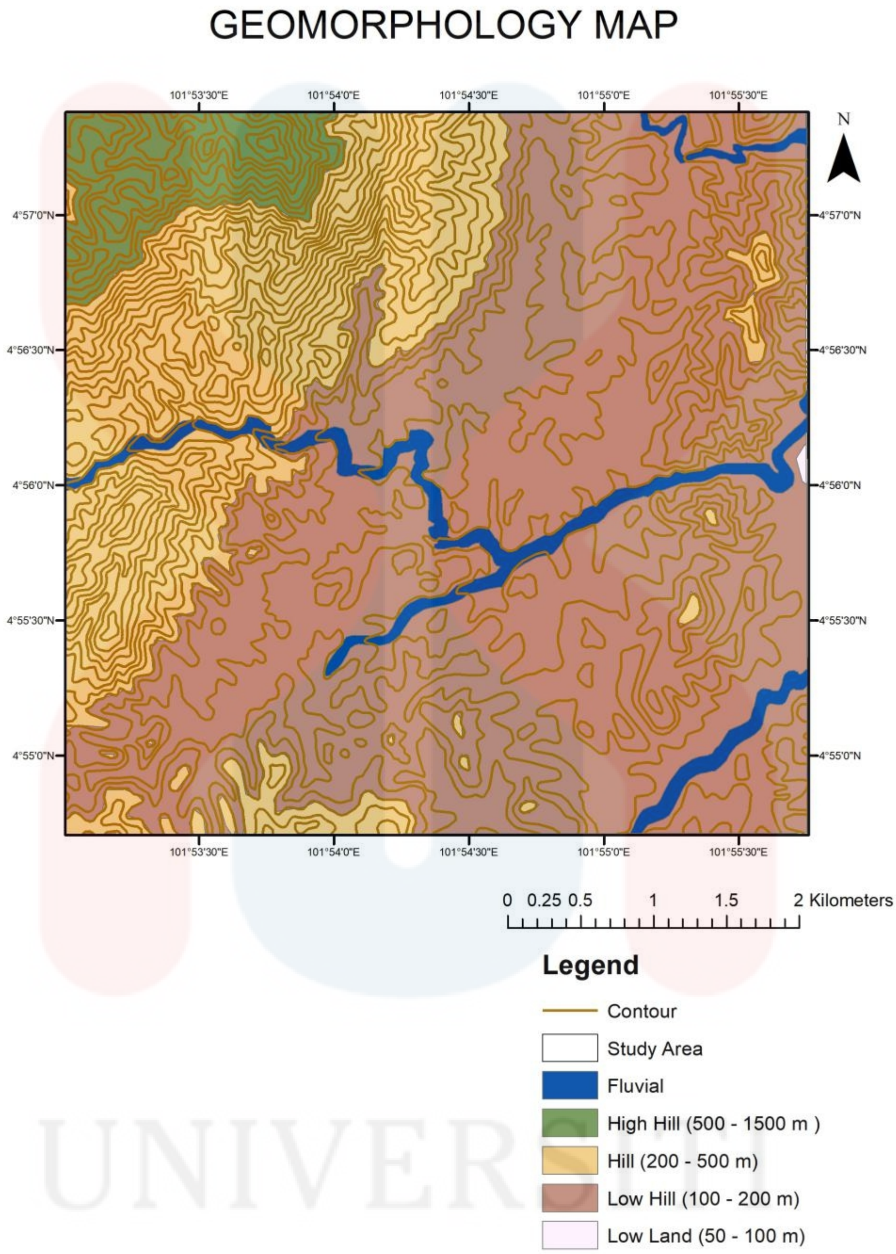


Figure 4.2: Geomorphology map of Subong Area, Gua Musang.

4.2.2 Drainage Pattern

Drainage pattern is a part of river system created by erosional process controlled by types of rock unit, soil and structural form. The type of drainage pattern commonly found on Earth are dendritic, parallel, trellis, rectangular, annular and radial. Drainage pattern in the study area comprises of major and modification drainage pattern which are subparallel, radial and dendritic as shown in Figure 4.3.

Subparallel drainage pattern is a modification pattern from parallel drainage pattern. In general, parallel pattern occurs in moderate to steep slopes with some relief which usually exist on elongate landforms along hill ranges. Tributaries run straight, flowing in the same direction, connected to main stream parallel to each other. Subparallel drainage pattern contrasting in terms of the irregularity of the parallel pattern which the streams direction upon connecting to mains streams and rivers are slightly parallel to each other. This pattern dominated the study area where it is distributed on granitic body and metasedimentary rocks which have a moderate to steep slope.

Dendritic drainage pattern forms irregular streams distribution and branching similar to tree branches on gently sloping areas. This pattern indicates relatively horizontal strata or non-uniform crystalline rocks with high resistance towards weathering. Dendritic drainage pattern exists in the north-west of the study area on metasedimentary rock unit where the streams flow into Sungai Rawang. This may indicate that the metasedimentary rock unit in the area are horizontally bedded and have high resistance.

Radial drainage pattern in the study area exists on one isolated low hill at west of the study area on metasedimentary rock unit. This pattern is most obviously seen on topographical map where the streams radiated outward and downward from the peak of the isolated hill with contour elevation of 200 metres above the sea level. This pattern may indicate that metasedimentary rock unit on the isolated hill is resistant towards weathering.

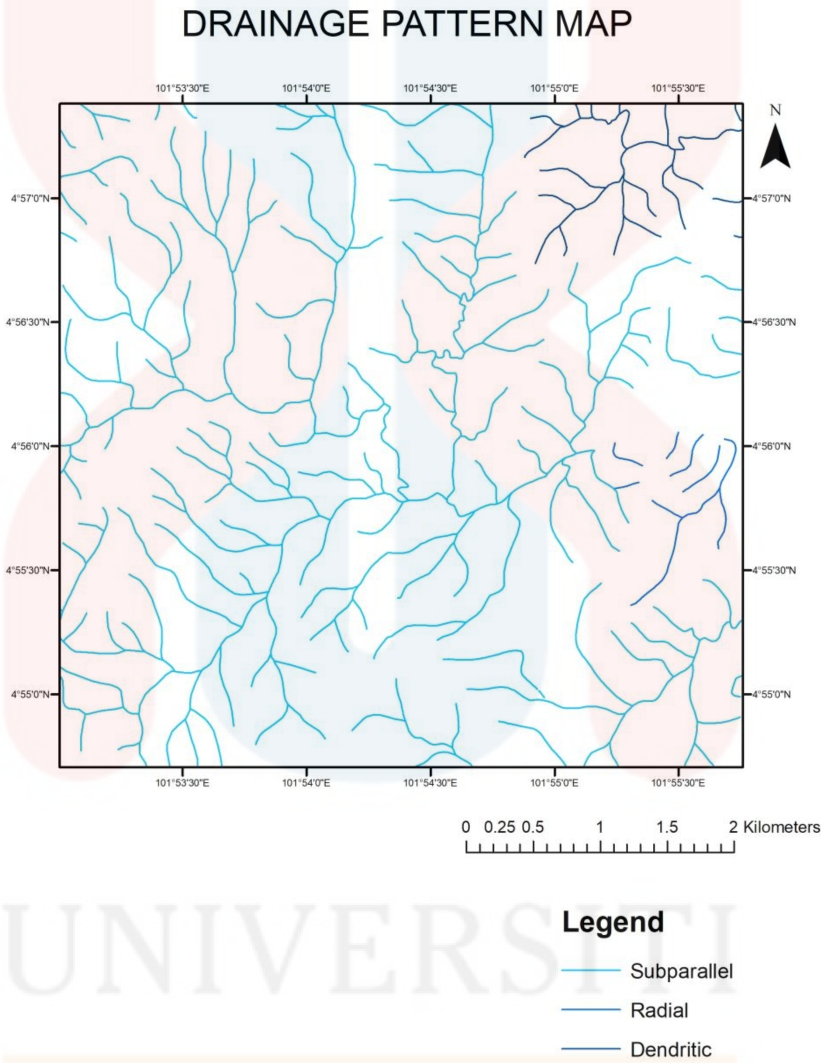


Figure 4.3: Drainage pattern map of Subong Area, Gua Musang.

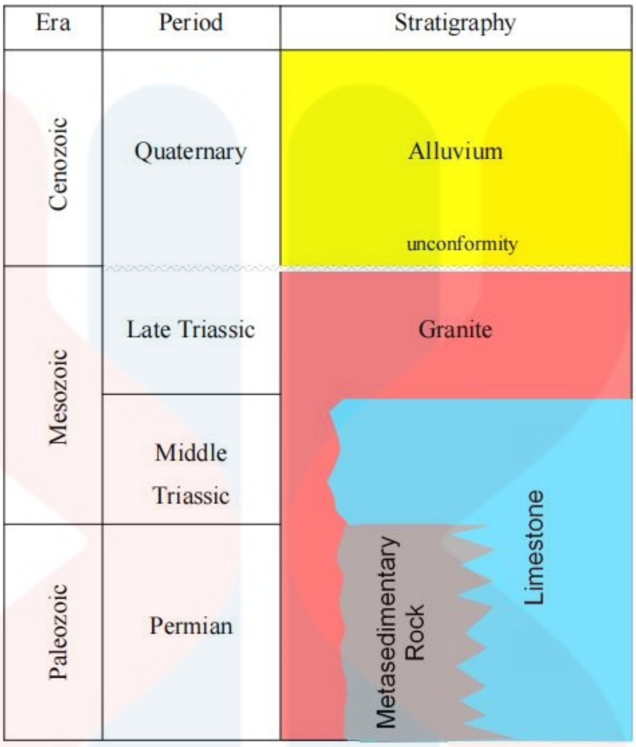
4.3 Lithostratigraphy

Stratigraphy is the study of rock layers, their ages and arrangement beneath the Earth while lithology is the study of rocks unit characteristics. Lithostratigraphy is a fundamental part in geology as it includes the analysis of rock properties and its arrangement to determine the geological history of an area and tectonic events occurring throughout the geological time scale. The lithology units and their distribution in this research are interpreted from the characteristics of contour lines in the study area and by referring to topography map.

4.3.1 Stratigraphic Position

The study area consists of four lithology units which are granite, metasedimentary rock, limestone and alluvium. Table 4.2 shows the stratigraphic column of the rock units in the study area which deposited from Paleozoic to Cenozoic era.

Table 4.2 : Stratigraphic column showing the sequence of lithology in the study area.



Its stratigraphic sequence in the study area is determined based on previous researches. The stratigraphy sequence initiated with the oldest unit from Permian period, metasedimentary rock followed by limestone from Permian to Middle Triassic, granite which developed during Permian to Late Triassic and alluvium deposition is the youngest unit which formed from Quartenary period.

Metasedimentary rock interfingered limestone unit as both of them were deposited at the same time during Permian period. The granite unit intruded the sequence of metasedimentary rock and limestone. However, there is an unconformity occurred between granite unit and alluvium as granite intrusion ended in Late Triassic but alluvium deposition was found in Quaternary period. Figure 4.5 shows the geological map along with the geological cross section of lithology of the study area.

4.3.2 Unit explanation

a) Metasedimentary Rock

Metasedimentary rock units in the study area are made up of Gua Musang argillaceous facies (Mohamed et al., 2016). According to previous research conducted by Nur Shahirah binti Che Azlan in 2018, the area is dominated with slate. Thus, it is inferred that the metasedimentary rocks are either phyllite, slate or shale. These rocks were originally deposited as a sedimentary rock unit and throughout time, these rocks undergone metamorphism process. The most significant factor that lead to occurrence of metamorphism process is due to the exposure and contact between these sedimentary rock units to high temperature during the intrusion of granite. The boundary of metasedimentary rocks is located on low hill landforms adjacent to the granitic body. It is determined based on the arrangement of contour lines which are not relatively close together compared to the contour lines represented by uplifted granite unit.

b) Limestone

Limestone is a sedimentary rock containing calcium carbonate ($CaCO_3$) commonly in the form of calcite mineral. It was deposited during Permian to Middle Triassic period. The limestone unit in the study area is one of the extensively distributed Merapoh Limestone bodies (Mohamed et al., 2016). The boundary of limestone unit is determined due to the existence of a karst morphology at the east, adjacent to the study area seen on Google Earth satellite imagery as shown in Figure 4.4.

c) Granite

Granite is an intrusive igneous rock formed from a felsic magma composition. The granite unit is originated from Central Belt pluton made up of mainly an I-type granite plutons situated to the east of Bentong-Raub suture line (Metcalfe, 2000). Granite unit boundary is determined based on the slope steepness of high hill landforms and closely arranged contours at the west region of the study area. The relatively close contour lines indicate an uplift process of igneous rock body.

d) Alluvium

Alluvium is loose, unconsolidated sediment that formed as a result of weathering of host rock. In this research, alluvium deposits are interpreted from the topography map and spatial location of main rivers in the study area. It lies along river on contour elevation of 100 m. Alluvium deposits are defined as particles that have been eroded and deposited by flowing water along river valley. The size of alluvium particles deposited along the rivers may vary from gravel (1.0 – 2.0 mm) to clay size (< 0.002 mm).

Figure 4.4: Satellite imagery showing karst morphology located adjacent to the boundary line of study area. (Source: Google Earth Pro, 2020)

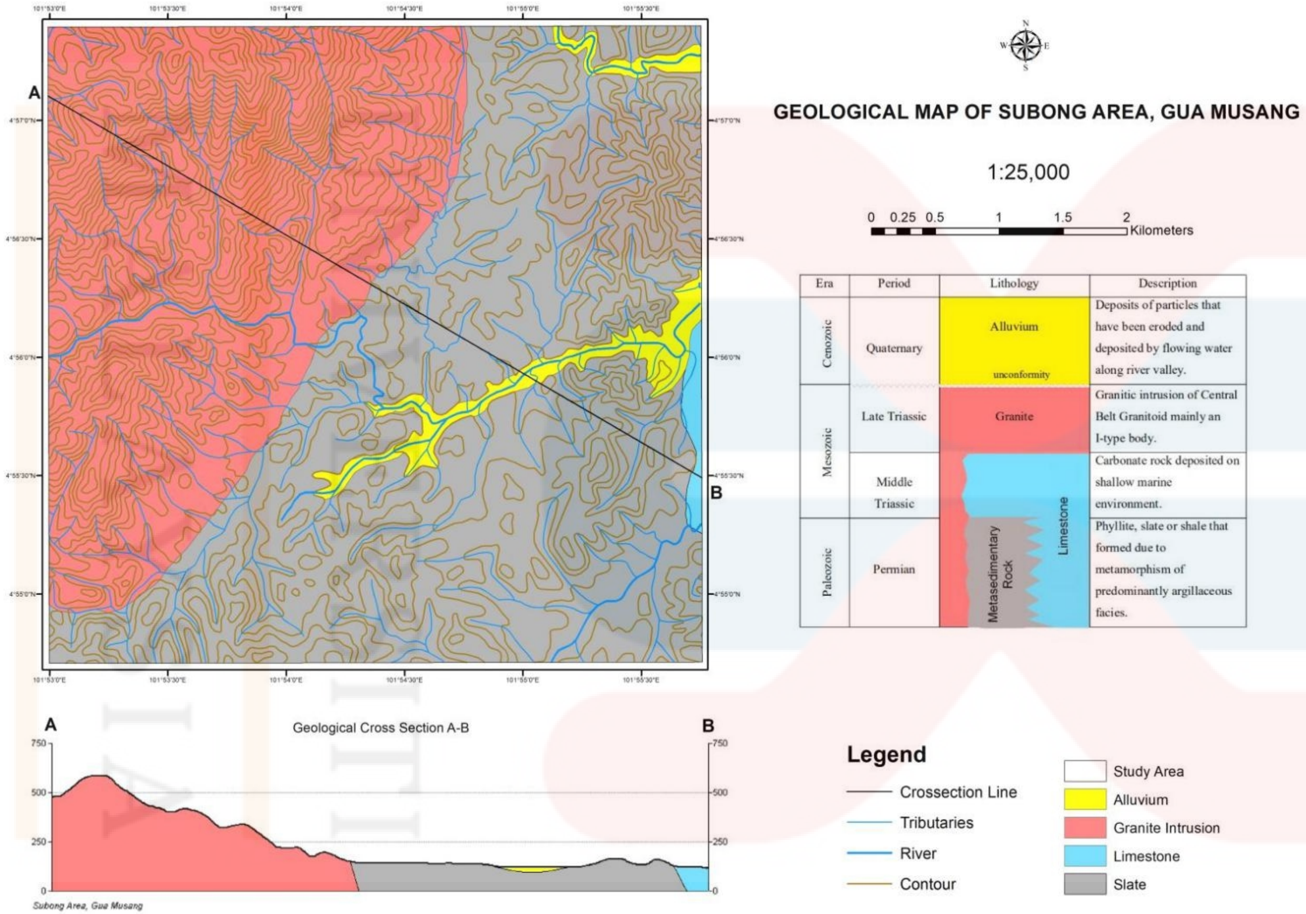


Figure 4.5: Geological map and geological cross section of Subong Area, Gua Musang.

4.4 Structural Geology

4.4.1 Lineament Analysis

Lineament is defined as a linear feature exist on a landscape or topography that presents geological features such ridges, valleys and streams besides being an indicator of mechanism of geological structure in the study area. In this research, lineament analysis is carried out by identifying negative lineaments located within valleys and streams on a 2-dimensional Triangular Irregular Networks (TIN) surface as shown in Figure 4.6.

There is a total of 50 negative lineaments and the azimuth of each lineaments is calculated in ArcGIS software with values as shown in Table 4.3.

Table 4.3 : The azimuth of negative lineament in the study area.

Azimuth (°)									
270	69	323	348	353	7	9	26	351	24
62	321	309	22	84	356	303	323	330	317
11	25	322	9	328	80	23	30	285	44
50	1	6	28	33	10	12	297	292	87
82	359	288	25	315	60	56	85	75	350

These azimuth values are inserted into GeoRose software to produce resulting rose diagram of lineament analysis as shown in Figure 4.7. Based on the Rose diagram, the principal force is from north-east direction within 50° - 60° North and south-west direction within 230° - 240° South.

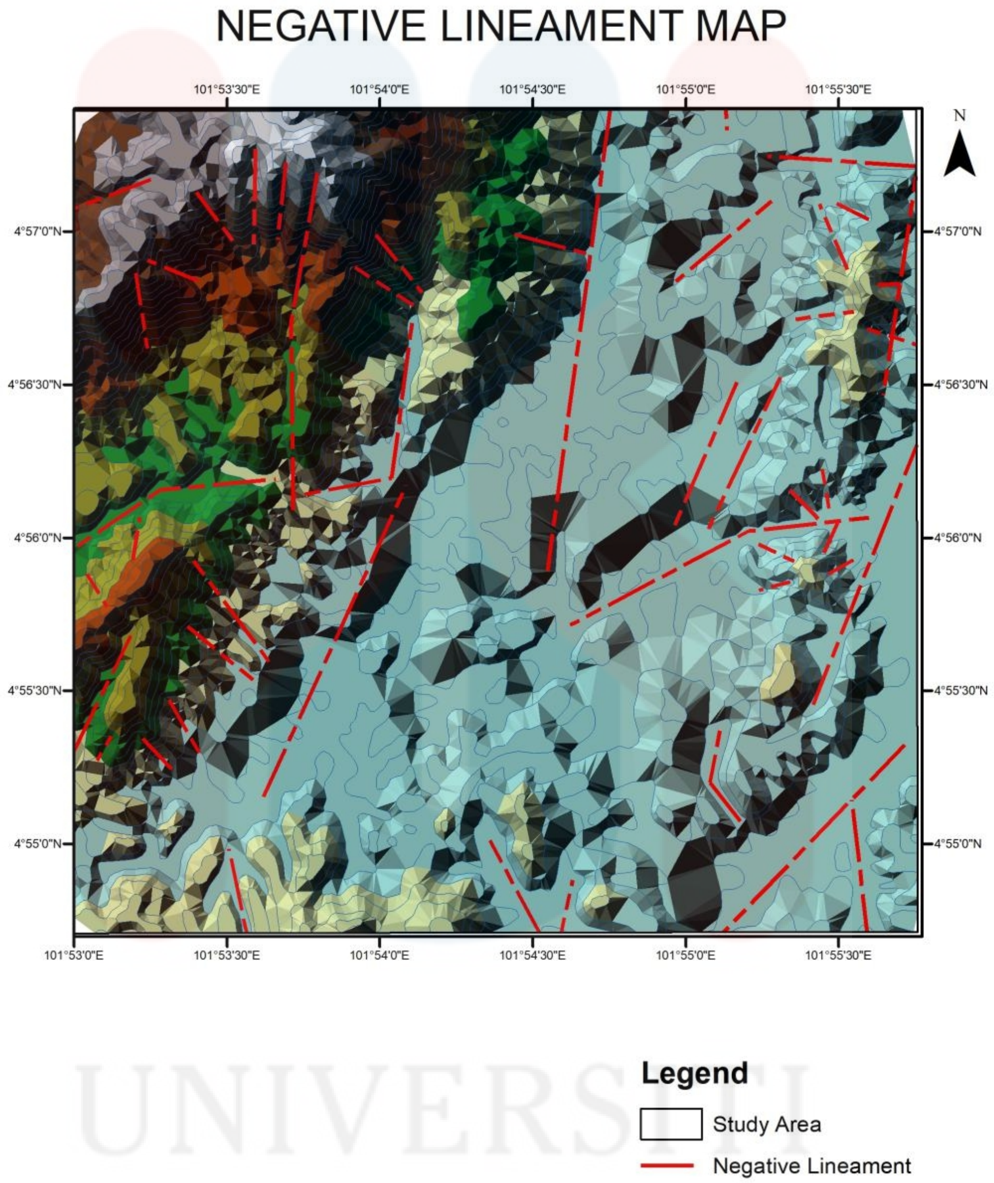


Figure 4.6: Negative lineament map of the study area.

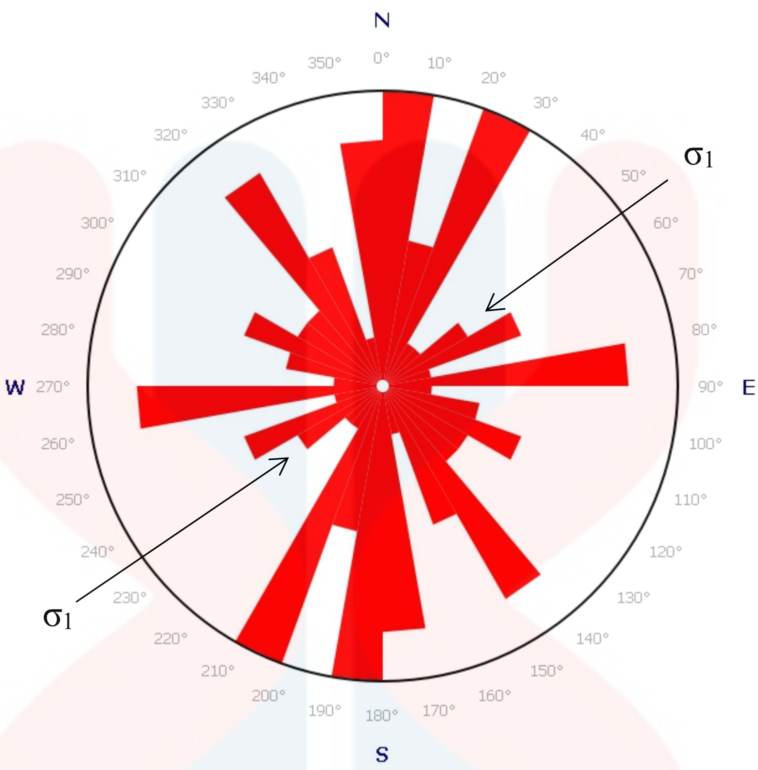


Figure 4.7: Rose diagram for lineament analysis of the study area.

4.4.2 Mechanism of Structure

The collision of Sibumasu and Indochina terrain and uplifting of granitic intrusion from beneath of the Earth surface have made a significant impact on the mechanism of structure in the study area. Based on Rose diagram produced (Figure 4.6), the direction of principal force from north-east and south-west direction indicates a sinistral strike slip (left lateral) motion of the terrain. This indicates that the structures in the location were formed due to compressional stress and shear forces. Figure 4.8 shows the net compressional stress of sheared zones. The slip movement of sheared blocks are parallel to the direction of compression.

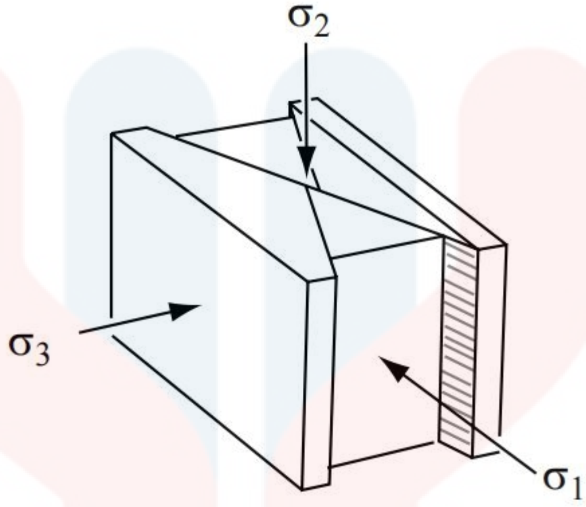


Figure 4.8: Net compressional stress of sheared zone. σ_1 is at acute angle from the fracture, σ_3 at an obtuse angle from the fracture and σ_2 force direction is vertical. (Source: Rowland, Duebendorfer & Schiefelbein, 2009)

4.5 Historical Geology

Historical geology in the study area is related to the collision of Sibumasu and Indochina terrain in Early Permian which leads to closure of Paleo-Tethys seaway. Gua Musang Formation was deposited during Permian to Triassic period in warm, shallow marine environment within Central Belt which previously was the Paleo-Tethys seaway (Mohamed et al., 2016). Argillite rocks deposited in Permian period have created a shallow marine platform, favourable for carbonate deposition in Permian to Triassic. This resulted in the widely distributed limestone units across Gua Musang. Central Belt granitoids developed from Permian to Triassic period due to the Palaeo-Tethys oceanic plate subduction beneath Indochina plate (Metcalfe, 2000). This subduction episode resulted in formation of East Malaya volcanic arc. I-type granite is produced in the volcanic arc (Metcalfe, 2000) and uplifted from beneath the surface and intruded a lithological sequence of slate and limestone during Late Triassic.

CHAPTER 5

GEODIVERSITY ASSESSMENT

5.1 Introduction

Geodiversity comprises of abiotic elements such as landforms, lithology, minera, hydrology and etc. that play an important role in showing the significant of geoheritage in a geosite. In this research, geodiversity assessment was applied to display the total geological features and its spatial distribution across the research area. A shape file of 10x10 grid index was generated on the study area in ArcGIS software. Then, each four partial indices were linked to the grid shape file. Spatial analysis on each partial indices were conducted in ArcGIS software by counting the number of occurrences of geological elements in each of the 100 grids. The quantified values of each geological elements occurrence in the shape file were classified using natural breaks classification by Jenks. Lastly, geodiversity index was produced by overlaying all four partial indices and classified using natural breaks (Jenks) as very low (1), low (2), medium (3), high (4) and very high (5).

5.2 Geodiversity Assessment

There are four geological elements (lithology, geomorphology, minerals and hydrology) were indexed and classified to produce partial indices maps on the study area. At the end of the data processing, all four partial indices were overlaid to sum up the total geodiversity and geodiversity index map was generated.

5.2.1 Lithology Index

Lithology in the study area are metasedimentary rock, limestone, granite and alluvium as shown in Figure 5.1. Lithology diversity in the study area ranged from 1 to 3 occurrences of lithology per grid that was classified into three classes as shown in Figure 5.2. 66% of the total grid cells is dominated with grids containing only one occurrence of lithology. The grids are distributed from the north-west to south-west region in which the grids are only occupied by granite unit and at the south region of the study area which grids are occupied by metasedimentary rock unit. 32% of the study area is covered by grids with two occurrences of lithology in an individual cell. Most of the grids with two lithological occurrences consist of an overlapping between alluvium and metasedimentary rock while the rest consist of an overlapping of granite or limestone with metasedimentary rock. Only 2% of the study area consist of three lithological occurrences. The two grid cells are located at the east region with an overlapping of limestone, alluvium and metasedimentary unit.

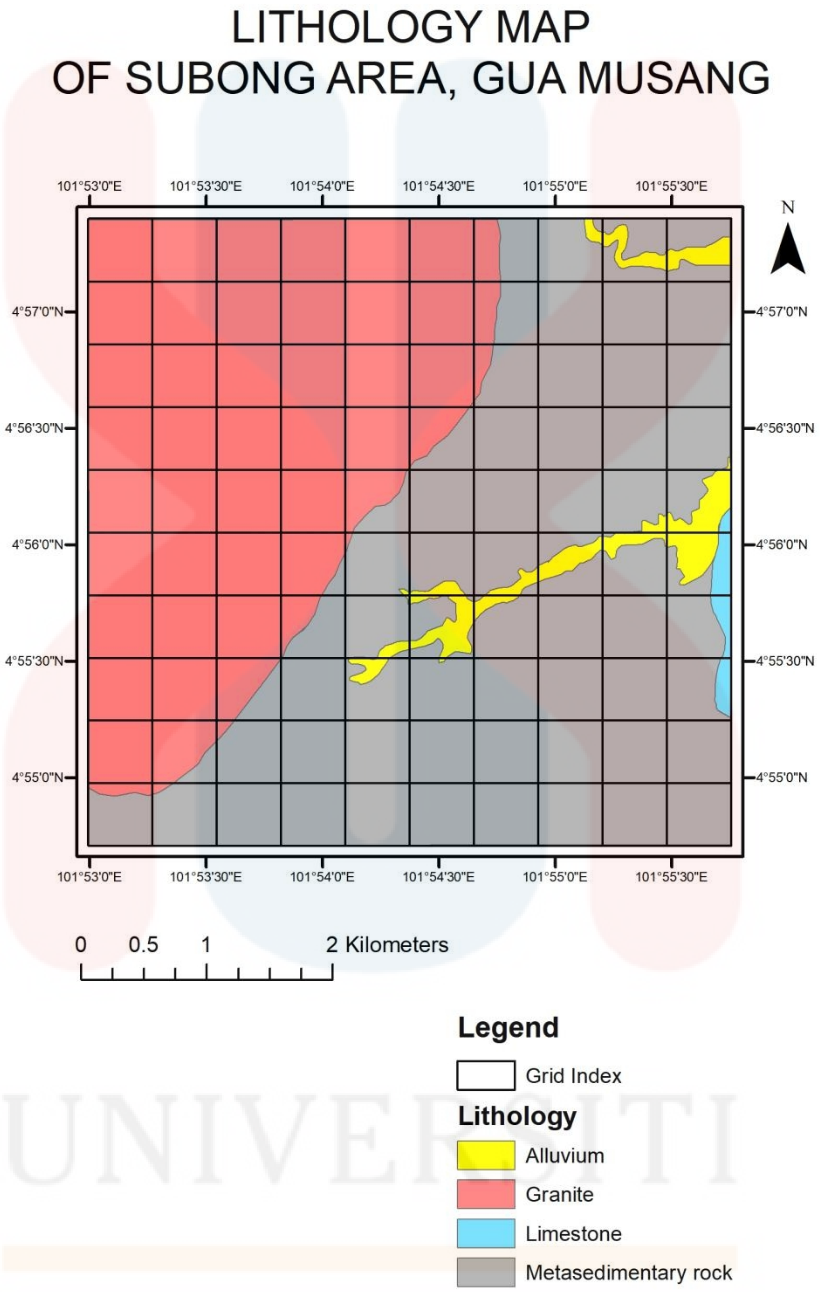


Figure 5.1: Lithology map of the study area displayed on grid index.

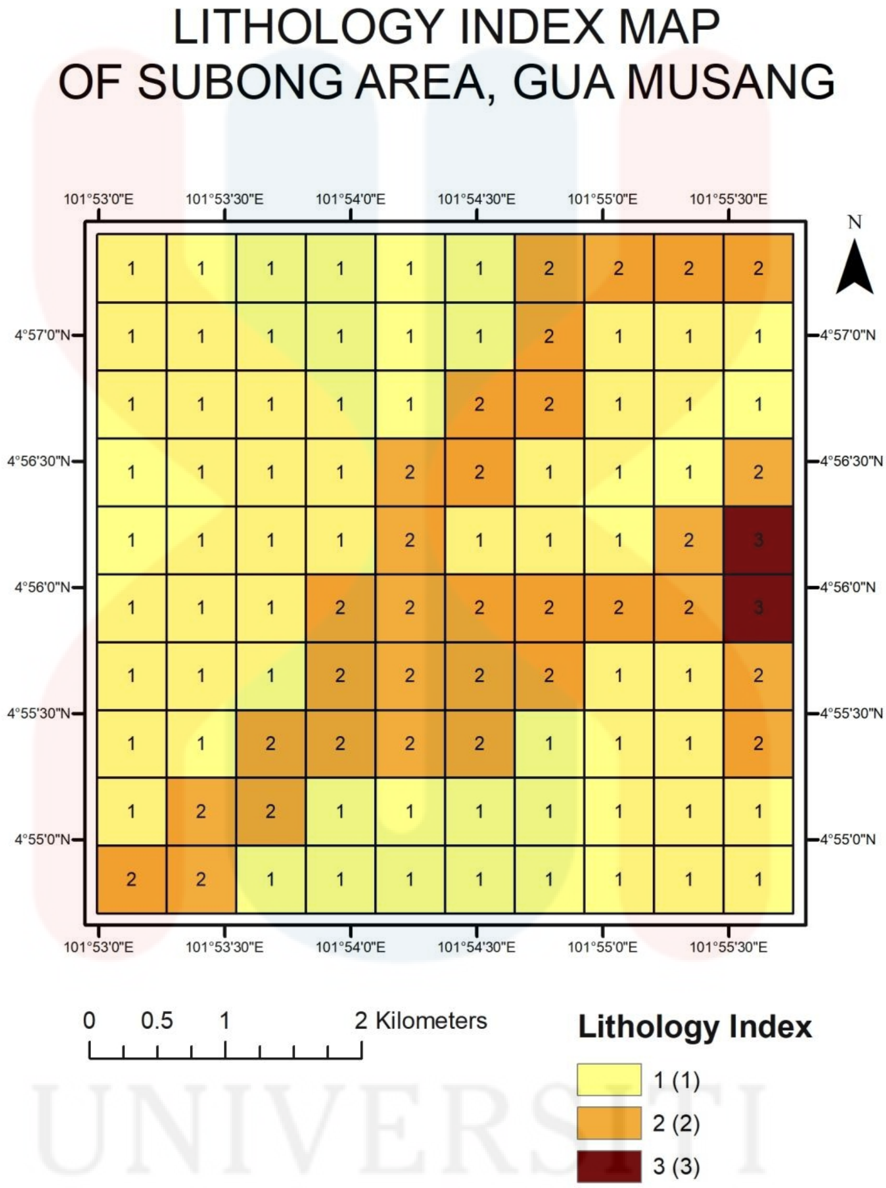


Figure 5.2: Lithology index map of the study area consist of three classes.

5.2.2 Geomorphology Index

Figure 5.3 shows the geomorphology study area that consists of five landforms unit; high hill, hill, low hill, low land and fluvial. Similar to lithological index, geomorphology diversity is classified into three classes with only 1 to 3 occurrences of geomorphology units per cells as shown in Figure 5.4. 62% of the total grids in study area have two occurrences of geomorphology units per grid cell. 31% of the study area is covered with just one geomorphology unit per grid cells. Remaining 7% of the total geomorphological diversity consist of grids with three occurrences of geomorphology units in a grid cells. Three of the grid cells with highest value of geomorphological occurrences are located at the west region with overlapping of hill, low hill and fluvial landforms meanwhile another four grid cells are located at the east region with overlapping of low hill, low land and fluvial landforms.

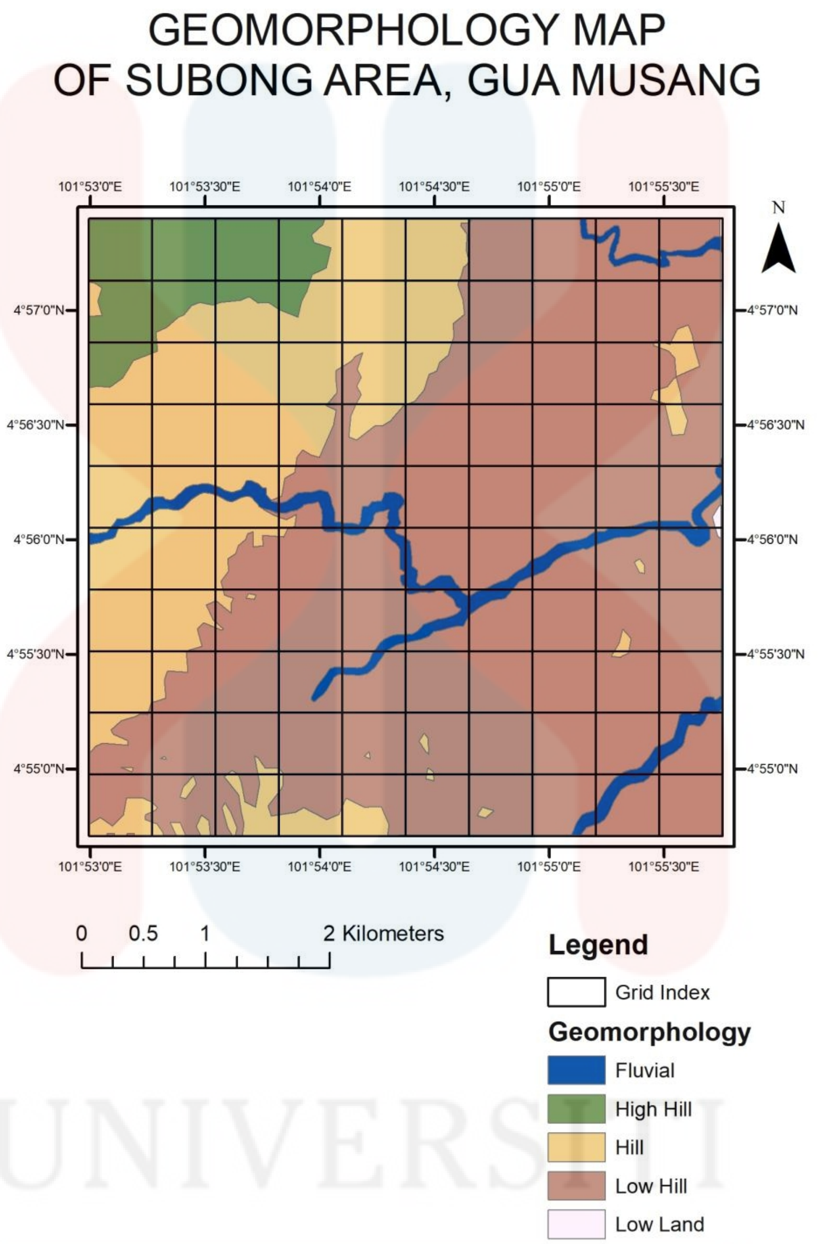


Figure 5.3: Geomorphology map of the study area displayed on grid index.

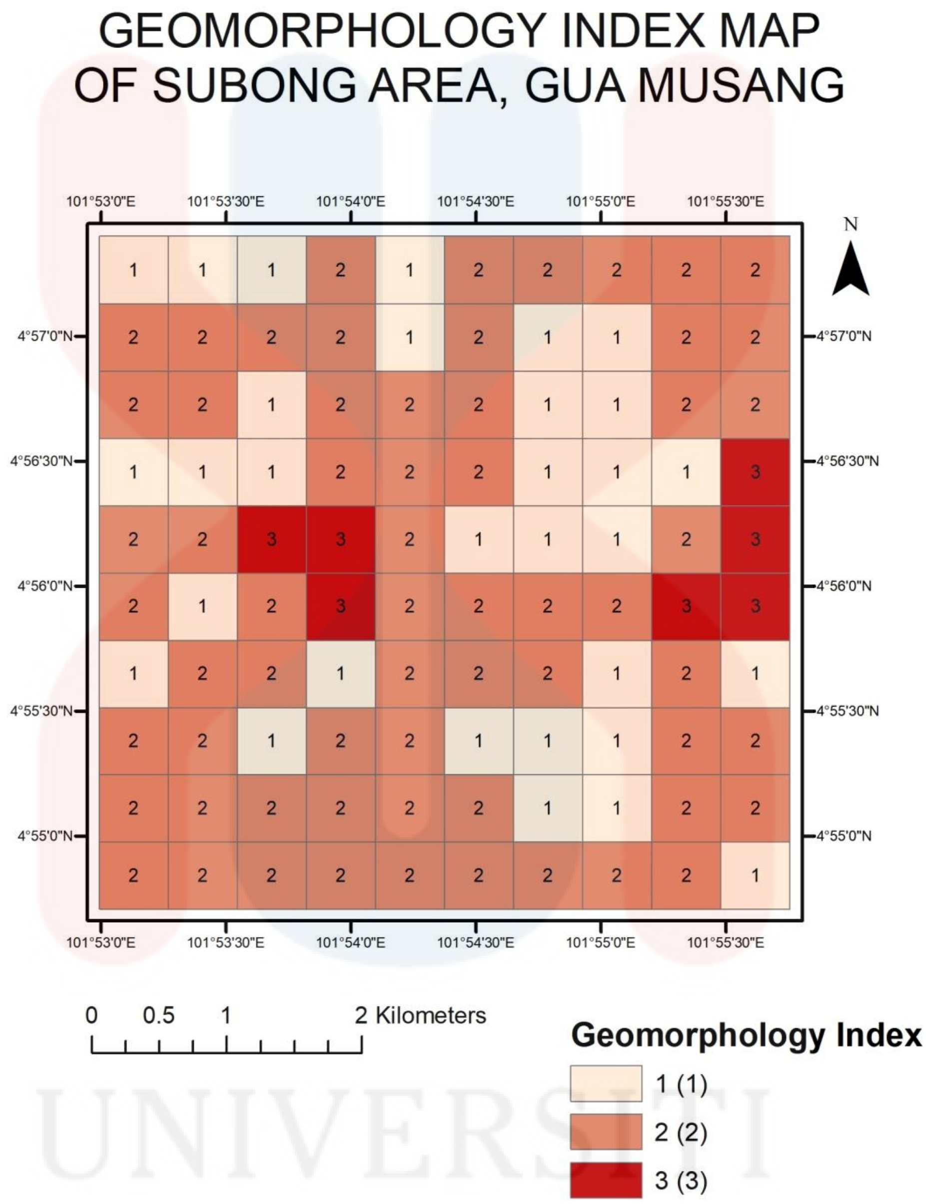


Figure 5.4: Geomorphology index map of the study area classified into three classes.

5.2.3 Mineral Index

Mineral diversity index in this research is quantified based on occurrence of any industrial minerals, precious metals or metallic minerals within the research area. Mineral resources in the study area is very limited in which it consist of only one occurrence. There is a quarry activity that extract manganese ore in the south-east region of the study area as shown in Figure 5.5. The manganese ores in the quarry occur in metasedimentary unit as the source rock and the colour range from grey to black (Nur Shahirah binti Che Azlan, 2018). As a result, the mineral diversity in the study area comprises of only 1% of total area having one mineral occurrence in the grid while 99% of total area has zero occurrence of mineral resources as shown in Figure 5.6.

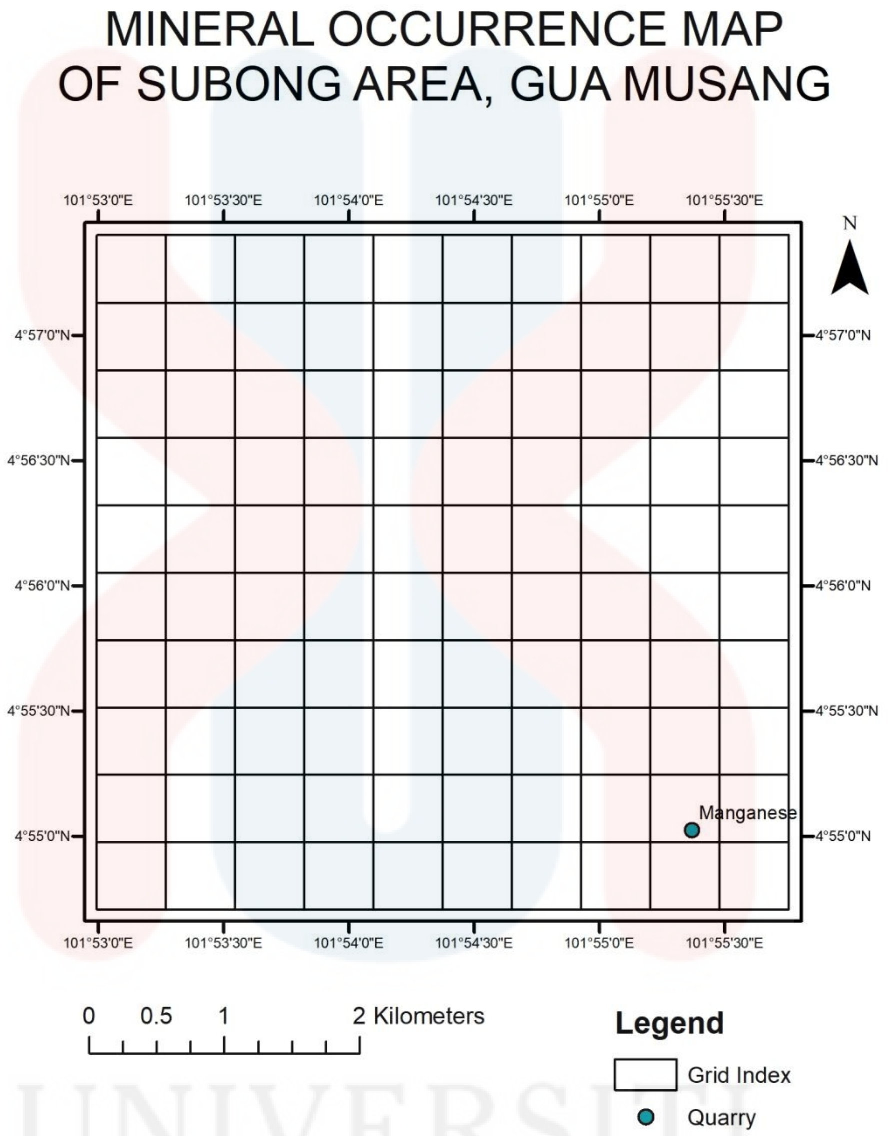


Figure 5.5: Mineral occurrence map of the study area showing the occurrence of manganese quarry.

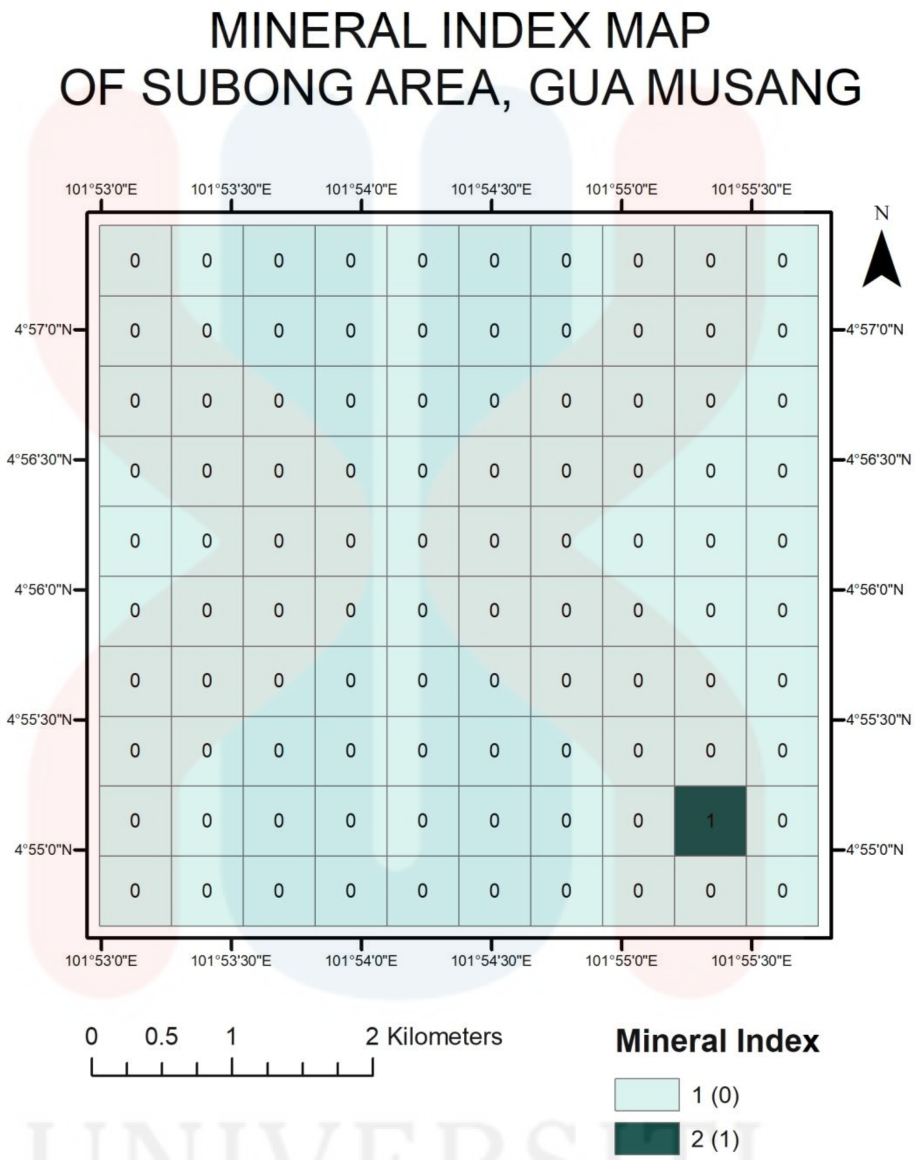


Figure 5.6: Mineralogy index of the study area consist of 2 classes.

5.2.4 Hydrology Index

Hydrology diversity index was quantified based on Stahler stream order processed using DEM data as shown in Figure 5.7. Each cells was quantified based on the occurrence of highest stream order in an individual cells. There are five stream orders within the study area which are classified into five classes of hydrology diversity index classes as shown in Figure 5.8. Grids with highest stream order (forth and fifth stream order) occurred at central towards the east region covering 14% of the study area. Meanwhile, 2% of the total grids in the study area has no occurrences of stream order. Grids with first stream order dominated most of the grids on the study area with 40% coverage. Lastly, 27% of the study area of the study area is made up of grids with third stream order.

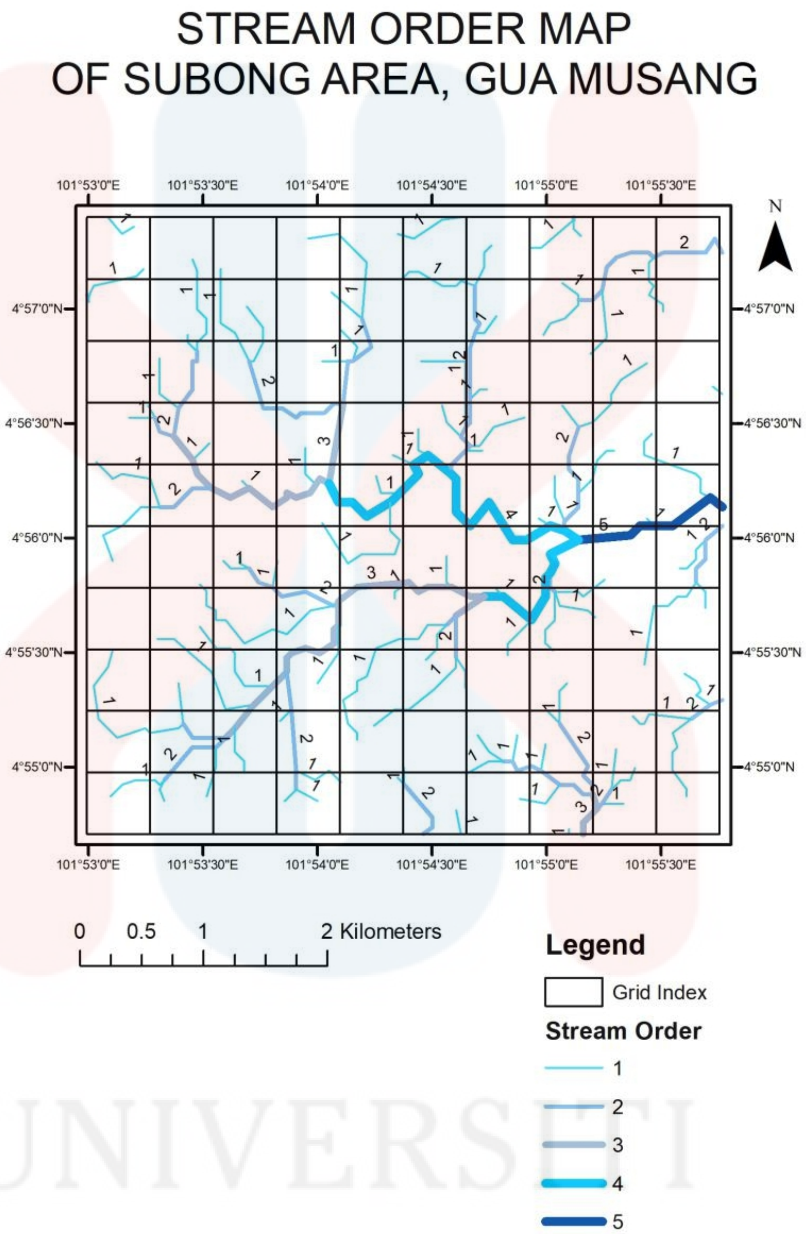


Figure 5.7: Stream order map of the study area consist of five stream order displayed on grid index.

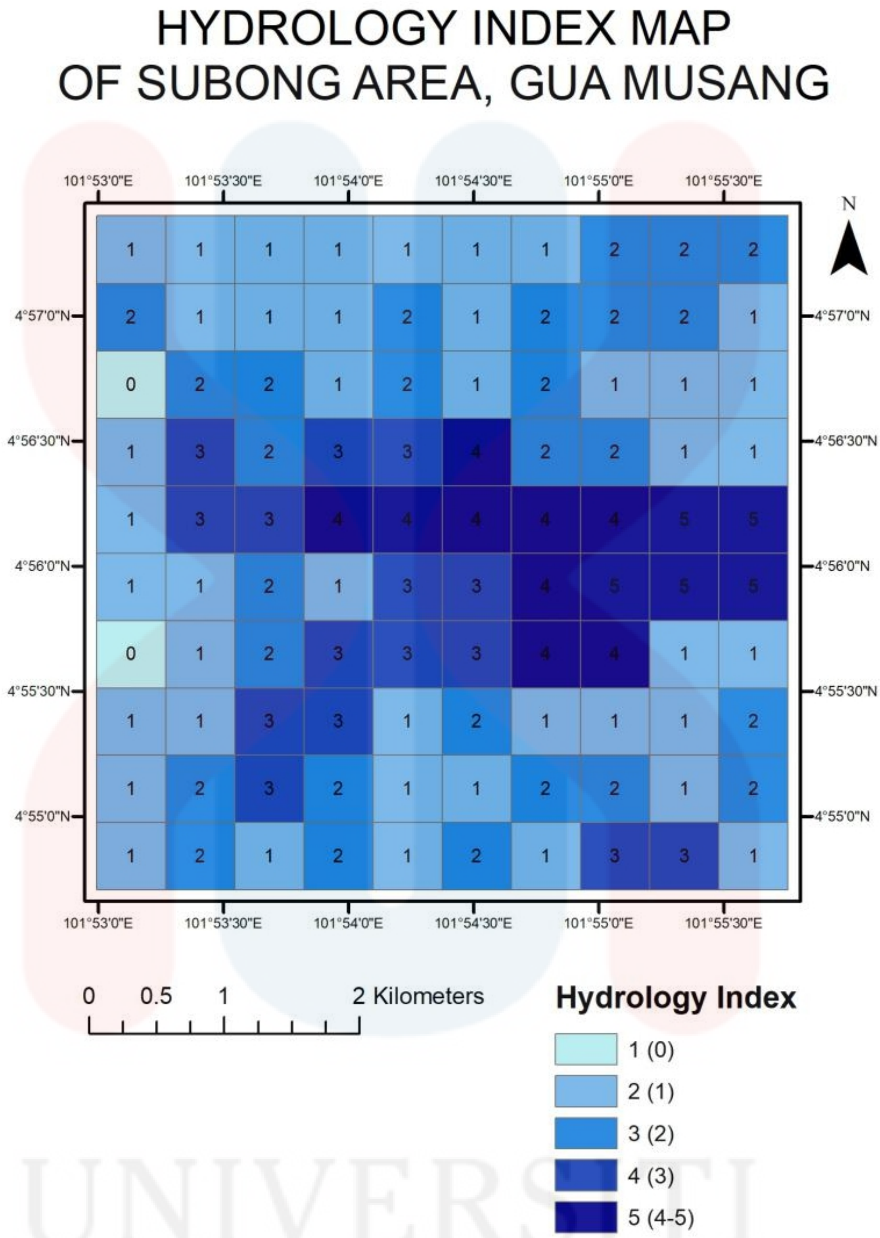


Figure 5.8: Hydrology index map of the study area classified into five classes.

5.2.5 Geodiversity Index

Geodiversity index is the total sum up of those four partial indices. In this research, the total geodiversity index in Subong area ranges from 2 to 11 as shown in Figure 5.9. It was classified into five classes using natural breaks by Jenks during processing phase in ArcGIS software. The classes of index shown are scattered around the study area with five classes of very low (1), low (2), medium (3), high (4) and very high (5) (Fernandez, et al., 2020). The highest value (10 to 11) covers only 3% of the study area located at the east region. The grids with highest value also scored the highest value in lithology, geomorphology and hydrology indices. The study area is dominated with 45% of very low geodiversity value (2 to 4). These grids also have a very low value occurrences of features in every partial indices. Low value of geodiversity index (5) covers 19% of the study area. Meanwhile, class three of geodiversity index scored a value ranges from 6 to 7 covers 26% of the study area which it mostly distributed at the central region. Lastly, high value (8 to 9) covers only 7% of the study area where the grids scattered in the central region.

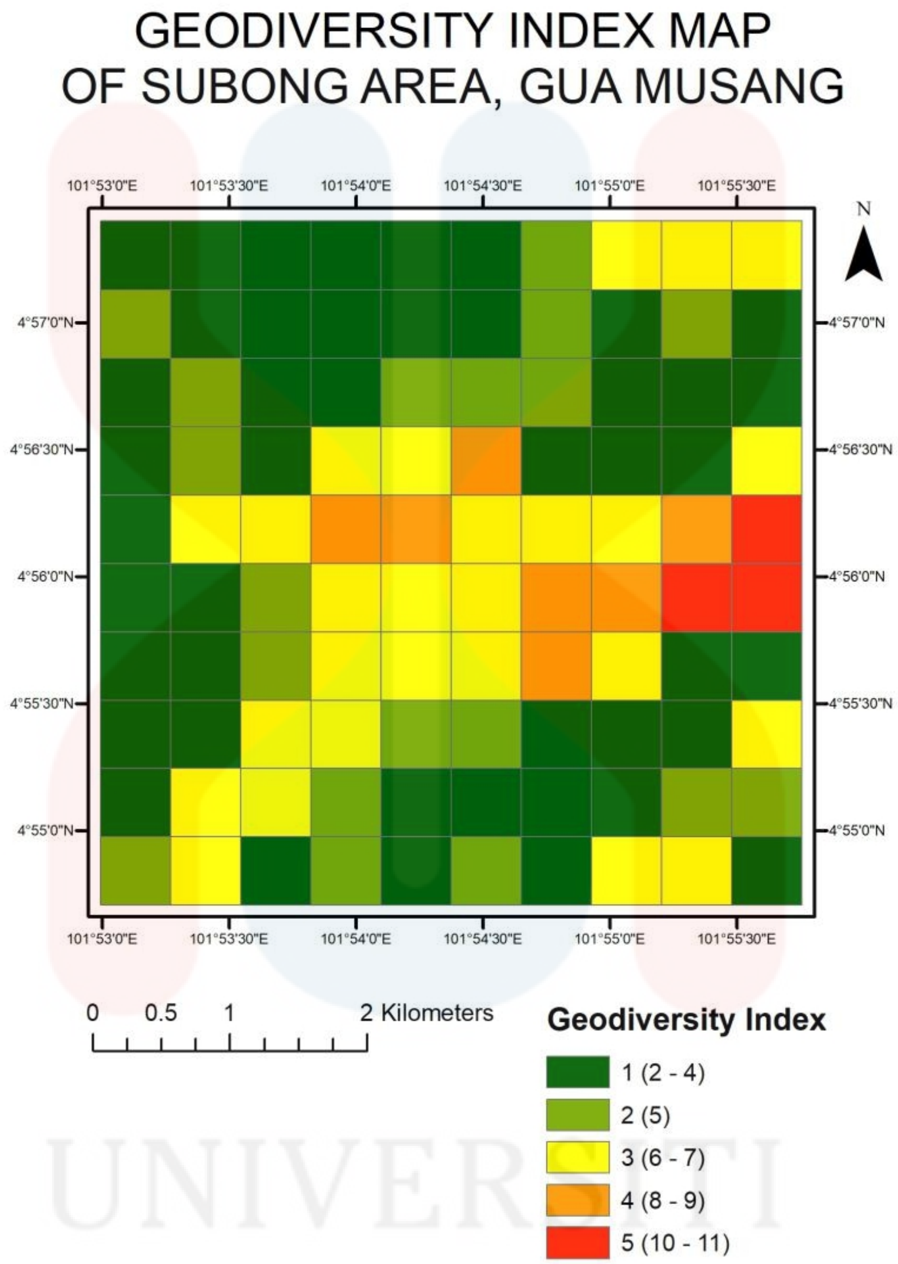


Figure 5.9: Geodiversity index map of the study area classified into five classes.The total value of geodiversity in the study area ranging from 2 to 11.

CHAPTER 6

CONCLUSION AND SUGGESTIONS

6.1 Conclusion

This research was carried out based on two perspectives; geology and geoheritage of Subong area, Gua Musang with objectives which are to generate a detailed geological map of study area with scale of 1:25000 and to assess the geodiversity in the study area for geoheritage potential. Overall, the objectives were successfully achieved.

The first objective was achieved by being able to produce a detailed 1:25000 geological map with the help of secondary data from satellite imagery, DEM and previous researches. DEM data was used in the processing phase to generate topography layer that was useful to interpret lithological boundaries and producing a geomorphological map. The study area consists of high hill, hill, low hill, low land and fluvial geomorphology and lithology of granite, metasedimentary rock, limestone and fluvial. Metasedimentary rock formed during Permian period followed by limestone from Permian to middle Triassic. Granite developed from Permian to late Triassic as a granitic intrusion body. The youngest lithology is alluvial. TIN map was used to interpret the geological structure in lineament analysis. The structural geology in the study area is influenced by compressional stress and shear forces from north-east and south-west direction.

On the other hand, the second objective which is to assess the geodiversity in the study area was achieved by being able to produce four partial indices maps; lithology index, geomorphology index, mineralogy index, hydrology index and overall geodiversity index map. The assessment method was based on quantitative approach where the occurrence and spatial distribution of geological elements were presented numerically. Four partial indices were summed up to produce geodiversity index. The geodiversity index scores range from 2 to 11 of total geodiversity. It was further classified into five classes; very low (2 - 4), low (5), medium (6 - 7), high (8 - 9) and very high (10 - 11). The highest geodiversity value with 10 to 11 occurrences of geodiversity are situated in east region of the study area with only 3% coverage. Meanwhile, the very low geodiversity value is the most dominant in the study area with 45% coverage of the study area with two to four total geodiversity occurrences.

The variation of geodiversity index value throughout the study area indicates the existence of a complex geological system in which the occurrence of different lithology, geomorphology, hydrology and minerals in the study area are the result of a prolonged tectonic events and weathering process. Each geological elements exist in the study area may also portray their own uniqueness with geoheritage values such as scientific, educational, aesthetic, recreational and cultural values. Hence, based on the concentration of geodiversity elements, the study area may possess its own geoheritage potential which it can be further classified as a geosite based on its lithology, geomorphology, hydrology, petrology or etc.

6.2 Suggestions

Geodiversity assessment method used in this research manifests the applicability of this method to be used in assessing and quantifying the occurrences and spatial distribution of geodiversity in a study area. Geodiversity index map produced in this research can be used as a comprehensive reference for further geoheritage evaluation, identification of areas with geoconservation potential or management and landuse planning in the study area. Locations with high geodiversity values should be considered for further identification and conservation process to protect the geological elements in the area from deterioration or destruction. In addition, this method is suitable to be applied in the earlier phase of geoheritage inventorying and evaluation where geoheritage values (scientific, educational, aesthetic, cultural and economic) of geodiversity elements are further assessed and geoheritage potential is determined. It is suggested to add a few more geodiversity elements to be quantified and indexed; for example, paleontology and pedology to provide a holistic geodiversity index map and improve the representation of available geodiversity in the study area.

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