GENERAL GEOLOGY AND PETROGRAPHY OF METAMORPHIC ROCK IN DESA ANABANUA, BARRU SUB-DISTRIC, BARRU REGENCY, SOUTH SULAWESI, INDONESIA.

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By

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

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2017

DECLARATION

I declare that this thesis entitled General Geology and Petrography of Metamorphic Rock in Desa Anabanua, Barru Sub District, Barru Regency, South Sulawesi, Indonesia 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 : ______________________________

Date : ______________________________

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General Geology and Petrography of Metamorphic Rock in Desa Anabanua, Barru Sub-District, Barru Regency, South Sulawesi, Indonesia.

ABSTRACT

Geological mapping of 25km^2 with the scale of 1:25000 were conducted in the Desa Anabanua, Barru Sub-District, Barru Regency, South Sulawesi, Indonesia. Geographically, this area located at between 4^o 27’0” – 4^o 29’30” South latitude and 119^{o}41’0” – 119^o 43’ 0” East longitude. The aim of the study is to produced updated map with better understand the geology of the study area and more specifically the petrography of the metamorphic rock in Desa Anabanua area. Unit lithology in the research area can be divided into three main unit. Description sequentially from the oldest to the youngest lithology unit are as follows Schist Unit, Ultramafic Unit and Limestone Unit. Both schist and ultramafic unit known as basement complex and the age is Triassic to Lower Createaceous while limestone unit is a part of Tonasa Formation with age is Eocene to Middle Miocene. Some part of this these rocks are chaotically mixed of igneous (peridotite, basalt and dacite), metamorphic (schist, garnet mica schist, blueschist, greenschist, phyllite, serpentinite and quartzite) and sedimentary rocks (limestone, claystone, chert and sandstone). These rocks are tectonically mixed as a result of subduction between the continental plates and oceanic plates. The geomorphology of the study area, Desa Anabanua can be divided into 2 units of morphology which is medium relief morphology unit and low relief morphology unit. In the research area, the main geological structures that occurred in the area such as folding and faulting. For petrography metamorphic rock, these rocks was determined based on texture, structure and composition of the minerals content. Based on these indication, it can be interpreted the type of the depositional environment of this unit and metamorphic grade.

Keywords : Petrography, Metamorphic Rocks, geological mapping

Pemetaan Geologi dan Petrografi Batuan Metamorf di Desa Anabanua, Kecamatan Barru, Kabupaten Barru, Sulawesi Selatan, Indonesia.

ABSTRAK

Pemetaan geologi 25km^2 dengan skala 1:25000 telah dijalankan di Desa Anabanua, Kecamatan Barru, Kabupaten Barru, Sulawesi Selatan, Indonesia. Secara geografi, kawasan ini terletak di antara 4^o 27'0" – 4^o 29'30" latitude selatan dan 119^{o}41'0" – 119^o 43' 0" longitud timur. Tujuan kajian ini adalah untuk menghasilkan peta yang dikemaskini dengan lebih memahami geologi kawasan kajian tersebut dan lebih khusus ialah petrografi batuan metamorf di Desa Anabanua. Unit litologi di kawasan kajian boleh dibahagikan kepada tiga unit utama. Penerangan secara berurutan dari yang paling tua kepada unit litologi termuda adalah seperti berikut Syis Unit, Ultramafik Unit dan Batu Kapur Unit. Kedua-dua syis dan ultramafik unit dikenali sebagai kompleks asas dan umur adalah Triassic hingga Createaceous Bawah manakala unit batu kapur adalah sebahagian daripada Pembentukan Tonasa dengan usia adalah Eocene ke Miosen Tengah. Ada sebahagian daripada ini batu-batu ini bercampur aduk daripada igneus (peridotite, basalt dan dacite), metamorf (syis, garnet mika syis, blueschist, greenschist, phyllite, serpentinit dan kuarzit) dan batuan sedimen (batu kapur, claystone, rijang dan batu pasir). Batuan bercampur secara tektonik akibat benam antara plat benua dan plat lautan. The geomorfologi kawasan kajian, Desa Anabanua boleh dibahagikan kepada 2 unit morfologi iaitu unit bantuan morfologi sederhana dan unit bantuan morfologi rendah. Di kawasan kajian, struktur geologi utama yang berlaku di kawasan adalah seperti lipatan dan sesar. Untuk petrografi batuan metamorf, batu ini telah ditentukan berdasarkan tekstur, struktur dan komposisi kandungan mineral. Berdasarkan petunjuk ini, ia boleh ditafsirkan dari segi jenis persekitaran pengenapan unit ini dan gred metamorf.

Kata Kunci : Petrografi, Batuan Metamorf, pemetaan geologi

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LIST OF ABBREVIATION

N	North
E	East
S	South
W	West
NW	North West
SE	South East

LIST OF SYMBOL

mm	Millimeters
km	Kilometer
%	Percentage
o	Degree

CHAPTER 1

INTRODUCTION

1.1 General Background

South Sulawesi is an island that has a lot of geological potential that has not been revealed clearly and definitely, it is due to geological mapping conducted in general still in regional scale 1:250,000. Based on that, a careful field observation and detailed geological mapping at the scale of 1 : 25,000 as well as petrographic studies have been done in the Desa Anabanua area in Barru Sub-District, Barru Regency, South Sulawesi, Indonesia. The area covers 5 x 5 kilometer square (25km^2), that is situated between 4^o 27'0" – 4^o 29'30" South latitude and 119^{o}41'0" – 119^o 43' 0" East longitude in the Sheet of Pangkajene and Watampone western part of Sulawesi.

The aim of the study is for better understanding the geology of the area and more specifically the petrography of the metamorphic rock in term of its characteristic. Basically, field observation of the rock can lead to the general classification of the type of rocks. Great geological mapping should be carried out in three phases especially planning, data collection and reporting. It is important to be precise and clear-cut as an accurate geological map because it is the basis of most geological works (Barnes, 2004).

Regional metamorphic rocks and accretionary units crop out in South Sulawesi. Those was exposed in restricted area namely Barru and Bantimala Complexes. The metamorphic rocks assemblages from these two area show at both metamorphic blocks were accreted slices in origin from wide range of tectonic environments and suffered high to intermediate pressure type metamorphisms in the subduction zone probably develop at the south eastern margin of Sundaland (Wakita et al., 1994; Maulana et al., 2010; Hamilton, 1979). According to Wakita et al. (1994), Bantimala Complex was well-known to be worldwide outcrop of high pressure and ultra-high pressure metamorphic rocks such as eclogite and blueschist. Whereas 30 Km north of this complex, low to medium grade metamorphic rocks expose in more restricted area namely as Barru Complexes (Setiawan et. al., 2014).

Metamorphic rocks in this area are bounded in the north with ultramafic rocks and in the east with Sedimentary rock of Tonasa Formation (Bhakti et al., 2003). The most common metamorphic lithologies in this area was variably of schist, garnet mica schist, serpentinite, phyllite, quartzite, blueschist and greenschist. However, there were lacks of publications about metamorphic rocks from Barru Complex in particularly their metamorphic evolution. This thesis explains the petrography of metamorphic rocks in Desa Anabanua which is a part from Barru Complex and detailed assessment of its characteristics.

1.2 Problem Statement

In regional scale, the geology of the study area has been studied by a number of scientists, particularly (Sukamto R. and Supriatna S., 1982) and (Hamilton, 1979). There were lack of publications about metamorphic rocks of Barru Complex and petrographic studies on them have not been yet performed. Therefore, a geological map in bigger scale (1:25,000) was needed to better understand the geological condition of the area and further study was focused on the petrography of metamorphic rocks at Desa Anabanua in Barru sub-district, Barru Regency, South Sulawesi.

1.3 Reserch Objective

The aim of the study was to better understand the geology of the study area and more specifically the petrography of the metamorphic rock in the Desa Anabanua. This aim would be expressed in an outlined objective as below:

a) To update the geological map in the scale of 1:25,000 of the study area.

b) To identify the characteristic of metamorphic rock based on thin section.

1.4 Study Area

The research area was held in Desa Anabanua which is located in the Barru Sub-Distric, Barru Regency and it covered an area of 5km × 5km ($25km^2$). Geographically, this area located between 4º 27’0” – 4º 29’30” South latitude and 119º41’0” – 119º 43’ 0” East longitude of Barru Complex. The base map was prepared and digitized by using ArcGIS 10.2 software and it shows the location of the study area (Figure 1.1). This area was located in the northeast city of Makassar with a distance of 120 km which is can be reached by using two-wheeled vehicles or four-wheel drive about 2 hours drive.

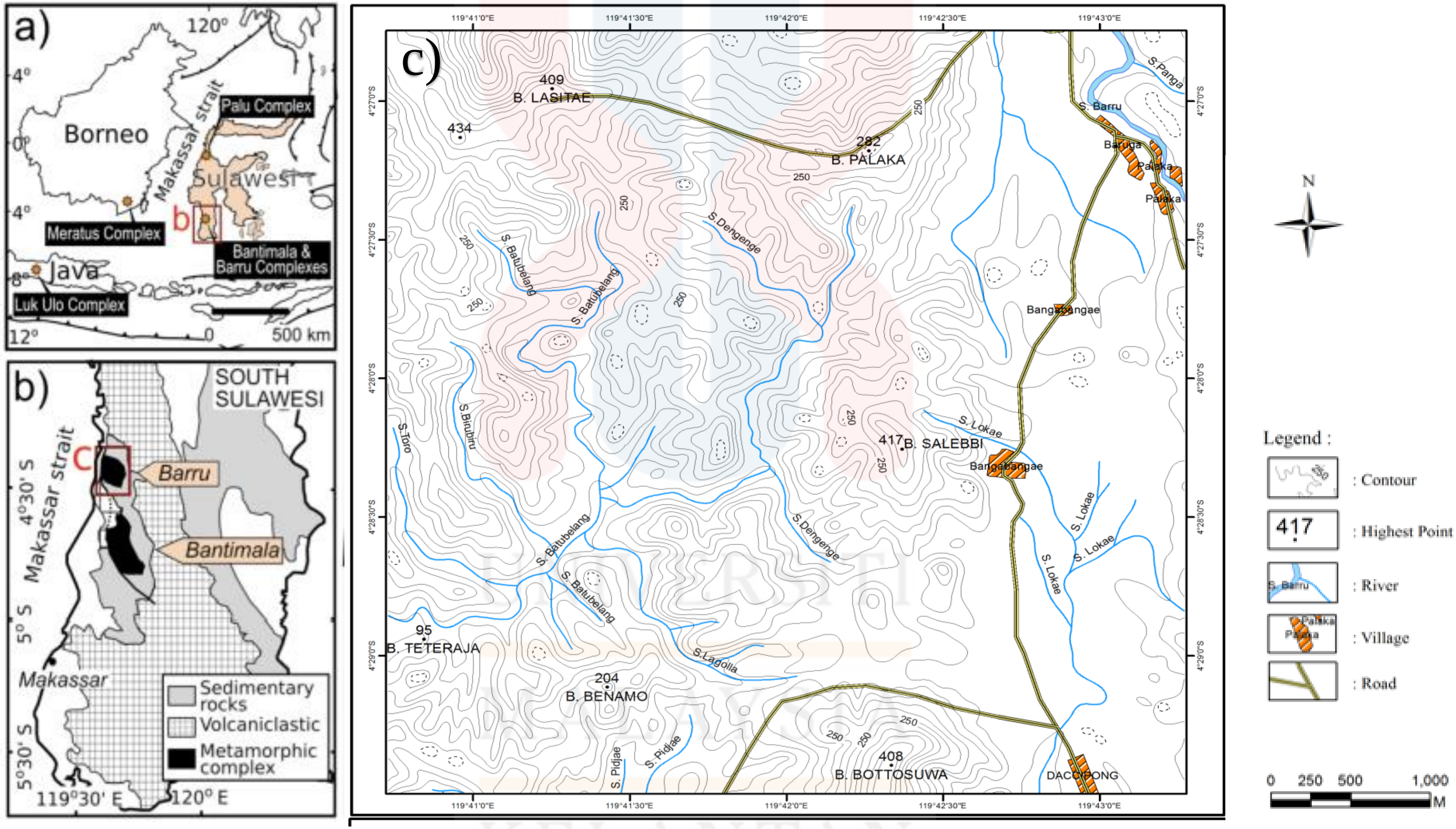


Figure 1.1 (a) Sulawesi Island. (b) Barru Complex. (modified after Sukamto, 1982) (c) Basemap of the study area which is located at Desa Anabanua, Barru Sub-District, Barru Regency.

1.5 Geography

a. Demography

Barru population based population projections for 2015 as shown in Table 1.1 were 171217 people consisting of 82207 inhabitants of the male and 89010 female population people. This compares with a total Barru Population in 2014, the Population growth of Barru are 0.53 percent with each percentage of the male population growth of 0.61 percent and 0.45 percent of the female population. While the magnitude of the sex ratio in 2015 the male population towards the female population are 92.36.

Population density of Barru District in 2015 reached 146 people/km² with the average number of residents per household are 4 people. Population density in 7 sub districts is quite diverse with the highest population density of subdistrict is located in the sub district Tanete Rilau with the number of density are 424 people/km² and the lowest in sub district Pujananting with 41 people/km². Meanwhile, the percentage of household growth is -3.98 percent from 2014. Generally, the number of populations in sub district Barru rose steadily and topped the chart with 40,374 people in 2015 and the population of people in Barru and others sub district increases over the years.

Table 1.1 Population And Sex Ratio By District In Barru Regency, 2015

District	Population			Sex Ratio
	Male	Female	Total	
(1)	(2)	(3)	(4)	(5)
Tanete Riaja	10694	11858	22552	90.18
Pujananting	6403	6639	13042	96.45
Tanete Rilau	16154	17410	33564	92.79
Barru	19496	20878	40374	93.38
Soppeng Riaja	8612	9245	17857	93.15
Ballusu	8696	9670	18366	89.93
Mallusetasi	12152	13310	25462	91.30
2015	82207	89010	171217	92.36
2014	81705	88611	170316	92.21
2013	81193	88109	169302	92.15
2012	80734	87300	168034	92.48
2011	80684	86972	167656	92.77

Source : Statistics of Barru Regency.

b. Rainfall

Rainfall in Barru Regency much depends on velocity of current winds, geography and climate in a certain season. Therefore, the amount of rainfall varies at certain place. Every month, the data of rainfall will be collected and recorded. The following Table 1.2 showing the total percentage of rainfall per month in Barru Regency areas from 2012 to 2015.

Table 1.2 Number Days Of Rain And Rain Fall By Month In Barru Regency, 2015.

Month	Area	Percentage
(1)	(2)	(3)
January	24	813
February	21	451
March	17	489
April	13	312
Mei	5	61
Jun	10	137

July	1	0
August	0	0
September	0	0
October	0	0
November	14	206
December	21	770
2015	126	3239
2014	143	2830
2013	162	5266
2012	161	2350

Source : Agriculture Extension Service of Barru Regency.

c. Land used

Food Crops

Area of in Barru becomes the pillar of food crops in many Subdistricts. As shown in data Table 1.3 from Agriculture and Forestry Service of Barru Regency, during 2015, Barru harvested 104213.43 tons of wetland paddy (Figure 1.2) and 2681.84 tons of maize. Meanwhile, if we take a look at type of irrigation used by farmers, most of them used traditional irrigation and rain depend as their main irrigation.

Table 1.3 Harvested Area, Production And Productivity Of Wetland Paddy and Corn By District In Barru Regency, 2015.

District	Wetland Paddy			Corn		
	Harvested Area (Ha)	Production (Ton)	Productivity (Kw/Ha)	Harvested Area (Ha)	Production (Ton)	Productivity (Kw/Ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tanete Riaja	2567	15077.72	58.74	118	618.81	52.44
Pujananting	2219	130339.78	58.76	29	148.50	0.00
Tanete Rilau	2265	13106.10	57.86	273	1511.39	55.36
Barru	4403	26068.63	59.21	41	220.85	53.87
Soppeng Riaja	2176	12518.11	57.53	16	84.59	52.87
Balusu	2077	12196.51	58.72	0	0.00	0.00
Mallusetasi	2114	12206.57	57.74	19	97.70	51.42
2015	17821	104213.43	408.56	496	2681.84	265.96

Source : Agriculture Extension Service of Barru Regency.

Figure 1.2 Paddy field in the study area.

Livestock

Table 1.4 shows majority of livestock lived in Barru is cow 13073 heads with the most populated livestock followed by goat, horse and buffalo. Figure 1.3 shows cowshed area in the study area.

Table 1.4 Livestock Population By District And Kind Of Livestocks In Barru Regency (Heads), 2015.

District	Cow	Buffalo	Horse	Goat
(1)	(2)	(3)	(4)	(5)
Barru	13073	0	397	1028

Source : Livestock Service of Barru Regency.

Figure 1.3 The cowshed in the study area.

Forest

The forest of Barru dominated by Protection Forest, followed by Limited Production Forest. From the current forest, the timber production gave 4954 hectares of teak in 2015 (Table 1.5).

Table 1.5 Area of Commodity, Plant Potention and Production of Forest in Barru Regency, 2015.

Kind of Plant	Potensional Area (Ha)	Expanded Area	Production
(1)	(2)	(3)	(4)
Ebony	900	0	0
Jati	4954	0	649.021,00
Sutra Alam	525	0	0

Pinus Merkusi	1500	0	30.00,00
Mahoni	1745	0	0
Gula Aren	1200	0	0
Rotan	1900	0	20.000,00
2015	14414	0	0

Source : Branch Service of Forestry Barru Regency.

Figure 1.4 View of forest in the study area.

Based on field observation, it can be concluded that the research area was dominated with Forest followed by Food Crop and Livestock. Most villagers in Desa Anabanua plant paddy, corns, vegetables and avenge cows as a side jobs. Distribution of land used in the study area as seen in Figure 1.5 below.

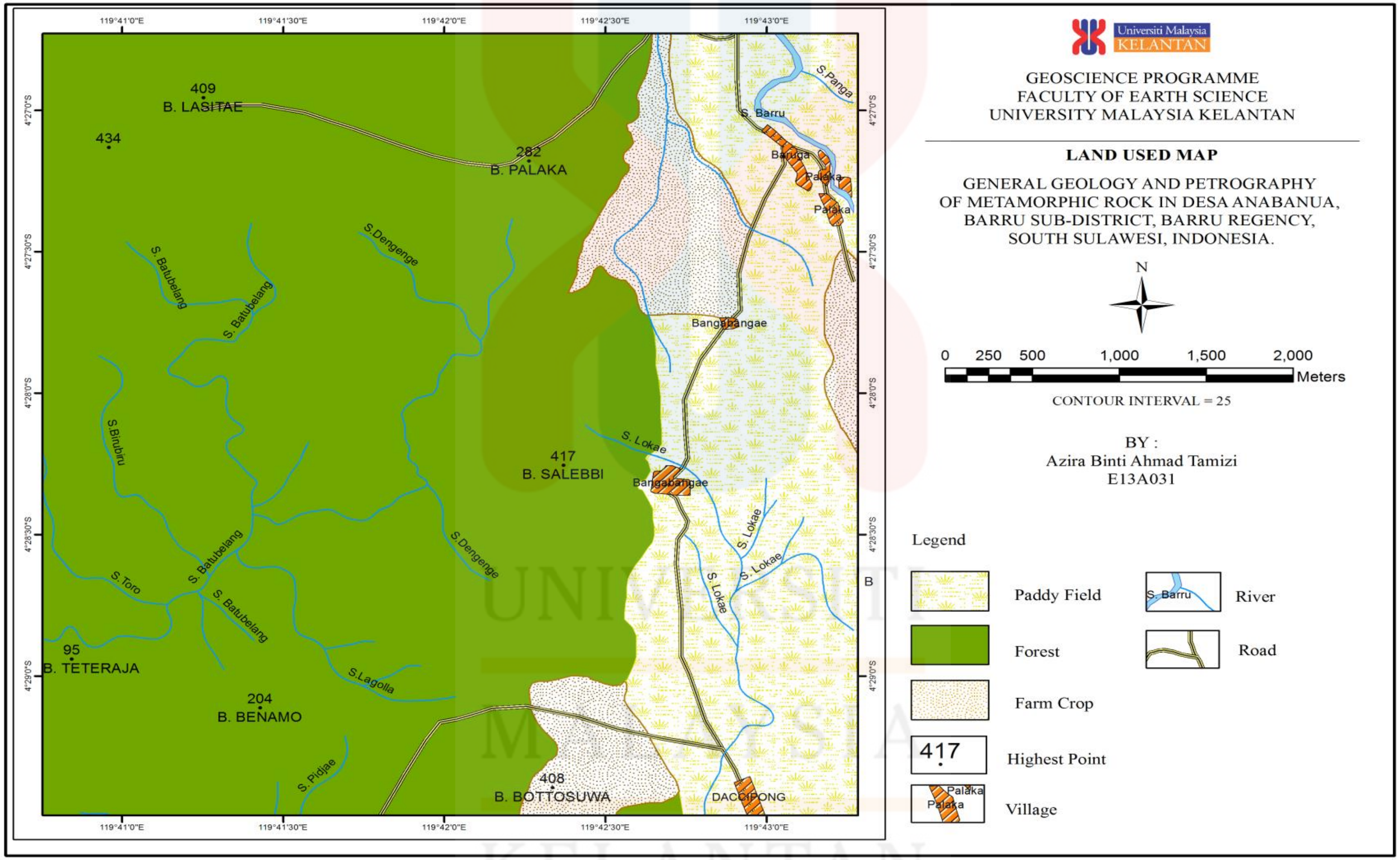


Figure 1.5 Land Used Map of Desa Anabanua area.

d. Social Economic

In Barru Regency, based on Figure 1.6 by classifying to main industries, 39.67% of populated aged 15 above worked in Agriculture, Foresty, Hunting, and Fisheries and 5.45% worked in Manufacturing Industry, 16.14% worked in Wholesale Trading, Retail Trading, Restaurant and Hotel, 20.65% worked in Community, Social and Personal Service and 18.09% worked in other. Also, considering the Total Working Hour during the previous week, majority of worker in Barru has worked more than 35 hours.

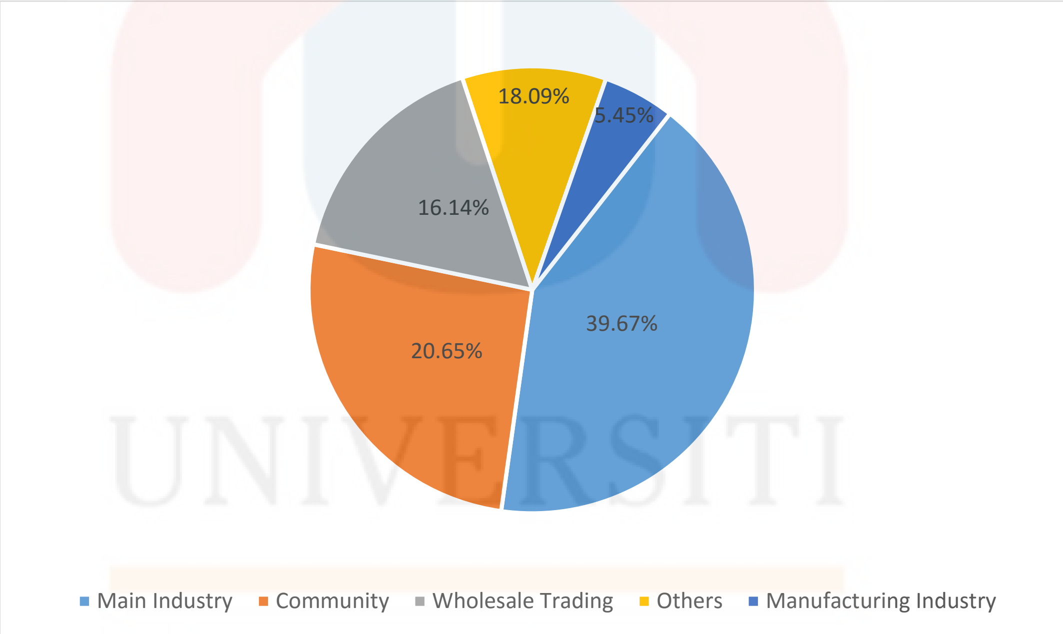


Figure 1.6 Population 15 Years Old And Over Who Worked By Main Job Status In Barru Regency, 2015 (Source: Statistics of Barru Regency)

Education

From the result of National Socio Economic Survey Kor, March 2015 (Table 1.6), the highest number of Net Enrollment Rate (NER) was earned in Elementary School level with NER 92.54 and Gross Enrollment Rate (GER) also in the Elementary School level with GER 102.93.

Data from Barru Regency's Service of National Education in 2015 Barru is home to 87 kindergartens, 225 Primary Schools, 27 Madrasah Ibtidaiyah, 38 Junior High Schools, 14 Madrasah Tsanawiyah, 9 Senior High School, 7 Vocational High Schools, and 12 Madrasah Aliyah.

Table 1.6 School Enrollment Rate, Net Enrollment Rate And Gross Enrollment Rate By Educational Level Of Barru Regency, 2015

Educational Level	APS	APM	APK
(1)	(2)	(3)	(4)
2015			
SD/MI	99.47	92.54	102.93
SMP/MTS	93.43	76.32	94.28
SMA/MA	74.34	69.01	90.62

Source : Statistic of Barru Regency.

Health

In 2015, there's only one Hospital established in Barru located in Subdistrict of Barru. Then, there are 45 Public Health Centers, 247 Maternal & Child Health Centers, 4 clinics and 15 Village Maternity spread in the whole Barru Regency (Table 1.7).

Table 1.7 Number Of Health Facilities In Barru Regency, 2011 – 2015

Health Facilities	2011	2012	2013	2014	2015
(1)	(2)	(3)	(4)	(5)	(6)
Hospital	1	1	1	1	1
Maternity Hospital	1	-	-	-	0
Public Health Center	43	33	33	44	45
Health Center	240	243	243	245	247
Clinic	1	-	-	-	4
Village Maternity	23	23	23	23	15

Source : Health Services of Barru Regency

Religion

Islam is the largest faith in Barru. According data 2015 in Table 1.8 below, the majority of population in Barru embraced it as their faith. On the other hand, there are 362 Catholic, 62 Protestant and 4 Buddhism settled. The count of places of worship is 268 mosques, 34 Mushola, 39 langgar and three churches.

Table 1.8 Population By District And Religion In Barru Regency, 2015

District	Moslem	Protestant	Catholic	Hindu	Buddhism	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tanete Riaja	37622	57	240	0	4	37923
Pujananting	33353	0	73	0	0	33426
Tanete Rilau	24909	0	27	0	0	24936
Barru	18725	2	0	0	0	18727
Soppeng Riaja	27497	3	5	0	0	27505
Balusu	17926	0	17	0	0	17943
Mallusetasi	13756	0	0	0	0	13756
2015	173788	62	362	0	4	174216

Source : Statistics of Barru Regency

e. **Road Connection**

Barru was located on the West Coast of of South Sulawesi. Geographically, Desa Anabanua was located in the Barru Regency, about 120 km towards the northeast city of Makassar and can be reached by two-wheeled and four wheel vehicles about 2 hours 26 minutes drive. Figure 1.7 shows the road connected from City of Makassar to Desa Anabanua, Barru Regency.

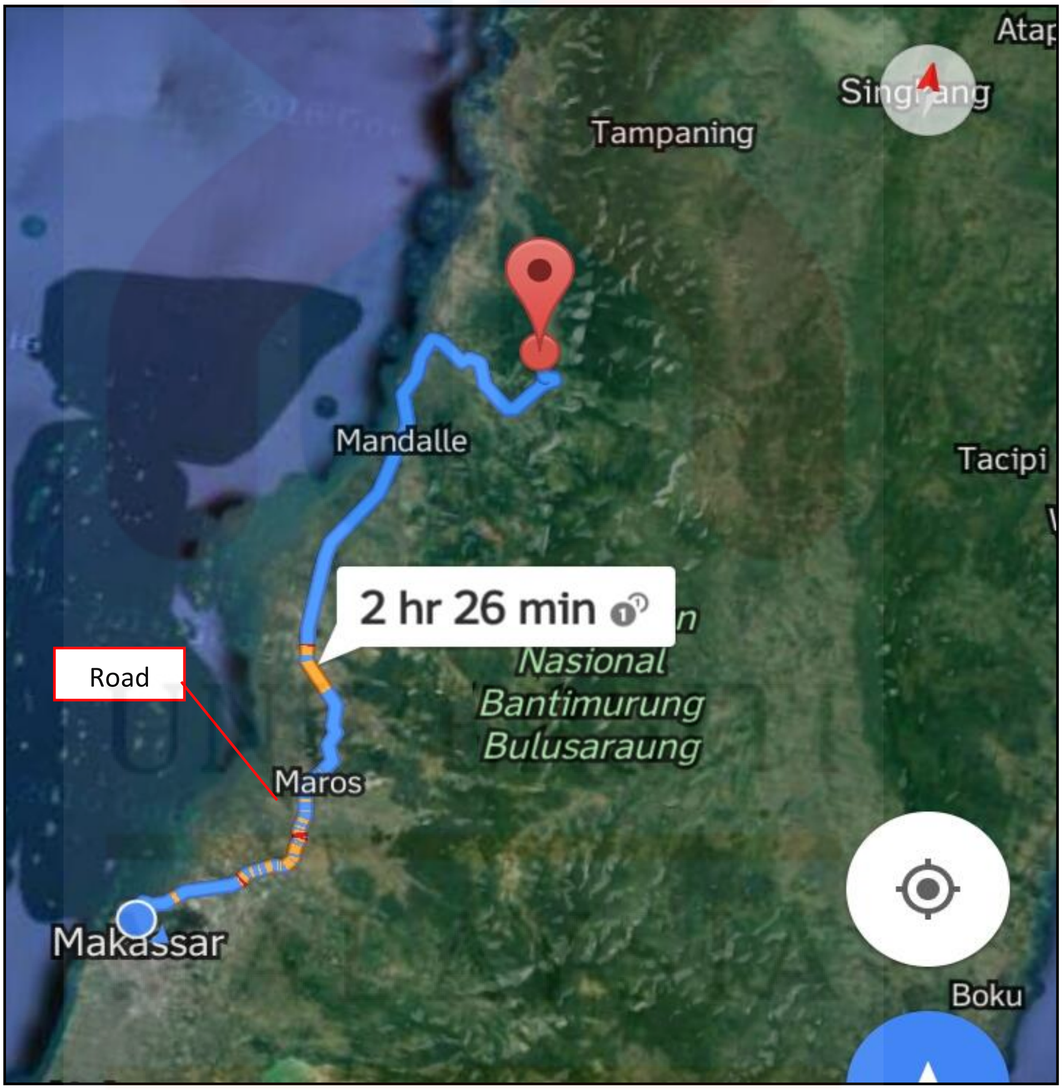


Figure 1.7 Road connection from Makassar city to Desa Anabanua area.

Sources : Google Maps.

1.6 Scope of the study

The research focused on the petrographic study of metamorphic rocks. The characteristics of metamorphic rock were described based on its structure, texture and minerals composition in thin section to interpreted the grade of metamorphism. The mapping in this research ware focused on geography, geomorphology, lithology and structural analysis of the study area. During mapping, the sample was collected for the petrography purpose. All detail obtained will be used for updated information in geological map of the study area by using ArcGIS 10.2. Finally, the geological history of the study area was presented.

1.7 Research Important

This research provided an updated and detailed geological map of the study area which is in scale 1:25,000. Large-scale maps of small areas was made to record specific geological features in great detail. Besides that, petrography of metamorphic rocks was the main focus of this research that was able to help the understanding of the characteristic of rocks and the conditions under which metamorphic rock were formed. It utilizes the classical fields of mineralogy and petrography to describe the structure and minerals composition in rocks.

CHAPTER 2

LITERATURE REVIEW

2.1 Regional Geology & Tectonic Setting

This research area located in the Sheet Pangkajene and Watampone western part of Sulawesi, which is has been mapped by Rab. Sukamto and Supriatna S. (1982). Discussion about regional geology consist of a description of the geomorphology, stratigraphy and regional structure.

2.1.1 Geomorphology Regional

Astronomically, Barru Regency was located between 4°05'49'' and 4°47'35'' South latitude, and between 119°35'00'' and 119°49'16'' East longitude. This research area was a part of sheet Pangkajene and Watampone western part of Sulawesi. This sheet covered the district of Maros, Pangkep, Barru, Soppeng, Pangkajene island and Pare-Pare. In terms of geographic position, Barru has boundaries as follows: North –Pare-Pare Municipality and Sidrap Regency; South – Pangkajene Kepulauan Regency; East – Soppeng Regency and Bone Regency; West – Makassar Strait. This sheet was located in between regional geology map Sheet of Majene and western part of Palopo in northern and Sheet of Ujung Pandang, Sinjai and Benteng in southern (Sukamto, 1982).

According to Sukamto and Supriatna (1982), there are two rows of mountains that extends almost parallel to the direction of the north – northwest and separated by river valley Walanae in Sheet of Pangkajene and western part of Watampone (Figure 2.1). The mountainous western part occupies almost half of the area, which extends in the south (50 km) and narrows in the north (22 km) with its highest peak is 1694 meter and the average is 1500 meters above sea level. Constituent mostly volcanic rocks while on the western slopes and in some places on the eastern slope there is a karts topography which is limestones. Among the karst topography on the western slopes of the hills are formed by rocks on the Pre- Tertiary age. This mountain was limited by wider plain area of Pangkajene – Maros and partly are continuation in the surrounding plains.

Mountains in the eastern part are relatively narrower and lower by an average of peak height is 700 meters above sea level while the highest is 787 meters, where most of these mountains are composed of volcanic rocks. In the southern part, the width is 20 km and more higher, but to the north, it becomes narrow and modestly and eventually subducting down the boundary between sheet Walanae and Bone plain (Sukamto, 1982).

Based on Sukamto (1982), in the northern part of the mountains, the surface of karst topography is partially pursed. Sheet of Walanae that separates the two mountains in the northern part is wider compared in the southern part. In the middle of the valley, there is a river of Walanae that flow to the north. Other than that, in the southern part comprised of low hills and in the northern part, there was formed a large alluvial plain which surrounds the Tempe Lake (Danau Tempe).

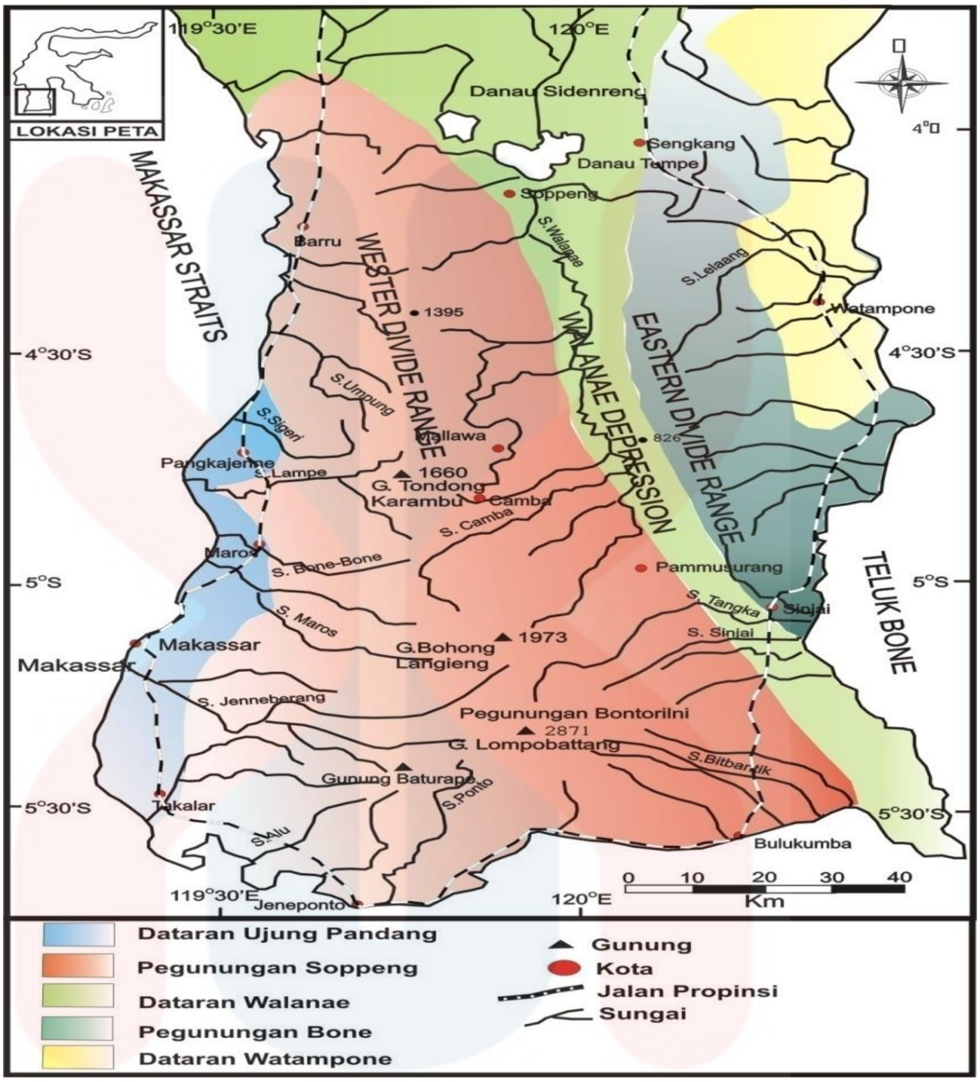


Figure 2.1 Geomorphic map of South Sulawesi that showed the three topographic expression differences include Western Divide Mountain Range, Walanae Depression and Eastern Divide Range (Wilson et al., 1996).

2.1.2 Stratigraphy and Historical Geology

Sedimentary rocks in Desa Anabanua included in Tonasa formation which is composed of sandstone, carbonaceous claystone and limestone. The age of Tonasa formation in between Late Eocene to Middle Miocene. Metamorphic rocks and ultramafic is a part of the basement complex in Barru. The age of metamorphic rock and ultramafic was Triassic (Sukamto and Supriatna, 1982).

There are distinct differences in geology between the western and eastern South Sulawesi, which are separated from each other by the WWF (Figure 2.2; Van Leeuwen *et al.*, 1981; Sukamto, 1982). In Western Divide Mountain, the oldest rocks of it was found on the western side as the basement complex, the Bantimala and Barru tectonic complex. The Bantimala Complex is composed by high pressure metamorphic rocks, melange, radiolarian cherts, turbidity sediments, shallow sedimentary rocks and ultramafics rocks (Miyazaki *et al.*, 1996). The Middle Cretaceous (Late Albian-Early Cenomanian) chert unconformably overlies on the high-pressure metamorphic rocks. These assemlages are unconformably overlain by shallow marine clastic sedimentary units of the Early and Middle Jurassic Paremba sandstone (Wakita *et al.*, 1994).

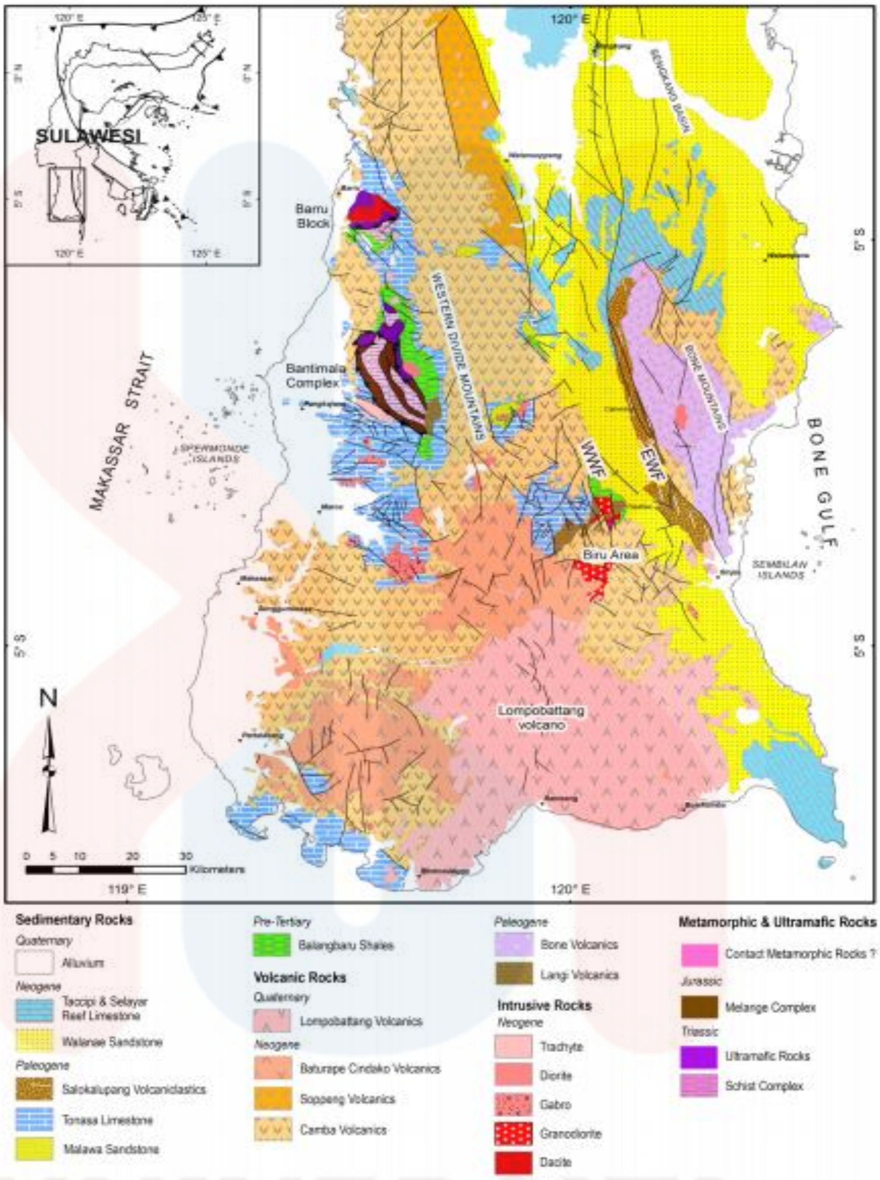


Figure 2.2 Geological Map of the south Sulawesi was showing the location of West Walnae Fault, East Walanae Fault and Barru area (modified after Van Leeuwen *et al.*, 1981; Sukamto, 1982)

The ultramafic rock was dominated by serpentiniesd peridotite which contains chromite lenses. Geological setting in the Barru area has not been well characterized, and the high pressure assemblages of metamorphic rocks was not found. Structure features of the Barru and Bantimala Complexes was also quite different. Bantimala area has foliations commonly NNW-SSE occasionally NW-SE striking and steeply dipping to NE. Whereas WSW-ENE striking and steeply dipping to SE foliation was developed in Barru area (Wakita *et al.*, 1994).

Metamorphic Rocks; mostly schist and slightly gneiss, based on microscope there are visible minerals like glaucophane, garnet, epidot, mica and chlorite. This metamorphic rocks are generally tilted toward the northeast, largely Brecciated and normal faulted toward southwest. This unit thickness not less than 2000 meters and fault contact with the surrounding rock units (Parkinson *et al.*, 1998). Mostly metamorphic rocks that had been found in this research area were located at along Salo Dengenge, Salo Batubelang, Salo Lagolla and Salo Birubiru.

Ultramafic Rock; peridotite, mostly serpentinized, colour dark green to blackish, mostly Brecciated and eroded through normal fault toward the southwest; the solid part looks like layered structure and at some place consisted chromite lense. This unit thickness not less than 2500 meters and has fault contact with the surrounding rock units (Sukamto, 1982). In Desa Anabanua, ultramafic rocks are dominated at Bulu Pallaka, Bulu Lasitae and its surrounding.

Tonasa Formation; age of this formation in between Late Eocene to Middle Miocene. The Tonasa limestone formation unconformably overlies the volcanic rocks and is overlain with angular unconformity by rocks belonging to the Sopo Volcanics. The lithology composed in this formation is solid coral limestone, colour white to light gray; bioclastic limestone and calcarenites, colour white, light brown and light gray, partly layered, interbedded with carbonaceous claystone, lower part consisted of bituminous limestone, some place have breccia limestone and sandy limestone. The formation also has abundant fossils such as foraminifera and algae. The Tonasa Formation thickness not less than 3000 meters (Sukamto and Supriatna, 1982).

2.2 Metamorphic Rock

A metamorphic rock is a part of the three basis rock categories which are formed by the recrystallization of pre-existing (older) rocks as a result of changes in pressure, temperature and fluid condition at depth below the earth's surface. This action product in changes of texture and minerals composition while the rock is remains in a solid state (means that the rock does not melt). In addition, metamorphic rocks can be derived from sedimentary, igneous or from other metamorphic rocks itself.

Therefore, the origin of metamorphic rocks different with the origin of igneous rocks which it derive from the cooling of molten rock while sedimentary rock which are products of surface processes. Actively forming mountain ranges and ancient mountain belts in continental interiors was a place that metamorphic rock often found exposed. The study of metamorphic rocks allow us to explore and learn the condition and processes that occur at various levels within the earth's crust.

2.2.1 Type of Metamorphism

There are two major types of metamorphism, which is contact metamorphism and regional metamorphism. Firstly, contact metamorphism. Contact metamorphism develop close to igneous intrusions and it was a result from high temperature correlate with the igneous intrusion. Contact aureole or metamorphic was called based on metamorphism is surrounded to the zone of intrusion since only the small area surrounding the intrusion was heated by the magma. Out of the contact aureole, the rocks are not affected by the intrusion and metamorphism does not occur (Jacques, 2002).

Anthony and Jay (1990) described that toward the intrusion, the grade of metamorphism will increases in all directions. This is because the temperature of the surrounding rock is difference and at shallow levels in the crust, the intruded magma is larger where pressure is low. Contact metamorphism is generally referred to as low pressure, high temperature metamorphism. The rock produced is usually a fine grained rock and shows no foliation.

According to David (1983), regional metamorphism often does not show any relationship with igneous bodies and it was occurs by large area. Mostly regional metamorphism is followed by different stress conditions or deformation under non hydrostatic conditions. Hence, regional metamorphism is often results in forming metamorphic rocks which are strongly foliated like slates, gneisses and schists.

The differential stress is common results from tectonic forces that produce confining stress in the rock for instance the collision between two continental masses. So, this type of metamorphism occur in eroded mountain ranges or the cores of thrust or fold mountain belts. Compressive stress due to folding of rock and thickening the crust tends to push the rocks to more deeper levels where they are lead to higher pressures and temperatures (David, 1983).

2.2.2 Texture and Mineralogical

The main classification petrography focus on mineral assemblages and texture. Mineralogical is the most differentiating minerals that are used as a prefix to know textural term. For instance, a schist which have biotite, feldspar, quartz and garnet would be called as biotite feldspar schist. While a gneiss containing pyroxene, hornblende, feldspar and quartz would be called as pyroxene hornblende gneiss (Anthony & Jay, 1990).

2.2.3 Facies Metamorphism

Generally, metamorphic rocks do not extremely alter the chemical composition during metamorphism. According to Jacques (2002), the alteration in mineral association are cause by changes in the pressure and temperature conditions of metamorphism. So, the mineral associations that are observed need to be an indication of the pressure and temperature environment that the rock was dominated to. This pressure and temperature environment is indicated as Metamorphic Facies (Facies 2.3).

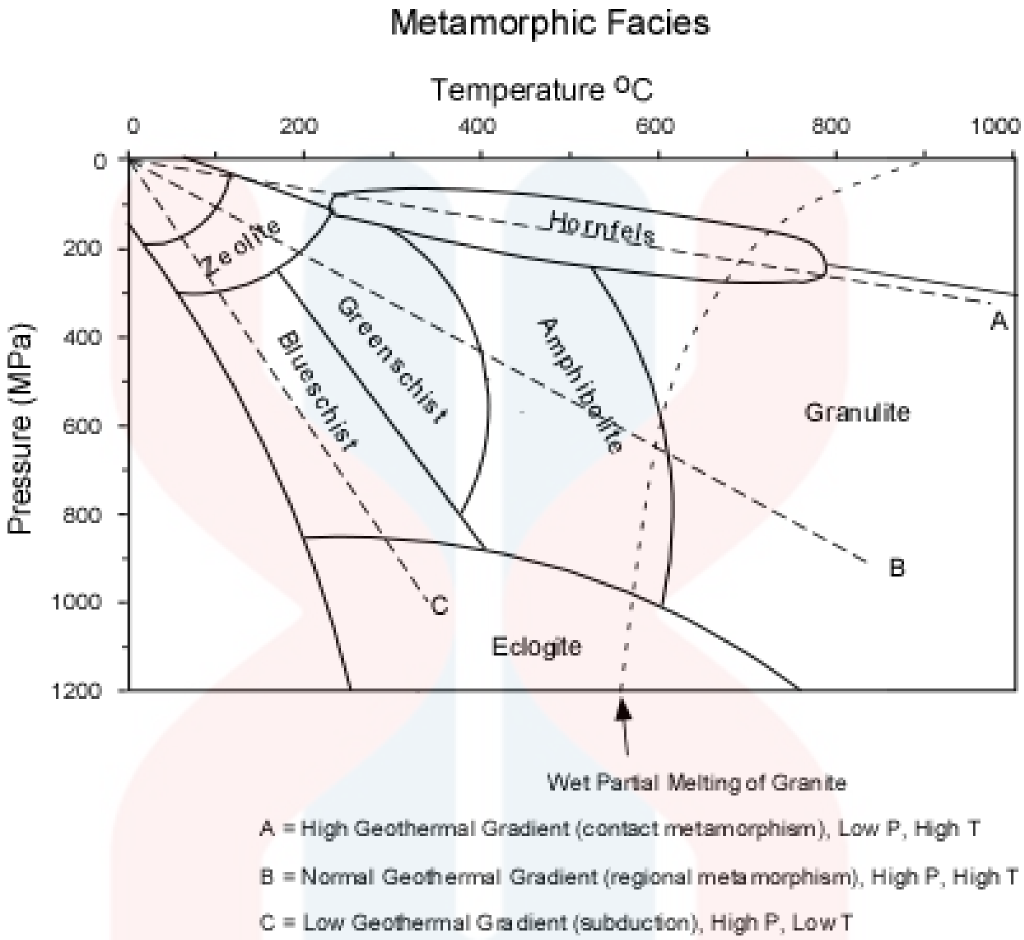


Figure 2.3 Diagram of Metamorphic Facies. Sources : Jacques (2000)

CHAPTER 3

MATERIALS AND METHODOLOGY

Introduction

In conducting geological mapping, we need a method for retrieval and processing of data. Systematic research stages were important with the aim that these geological mapping can run smoothly by following the time that has been planned. The stages of the study, presented in the form of a flowchart in Figure 3.1.

In order to achieve maximum results in this research, there was several systematic and planned stage were carried out which included preparation phase, mapping, data processing, data analysis stage and the stage of report writing to complete the thesis.

RESEARCH FLOW CHART

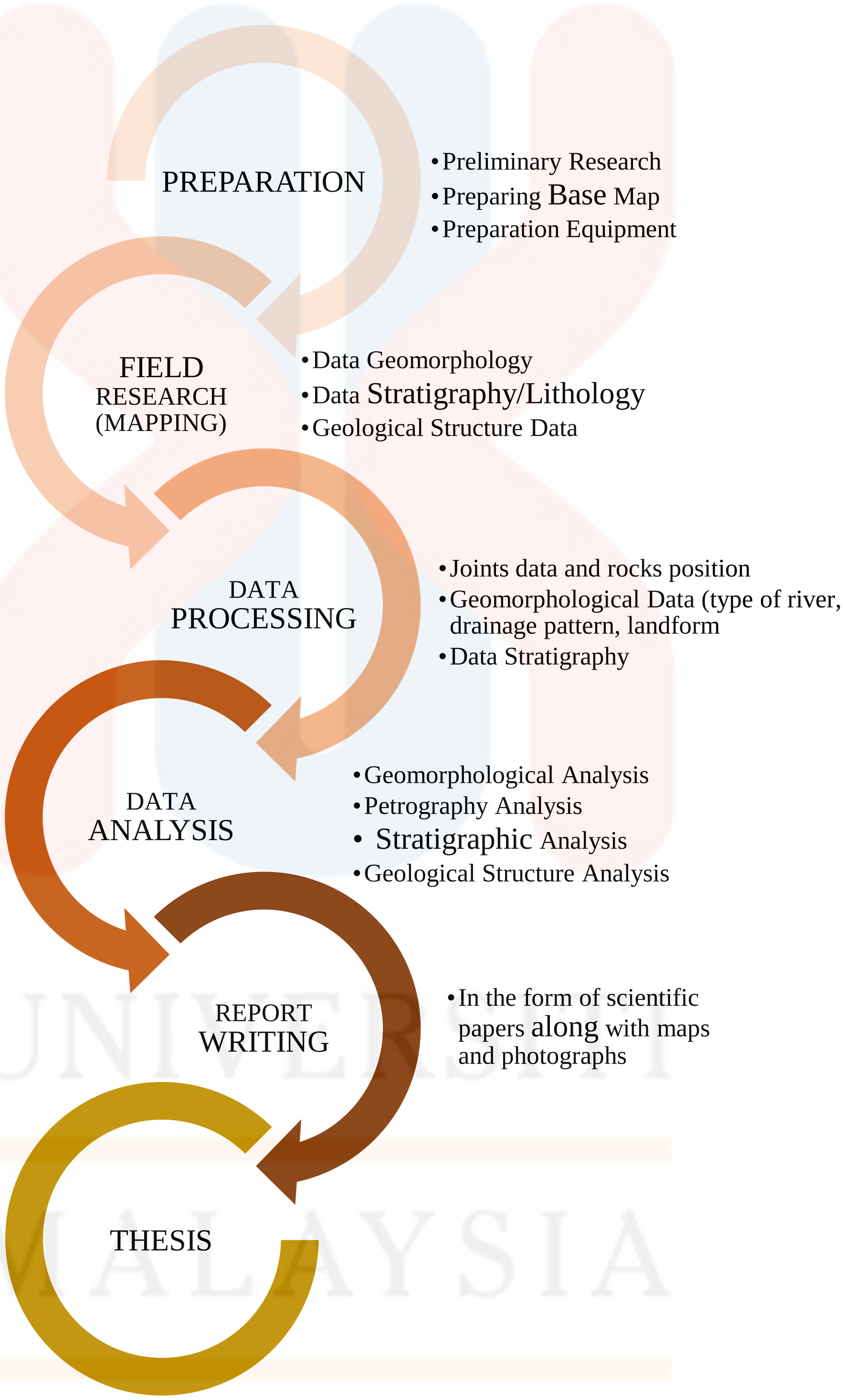


Figure 3.1 Flow chart method and the research phase.

3.1 Materials

For geological mapping purpose, a few equipment that indicates the parameters of the study will be used as seen in Figure 3.2. The required equipment such as a geological hammer, Global Positioning System (GPS), compass, sample bags for rock sampling, digital camera for the photograph, clipboard, pencils and eraser, measuring tape and polarizing microscope. For digitizing the map of the study area, the GIS software used are ArcGIS v.10.2 ESRI Company.

Figure 3.2 Equipment that indicates geological mapping purposed.

3.2 Methodology

3.2.1 Preparation Phase

a. Preliminary Research

The first method used was preliminary researches. Preliminary research was the initial process of gathering information about anything that related to the title and the study area. At this stage, a process of finalizing the thesis topic by revising previous works, journals and related published were carried out. Library research (geomorphology, structural geology, stratigraphy and petrology), studying previous researchers literature (regional geology of research area) that is intended to gather information about the condition of the study area.

The preliminary study can be considered as the preparation and collection of data before run the project and site visiting. This study is important to gain information and knowledge about geology and petrology of metamorphic rocks and its surroundings from secondary resource and understand the study area for the proper site visit. In addition, through this preliminary research, the early information about lithology and topography area can be used as references.

b. Preparing Base Map and Equipment

This stage included the preparing of the base map for plotting data in the field. Geographically research area located at coordinates 4^o 27’0” – 4^o 29’30” South latitude and 119^{o}41’0” – 119^o 43’ 0” East longitude which located in the Sheet Pangkajene and Watampone western part of Sulawesi. This map was enlarged to a scale 1:25000 to be used as a base map. The equipment preparation stage includes the preparation of tools such as a geological hammer, Global Positioning System

(GPS), compass, sample bags for rock sampling, digital camera for the photograph, clipboard, pencils and eraser and measuring tape were used in the field research and data collection.

3.2.2 Field Research (Mapping)

Geological mapping was the process of observing and recording geological features in the field. Geologic mapping is done to proceed to the next steps in order to provide more understanding about the area. Geological mapping was conducted according to the base map. In geological mapping, there are several mapping methods which are traversing, mapping in a poorly exposed region and the following contact. Traversing is important in controlling the movement progress across the country. Traversing method is a combination of usage of both compasses and Global Positioning System (GPS) to note the checkpoint in the study area. Whilst, the compass is used to record the orientation (dip and strike) of the structure such as the orientation of the foliation and joint in the each of the locality in the study area.

Technically, at any observation station, geological features were collected and recorded such as outcrop condition which included the dimensions, contacts and direction of the rocks. The rock observation of physical conditions can be observed directly in the field, taking rock samples for laboratory analysis and observations of geomorphology.

3.2.3 Data Processing

a. Sampling

Rocks are collected from the site for analysis of petrographic purpose. The samples are important to determine the lithology of the study area. So, fresh sample was taken to proceed with a thin section because a weathered sample had changed their chemical composition and will provide an inaccurate result. The sample was taken by using the geological hammer. All the sample were kept in sampling bags and labeled with location coordinate to avoid any mistake while conducting the samples.

b. Laboratory work

After finishing the field studies, the sample is taken and doing laboratory analysis which is petrography analysis. The petrographic analysis is done when the rock sample was observed by using hand specimen and analyzed thin section under petrographic microscopic. The texture of a rock described by hand specimen and texture of mineral was described by polarized microscope.

Laboratory analysis was needed to identify a type of rocks from the thin section by using the petrographic microscope, also known as the polarizing microscope. The preparation of thin section as shown in Figure 3.3. The thin sections observed are analyses and interpretation will be made to determine the type of lithology found in the study area.

STEP 1
- A chip from the rock sample is cut by rock cutting machine.

STEP 2
- The chip is mounted on a grinder to have a smooth surface on one side of the chip.

STEP 3
- The chip is lapped on a piece of glass with help of Silicon Carbide Powders. This is done to smoothen the surface that has been ground before.

STEP 4
- After the surface has been polished, it is mounted onto a glass slide using Canada Balsam on a hot plate set at about 120C.

STEP 5
- The rock chip is trimming down to get a thin rock slide using trimming machine.

STEP 6
- The grinding process is conducted again in order to minimize the thickness until a very thin slide can be obtained.

STEP 7
- The sample is lapped until it is only 50 µm thick, so that with a final polish its thickness is between 20 - 30 µm thick.

STEP 8
- The last stage is cemented a cover glass on top with some material used as before. No air bubbles remain trapped in between cover glass and glass slide is ensured.

Figure 2.3 The preparation of thin section.

c. Studio Lab

In studio lab, ArcGIS 10.2 software was used to create map, update information and digitized data of the study area. Besides that, interpretation of geological structure data, such as joints was analysed by using Rose Diagram to identify its main force direction in the research area.

3.2.4 Data Analysis

Based on the preliminary study, field studies, laboratory work and data processing, the data gain can be combined to interpret the characteristic and lithology in the study area. The naming of the rock can be confirmed through this section analysis and the map will be updated with much useful information. Other that that, field data is subsequently processed for further analysis and interpretation includes aspects of geomorphology, stratigraphy and structural geology.

3.2.5 Report Writing

Data had been collected, processing and analyzed in detail and interpreted and made inferences about the geological conditions of the study area. At this stage also conducted and produced maps of geology, geomorphology, station and drainage pattern type. The final data was processing to produce the completed final year report.

CHAPTER 4

GENERAL GEOLOGY

4.1 Geomorphology

In this chapter will be discussing the geomorphology, petrology, stratigraphy, structural geology, and historical geology of the study area. Discussion of the geomorphological research areas includes clarification of the division of geomorphology, the description of the rivers in the study area, including the type of river, river classification and genetic type which in turn will produce a conclusion about the stages of research areas.

According to (Van Zuidam, 1985) he defined geomorphology as the study of descriptive geomorphological landforms and processes and find relationships between landforms and processes in spatial arrangement. The landscape has a varied and can be classified based on certain factors such as process, study area, type of lithology as well as the influence of geological structure or tectonic (Van Zuidam, 1985). There are parameter used to identify geomorphological landform based on elevation as shown in Table 4.1.

Table 4.1 Classification for Relief Elevation

Relief / Landform	Elevation (meters)
(1)	(2)
Lowland	<5
Low-lying plain	5 – 100
Low Hill	100 – 200
Hill	200 – 500
High Hill	500 – 1500
Mountain	1500 – 3000
High Mountain	>3000

Source : Van Zuidam (1985)

According to the state of the landscape, Desa Anabanua can be divided into 2 units of morphology which is medium relief morphology unit which is included Low Hill and Hill landform while low relief morphology unit was Low-lying Plain landform. The classification of landform of the study area as shown in Figure 4.1.

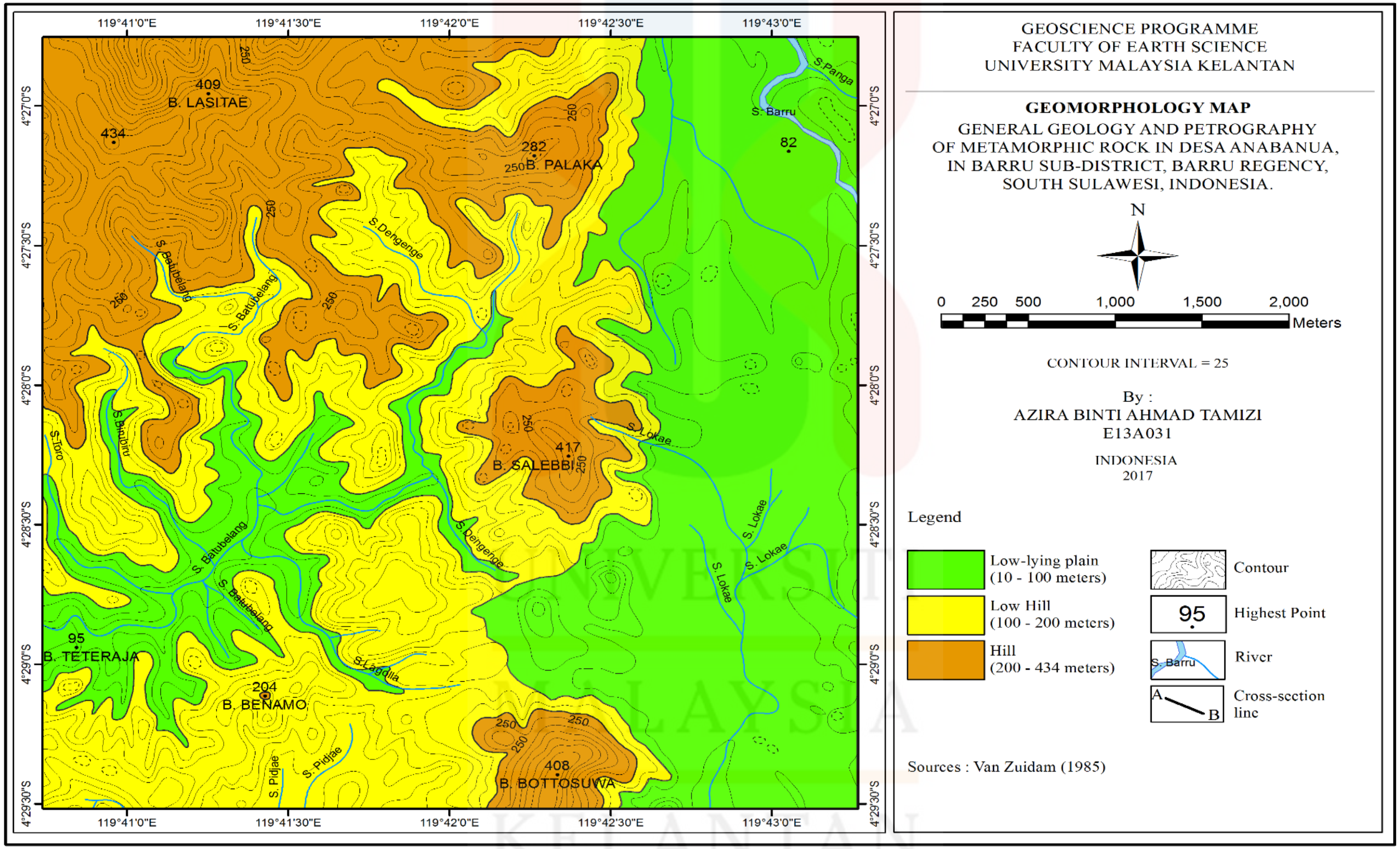


Figure 4.1 Relief morphology unit in the study area.

Medium relief morphology unit which composed of the Hill and Low Hill landform has properties of topographic relief from moderate to high and topographic texture from moderate to rough and slope slightly sloping to moderately steep. The top of the hills are Bulu Lasitae (434 m), Bulu Salebbi (417 m), Bulu Bottosuwa (408 m), Bulu Palakka (282 m) and Bulu Benamo (204 m). Rock constituent composed of ultramafic, sedimentary and metamorphic rock. Distribution of metamorphic rocks dominate the western region and in the eastern region is dominated by sedimentary rocks. The Hill landform was at the elevation from 200 to 460 meters while Low Hill landform from 200 to 100 meters. Figure 4.2 shows the medium relief morphology unit.

Figure 4.2 View of medium relief morphology unit in the study area.

Low relief morphology unit or Low-lying plain landform has the properties of low topographic relief and smooth topographic texture. Rock constituent composed of sedimentary rocks such as limestone and claystone. Distribution of these rocks dominate the eastern part of the study area which is a mostly paddy field and residential area. The area was at the elevation from 5 to 100 meters from sea level. Figure 4.3 shows the low-lying plain landform in the study area.

Figure 4.3 Low-lying plain landform in the study area.

4.1.1 Weathering

Geomorphology analysis of the research area was the analysis of the natural formation characteristics that resulted of processes that change the shape of the earth due to the process of weathering, erosion, and sedimentation material movement. There are three types of weathering that occurring in the research area such as physical, chemical and biological weathering.

a. Physical Weathering

Physical weathering was characterized by fracturing the rock, constituent of the research area which was resulted the rock physically break apart into a smaller pieces. The result of weathering can be seen in the field in the form of loose and small fragments which due to effects of dynamic temperature on the rocks (thermal expansion).

Thermal expansion represent the effect of heating and cooling of the rock. Over the time, the rock was heated and cooled frequently when exposed to the mild climate. During the day, the rock was exposed to sunlight, continuously heating the rock and make it to expand. As the temperature drop at night, the rock commence to cool and contract. Thus, the repeated heating and cooling stress on the rock can cause it to formed fracture and break apart. This happens usually in the place where there are a few soil and plant grow such as in hilly area as seen in Figure 4.4 below.

Figure 4.4 Physical Weathering at the Station 40, Bulu Lasitae.

b. Chemical Weathering

These physical changes did not result in a change of the rock composition. While chemical weathering characterized by a colour change of rock, which originally red coloured to reddish brown. It indicates that the rocks have been changes in the chemical composition which eventually became soil forming materials. These chemical processes need water and occur more rapidly at higher temperature such as warm and damp climates. Chemical weathering, especially hydrolysis and oxidation was the first stage in the production of soils and it was developed in place (in situ) from the underlying rock.

The level of weathering in the research area (medium relief), which can be seen from the thickness of the soil are around 0.5 – 1 meters (Figure 4.5). Soil type is generally a kind of residual soil that was formed by the weathering of the bedrock immediately beneath it. It is made up of rock particles weathered from the bedrock below and therefore chemically similar to that bedrock.

Figure 4.5 Peridotite soils at Station 43, Bulu Lasitae.

Besides that, clay (kaoline) also occurs in plenty in soils that have formed from the chemical weatherinf of rocks in hot and moist climates. It was soft, white, earthy, yellow in colour and originated by chemical weathering of aluminium silicate minerals such as feldspar as shown in Figure 4.6.

This clay (kaolinite) deposits was classified as blanket deposits which is it was derived from the areas of igneous rock like basalt and peridotite. Blanket deposit also known as deposit that was repeatedly intercalated between rocks of contrast origin and lithological characteristic in which they are nature of contact deposits.

Figure 4.6 Clay (kaolinite) was founded at the Station 34.

c. Biological Weathering

Biological weatering was not really a process, but living organism can cause both physical and chemical weathering to occur. The bushes and trees growing from cracks or fracture in the rock. As they expand bigger, the roots make a crack wider and deeper. The growing roots will produced a weak acid that may dissolve the rock, make a little hole for the rootlet to cultivate and gain nutrients (food). At last, pieces of rocks are fall away. This is generally known as biological weathering (Figure 4.7).

Figure 4.7 Biological weathering of limestone at Station 1, Bulu Salebbi.

4.1.2 Erosion

Based on American Geological Institute's Dictionary of Geological Terms in Van Zuidam (1985), erosion is the process by which the surface of the Earth is broken or removed and transported from several parts of the earth's surface then transport it away to another location caused by natural elements such as wind and water flow. Evidence that can be seen from this process in the research area found the existence of gully erosion. Gully erosion occurs when is channelled across unprotected land and washed away the soil along the drainage lines as seen in Figure 4.8. In the research area, this kind of gully erosion occurred in lithology that has a low level of resistance and weathered.

Figure 4.8 Gully erosion at the Station 37, Bulu Palaka.

Mass wasting is a part of an important part of the erosional process. According to Thornburry (1969), mass wasting also known as slope movement or mass movement is the down slope movement of Regolith (loose uncemented mixture of soil and rock particles that covers the Earth's surface) typically as a mass, largely under the force of gravity without the aid of a transporting medium such as ice, water or wind but still water plays a key role. In addition, denudasional process that occurred in the study area was characterized by the presence of mass movement in the form of debris slides (Figure 4.9). Debris slide differs from slumping in that the movement does not exhibit backward rotation. Instead, there is a sliding or rolling motion and the amount of water is usually small. Debris on a slope collapses and suddenly or with a gradual acceleration was transported down the slope.

Figure 4.9 The appearance of the ground motion in the form of debris slide, where the materials are mixture of soil material and rock fragments. Station 52, Bulu Bottosowa.

4.1.3 Spring

At station 5, spring was found at this station. Spring was developed when the pressure in an aquifer causes portion of the water to stream out at the surface. Spring often happens at low elevations and at the bottom of slopes. This spring has been just tiny leak of water permeate from the ground. Based on the observation, this spring was classified as type of seepage spring, which means groundwater seeping out to the surface of rocks. It slowly let the water seep out through crack and loose schist rock as seen in Figure 4.10.

Figure 4.10 Seepage spring from schist rock at Station 5, Salo Dengenge.

4.1.4 Drainage Pattern

In geomorphology, drainage systems or river streams are the pattern developed by the streams, lakes and rivers in the particular drainage basin where water discharge naturally to develop a pattern and a certain alley on the surface (Thornbury, 1969). He point out of flowing water is a considerable geomorphic agent in most environments, and a dominant one in fluvial environments. It carves many erosional landforms, including rills and gullies, alluvial channels and bedrock channels. Based on the water content in the body of the river, the type of river can be divided into several types such as:

- Normal River (permanent): A water volume of the river throughout the year is always normal.
- Periodic River: A river of water content depending on the season, usually located in arid climates where evaporate is greater than precipitation.

- Episodic River: Rarely occurring rivers formed from run-off channels in very dry regions.
- Exotic River: These are rivers that flow through arid (desert) regions.

Based on field observation, there is one type of river which is a normal river (permanent) river. Salo Lagolla, Batubelang, Dengenge, Lokae, Toro, Birubiru and Pidjae in the study area ware classified as a permanent river. According to Bridge J., (2003), permanent rivers was fed by groundwater only in the rainy season when the water table is higher than the level of the riverbed. The main sources of water for this research area is groundwater and the water table was located above the stream bed for most of the year. Surface water run off contributes to the stream flow as well as seen in Figure 4.11.

Figure 4.11 Type of periodic river in Salo Dengenge.

Thornbury (1969) states that the rivers form networks that may be described by several geometrical and topological properties. The drainage system is an amalgamation of several individual streams that are interconnected to form a pattern in the spatial unity. The development of river flow patterns existing in the study area is controlled by the following factors such as slope, structural control, and geomorphology of a basin river flow patterns, vegetation and climatic conditions.

Based on field observation, there was two type of drainage pattern of Salo Lagolla, Batubelang, Dengenge which is dendritic drainage patterns while Salo Lokae is parallel drainage pattern. Dendritic drainage pattern is similar to a branching tree and hence the name. In a dendritic system, there are most contributing streams which are then jointed together into the branches of the main river. It is evolve through river channel and follows the slope of the terrain. This type of flow pattern developed in the research area was dominant compared to parallel pattern. Existence of major fault that cuts across an area of steeply folded bedrock was usually act as indicator of parallel drainage pattern.

The flow pattern of dendritic occupies about 80% of the research area that extends relative from the north to the west, which is included area of Bulu Salebbi, Bulu Palaka, Bulu Lasitae, Bulu Bottosowa, Bulu Benamo and Bulu Teteraja. Figure 4.12 shows the drainage pattern map of the study area.

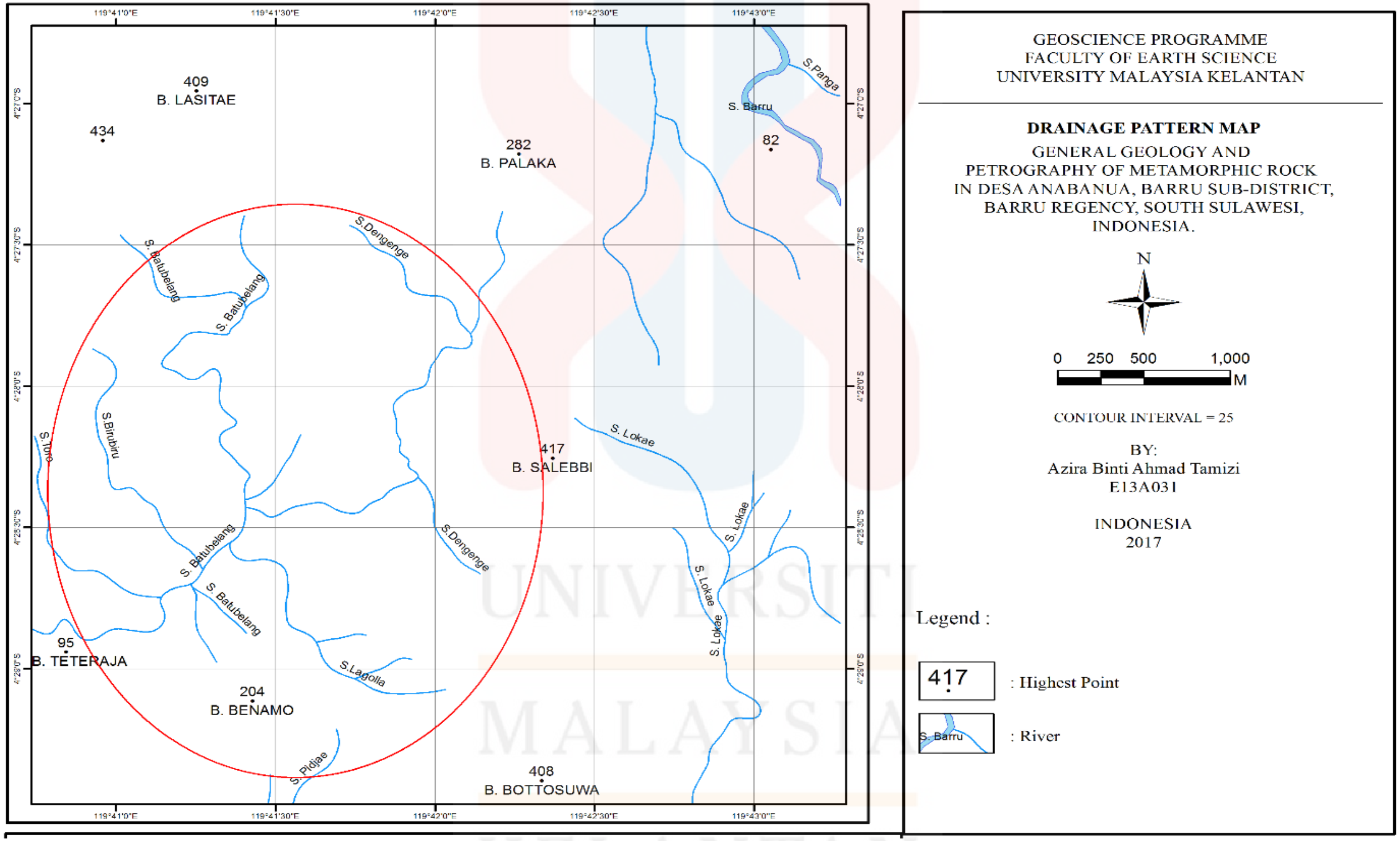


Figure 4.12 The drainage pattern map of the study area.

4.2 Stratigraphy

In the study area, there are three types of lithology which are igneous rocks, metamorphic rocks and sedimentary rocks. The reference used in petrographic analysis of igneous rock and metamorphic rock was based on (Travis R. B., 1955). The references to naming types of sedimentary rocks by referencing to (Dunham, 1962).

Generally, lithology of the study area consisted of igneous rocks, metamorphic rocks and sedimentary rocks. It can be seen from the different lithological characteristics that appear in the field and contact rocks where the contact limit can be placed on a real field or if changes were not clear then the limit of an area estimated.

Based on the lithology of this study area with scale 1 : 25000, Unit lithology in the research area can be divided into three (3) main unit as seen in the Geological Map (Figure 4.13) and distribution of rocks in this research area as shown in Station Map (Figure 4.14). The stratigraphic is based on lithostratigraphic units and will be presented sequentially from the oldest to youngest. The stratigraphic coloum was presented in Figure 4.15. The discussion included nomenclature, distribution, thickness, type and characteristic of the rocks (field, specimen and petrography), age, depositional environment and the stratigraphic relationship with the other units.

- Schist Unit
- Ultramafic Unit
- Limestone Unit
- Melange Unit

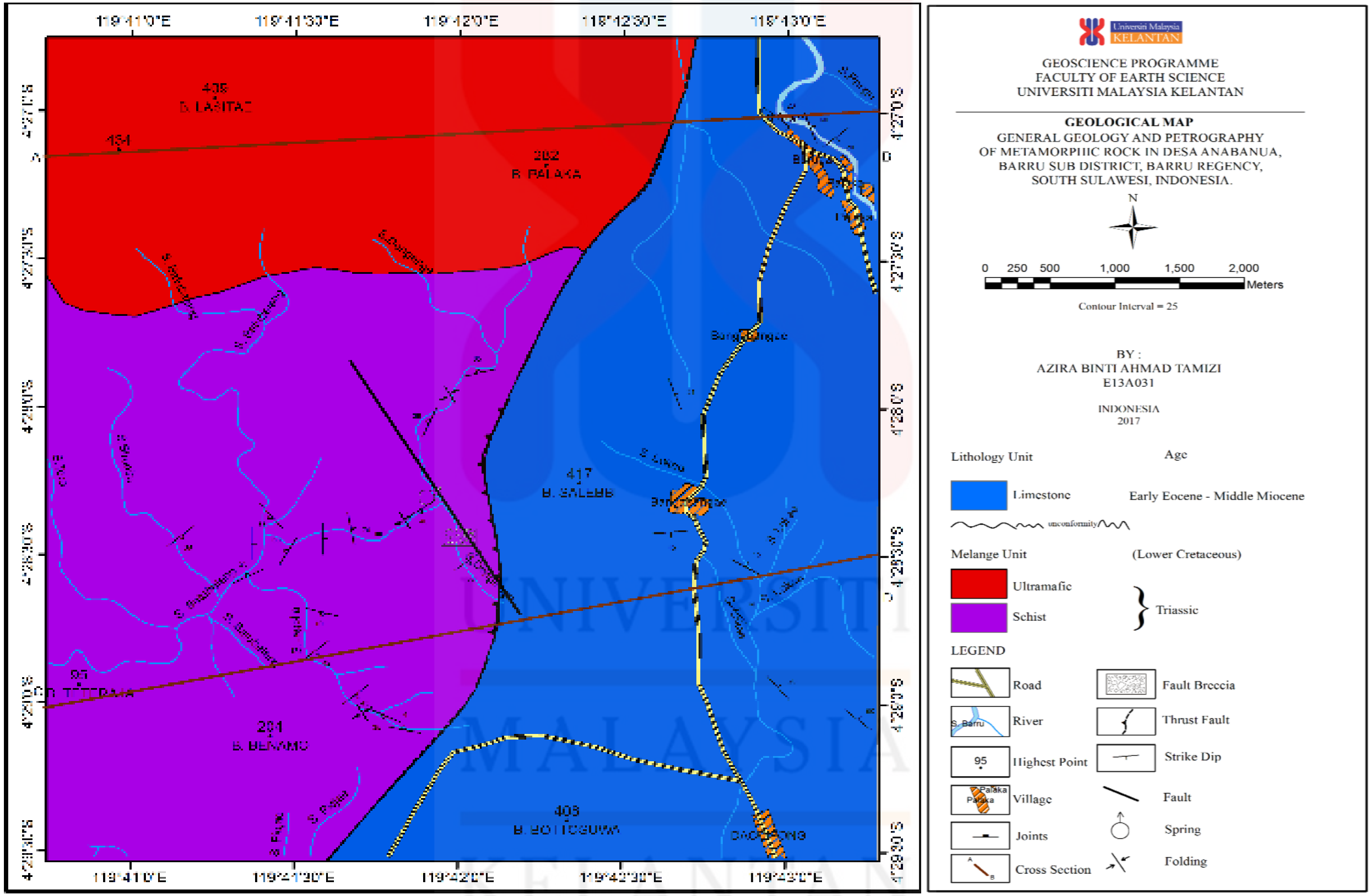


Figure 4.13 Geological Map of the study area.

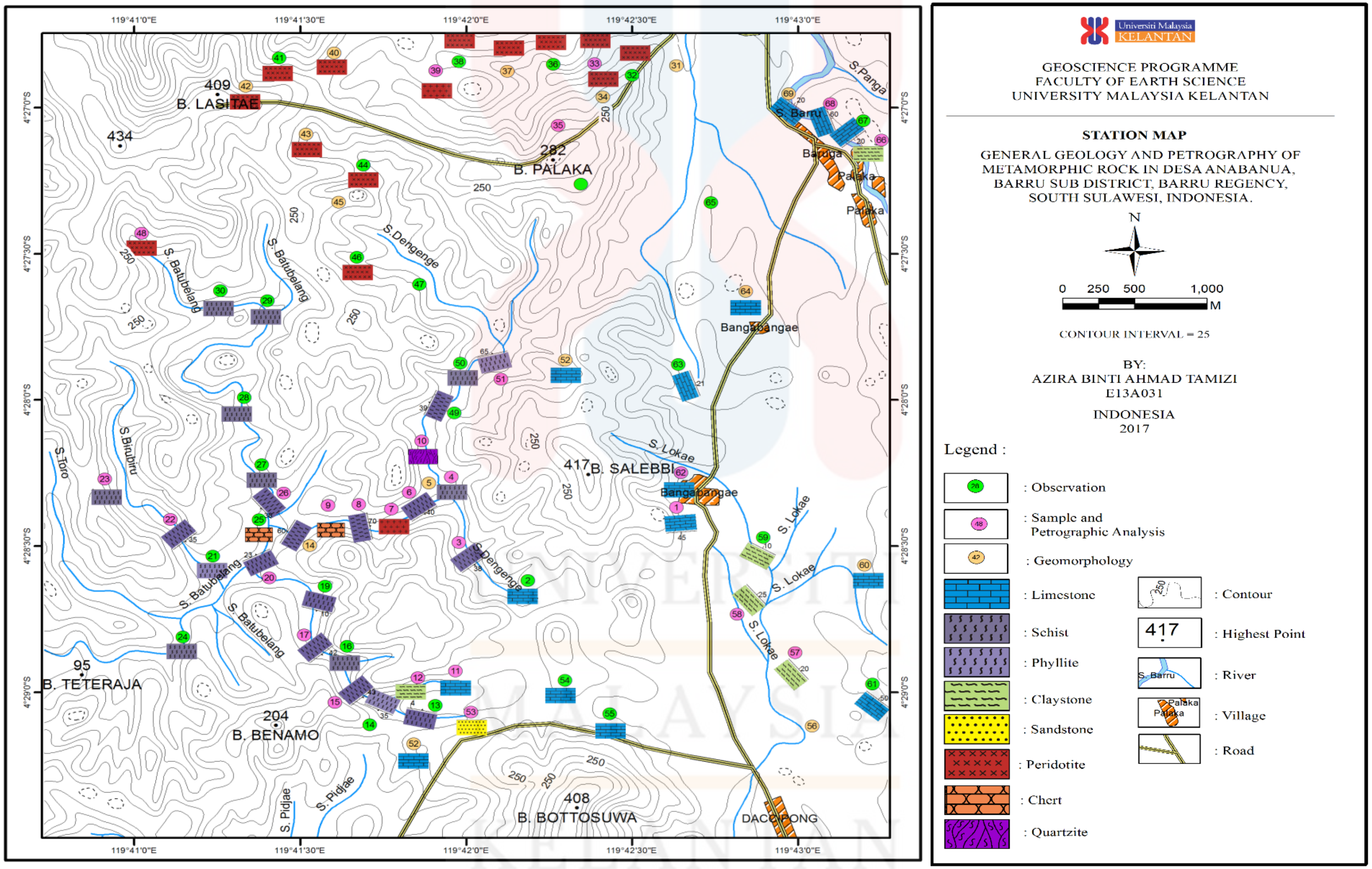


Figure 4.14 Station Map of the study area.

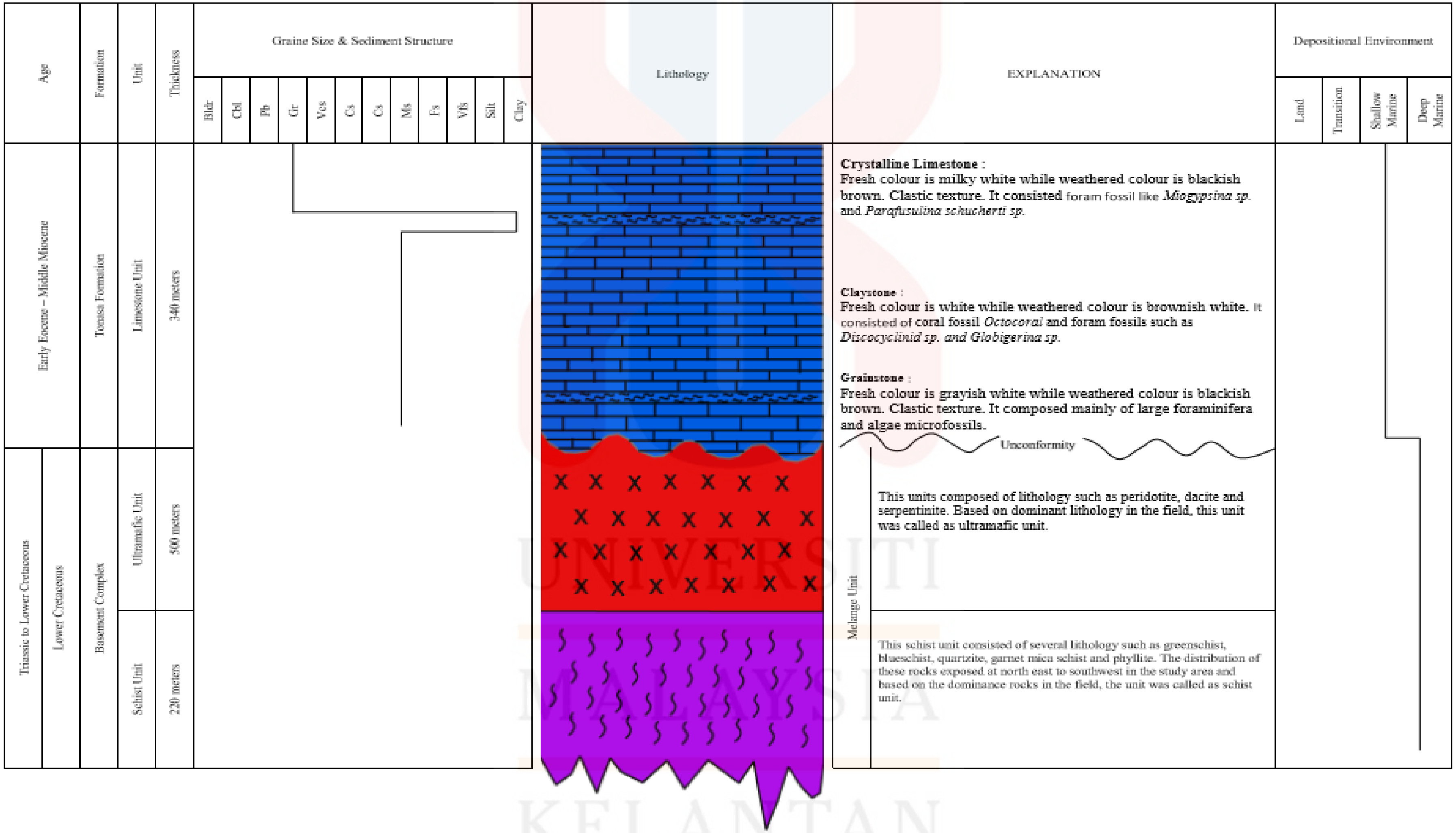


Figure 4.15 Lithostratigraphic coloum of the study area.

4.2.1 Schist Unit

Schist was the dominance rock in schist unit. The unit consists various type of schist such as garnet mica schist, greenschist, blueschist and other type metamorphic rocks like quartzite and phyllite.

a. Nomenclature

Nomenclature of these units was based on the physical characteristic of lithology. The naming of this rock unit was divided into two ways which are naming the rock in megascopic and microscopic. Megascopic observation was determined directly in the physical and mineralogical composition by referring (Travis R. B., 1955) as seen in Table 4.2 below. Meanwhile, for microscopic, the petrographic analysis was used for the observation of optical properties of minerals and specific mineral composition and then determined the name of rock by using the classification of metamorphic rocks by (Travis R. B., 1955). Based on field observation, this schist unit consisted of several lithology such as greenschist, blueschist, quartzite, garnet mica schist, schist and phyllite. The distribution of these rocks exposed at northeast to southwest in the area of the study area and based on the dominance rocks in the field, the unit was called as schist unit.

Table 4.2 Classification of Metamorphic Rocks

COLOUR	CHIEF MINERALS	ACCESSORY MINERALS	NONDIRECTIONAL STRUCTURE (MASSIVE OR GRANULOSE)		DIRECTIONAL STRUCTURE (LINEATED OR FOLIATED)					
			CONTACT METAMORPHISM		MECHANICAL METAMORPHISM	REGIONAL METAMORPHISM HIGHLY FOLIATED ↔ LESS FOLIATED				PLUTONIC METAMORPHISM
			FINE	FINE TO COURSE	CATACLASTIC	SLATY	PHYLLITIC	SCHISTOSE	GNEISSOSE	MIGMATITIC
						APHANITIC	FINE	FINE TO COURSE		
LIGHTER ↕ DARKER	FELDSPAR	ACTINOLITE ALBITE ANDALUSITE ANTHOPHYLLITE BIOTITE CHIASTOLITE CHLORITE CHLORITIOD CORDIERRITE DIOPSIDE ENSTATITE EPIDOTE GARNET GLAUCOPHANE GRAPHITE KYANITE MUSCOVITE OLIVINE PYROPHYLLITE PHLOGOPITE SCAPOLITE SERICITE SERPENTINE SILLIMANITE STAUROLITE TOURMOLITE WOLLASTONITE	HORNFELS	METAQUARTZITE	These rock are formed by crushing with only minor recrystallization CATACLASITE Nondirectional MYLONITE Foliated, aphanitic PHYLLONITE Foliated, fine grain, resembles a phyllite FLASER GRANITE, FLASER DIORITE, FLASER CONGLOMERATE Flaser structure, lenses and layers of original or relatively unaltered granular minerals surrounded by matrix of highly sheared and crushed material. AUGEN GNEISS	SLATE	PHYLLITE	SCHIST (AMPHIBOLITE) GNEISSIC SCHIST	GNEISS AUGEN GNEISS SCHISTOSE GNEISS	These rocks have a gneissose, streaked or irregular structure produced by intimate mixing of metamorphic and magmatic materials. When they can be recognized as 'mixed rock", they are called migmatite gneiss. They may originated by injection (injection migmatite, injection gneiss, or lit-par-lit gneiss) or by differential fusion. Many so called migmatites probably originate by partial granitization or by metamorphic differentiation. But at great depth these processes apparently do not differ substantially from the igneous processes forming migmatite, so the products are usually indistinguishable. Migmatites are named by prefixing the rock name of the granitic material to the appropriate root as 'granite migmatite', 'nonzonite injection migmatite', etc.
	QUARTZ									
	MICA									
	HORNBLENDE			AMPHIBOLE						
	CHLORITE									
	ACTINOLITE									
	TREMOLITE									
LIGHTER ↕ DARKER	TALC			SOAPSTONE						
	CALCITE AND/OR DOLOMITE			MARBLE						
	CALC-SILICATES			SKARN						
	SERPENTINE			SERPENTINITE				SERPENTINITE		

Source: Modified after R.B. Travis, 1955.

b. Distribution and Thickness

The distribution of this unit almost dominated the research area by occupying approximately 40 percent (%) of the research which is a round of 8 kilometers square (km^2). The distribution of these rocks exposed at northwest to southwest of the study area and the lithology constituent unit was exposed very well in the area of Salo Dengenge, Salo Batubelang, Salo Lagolla, Salo Birubiru, Bulu Benamo and Bulu Teteraja. The thickness of this rock unit based on the calculation of the geological cross section C – D is 220 meters (m) (View Geological Map).

c. Type and Lithology Characteristic

i. Schist

Schist was the dominance rocks in Schist Unit. The distribution of schist was located at Station 8, 13, 17, 18, 19, 20, 25, 26, 27, 28, 29, 30, 47, 49 and 50. This lithology exposed very well in the area of Salo Dengenge, Salo Lagolla and Salo Batubelang.

Based on field observation Station 8 (Figure 4.15) with physical characteristic such as fresh colour was light gray while weathered colour was gray. Type of structure is schistose with strike dip reading is N52°E/38°. Grain size was fine to medium grained. Dominant minerals composed of quartz, Muscovite, garnet.

Based on petrology description, with a reference sample number D1 S10 001, absorption colour is yellow, interference colour is grayish white, texture is lepidoblastic, shape is euhedral to anhedral, size of the minerals in between 0.05 to 3 mm and mineral composition composed of quartz (33%), muscovite (30%), chlorite (10%), garnet (7%) and opaque mineral (3%). **Name of rock: Quartz – Muscovite – Schist** (Travis R. B., 1955) (Figure 4.16).

Figure 4.15 The appearance of schist outcrops showing the foliation structure at Station 8, Salo Dengenge.

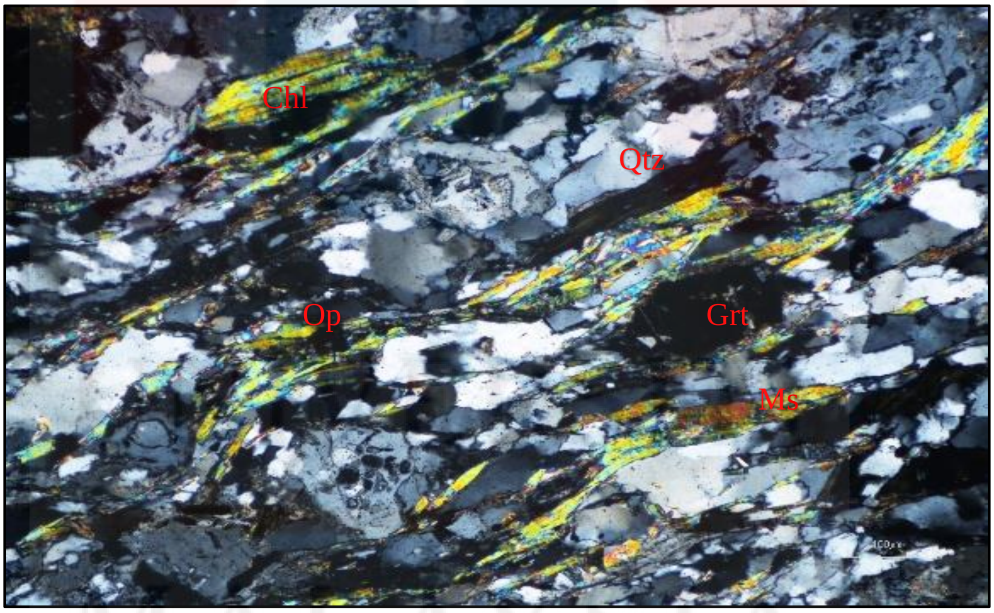


Figure 4.16 Microphotograph of Schist (D1 S10 001) with mineral composition of quartz (Qtz), muscovite (Ms), chlorite (Chl), garnet (Grt), opaque mineral (Op), XPL image, 40x magnification.

i. Garnet Mica Schist

The garnet mica schist was located at Station 3 with the outer surface was gray in colour, while the fresh inside part was light gray. Texture foliated and have fine to medium grained. This lithology exposed very well in the Salo Dengenge area. Based on field observation, with a reference sample number D1 S2 001, type of structure was foliated (Schistose) with strike dip reading is N52°E/38°. Dominant minerals composed of garnet, mica minerals (muscovite) and quartz (Figure 4.17).

Based on petrology description, absorption colour is colourless, interference colour is light brown, shape is subhedral to anhedral, size of the minerals in between 0.625 to 4 mm, size of the minerals in between 0.6 to 5 mm. Mineral composition composed of garnet (30%), muscovite (30%), quartz (25%) and opaque mineral (5%). **Name of rock: Garnet Mica Schist** (Travis R. B., 1955) (Figure 4.18).

Figure 4.17 The appearance of garnet mica schist outcrop at Station 3, Salo Dengenge.

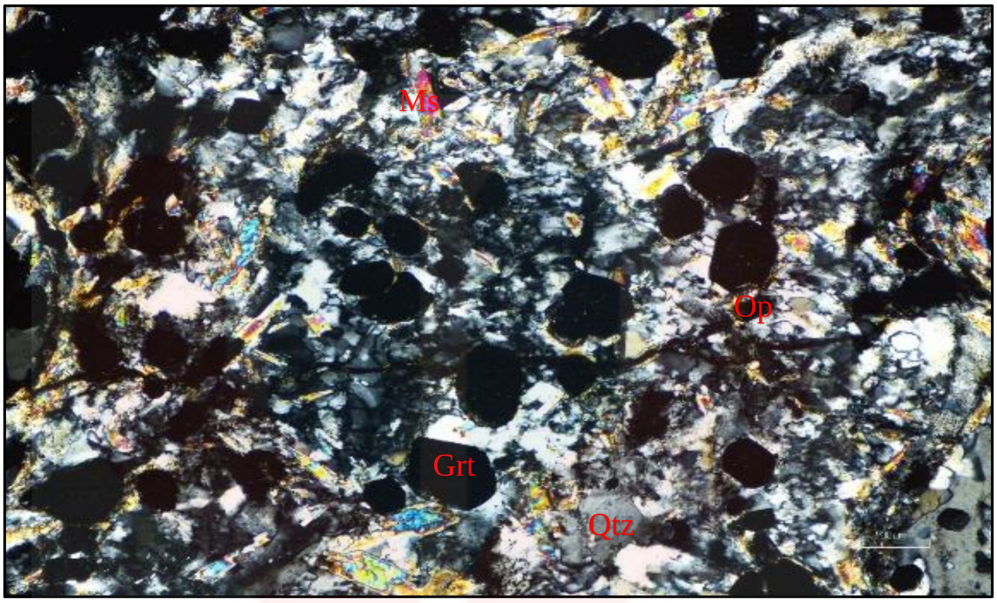


Figure 4.18 Microphotograph of garnet mica Schist (D1 S2 001) with mineral composition of garnet (Grt), muscovite (Ms), quartz (Qtz) and opaque minerals (Op). XPL image, 40x magnification.

ii. Greenschist

The distribution of greenschist was located at Station 22 and 24. This lithology exposed very well in the area of Salo Birubiru and Salo Batubelang. The outer surface was greenish black in colour, while the fresh inside part was greenish gray. Greenschist at station 22 as seen in Figure 4.19 was a fine to medium grained and foliated metamorphic rock. Greenschist has foliation resulting in mineral alignment, especially of chlorite and actinolite with strike dip reading is N50°E/35°. Dominant minerals composed of chlorite, actinolite, muscovite, quartz and sericite. Fresh sample was founded at Salo Birubiru.

Based on reference sample number is D2 S11 001, absorption colour is brownish, interference colour is brownish gray, texture is lepidoblastic, shape is subhedral to anhedral, size of the minerals in between 0.005 to 1.75 mm. Mineral composition consisted of chloride (50%), actinolite (20%), muscovite (10%), quartz (10%) and sericite (10%). The name comes from having an abundance of green minerals such as chloride and actinolite. **Name of rock: Chlorite Actinolite Schist**. (Travis, 1955) (Figure 4.20).

Figure 4.19 The appearance of garnet mica schist outcrop at Station 22, Salo Birubiru.

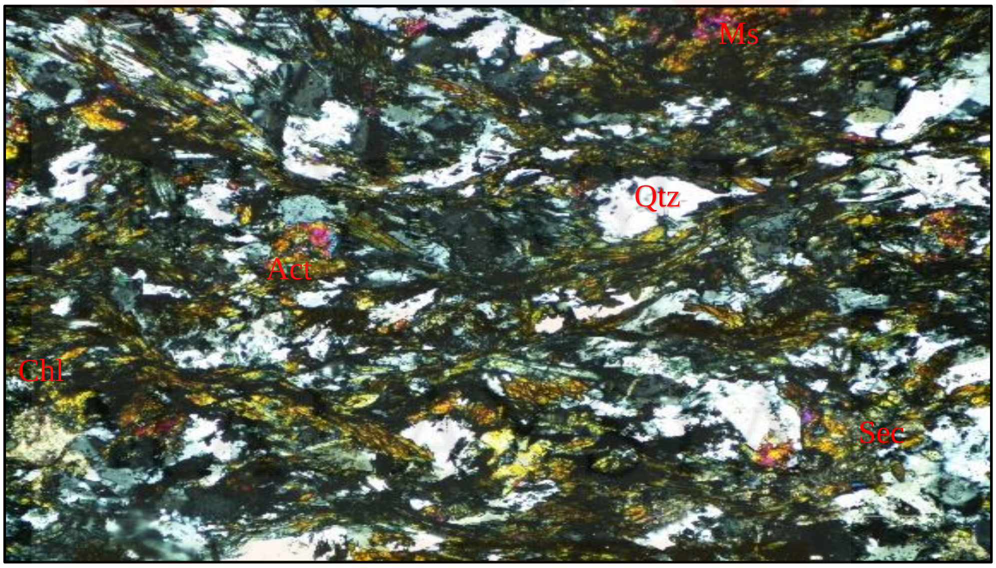


Figure 4.20 Microphotograph of greenschist (D2 S11, 001) with mineral composition of chlorine (Chl), actinolite (Act), muscovite (Ms), quartz (Qrt), and sericite (Sec). XPL image, 40x magnification.

iii. Blueschist

Blueschist was located at Station 23. This lithology exposed very well in the area of Salo Birubiru (Figure 4.21). The outer surface was dark grayish in colour, while the fresh inside part was grayish blue. Greenschist was a fine to medium grained, foliated and have schistose texture. The blue colour of the rock comes from the presence of the predominant minerals glaucophane. Strike dip reading for this foliation is N50°E/43°. Dominant minerals composed of glaucophane and chlorite.

Based on the petrology description with reference number of thin section D2 S12 001, absorption colour is brownish yellow, interference colour is brownish gray, shape is subhedral to anhedral, size of the minerals in between 0.025 to 7 mm. Mineral composition composed consisted of glaucophane (43%), chlorite (34%), muscovite (12%), garnet (7%) and opaque mineral (4%). **Name of rock: Glaucophane - Chlorite Schist** (Travis R. B., 1955) (Figure 4.22).

Figure 4.21 The appearance of blueschist outcrops showing the foliation structure at Station 23, Salo Birubiru.

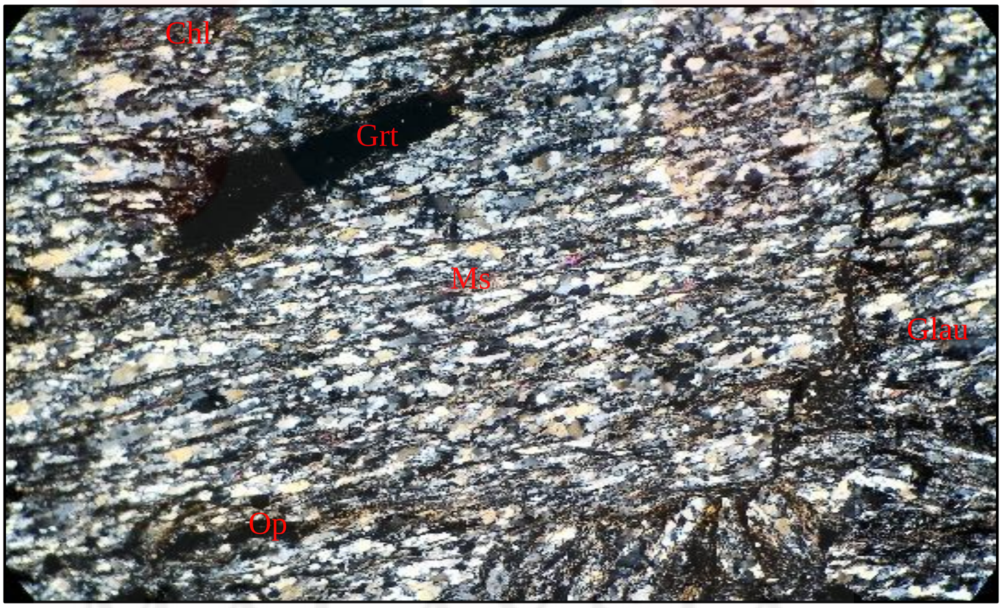


Figure 4.22 Microphotograph of blueschist (D2 S12 001) with mineral composition of glaucophane (Glau), chlorite (Chl), muscovite (Ms), garnet (Grt) and mineral opaque (Op). XPL image, 40x magnification.

iv. Quartzite

Based on field observation with reference sample number is D1 S8 001 at Station 10, the lithology is quartzite. Fresh colour is white, while weathered colour is dull white. Quartzite is a hard and non foliated metamorphic rock. Grain size is medium grained and can see interlocking quartz crystals with the naked eye. Dominant minerals are quartz. This outcrop has been found at Salo Dengenge (Figure 4.23).

Based on petrology description, absorption colour is colourless, interference colour is blackish gray, texture is granular, size of materials in between 0.0075 to 6.25 mm.. Size of minerals in between 0.007 to 6 mm. It generally comprises greater than 90% quartz and quartz crystal is interlocking network. Quartzite consisted of quartz, mostly 98% and opaque mineral 2%. **Name of rock: Quartzite** (Travis R. B., 1955) (Figure 4.24).

Figure 4.23 The appearance of quartzite outcrops at Station 10, Salo Dengenge.

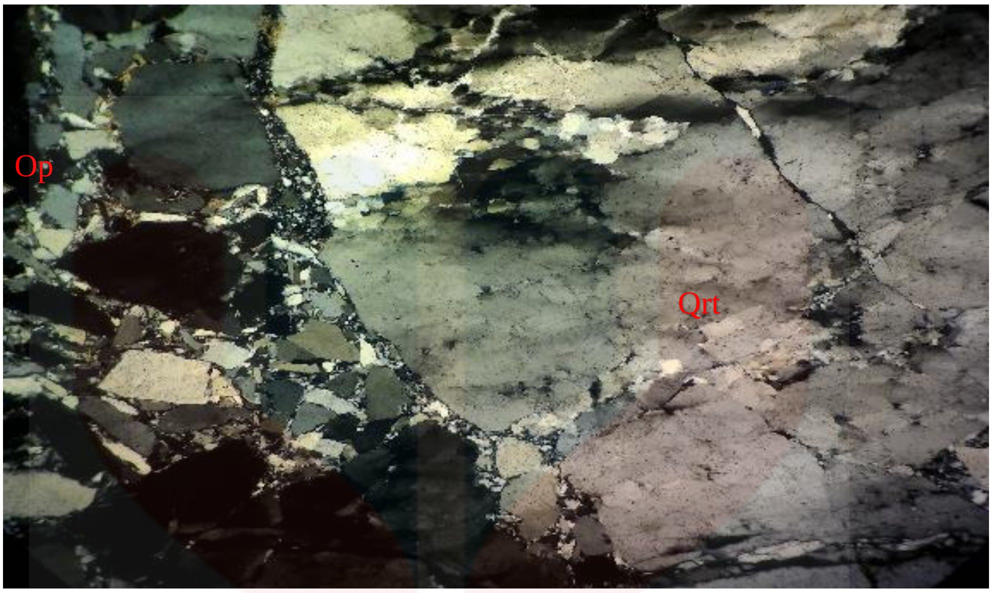


Figure 4.24 Microphotograph of quartzite (D1 S8 001) with mineral composition of quartz (Qrt) and mineral opaque (Op). XPL image, 40x magnification.

v. Phyllite

The distribution of phyllite was located at Station 6, 14 and 51. This lithology exposed very well in the area of Salo Dengenge and Salo Lagolla. Based on field observation at Station 14, fresh colour is grayish while weathered colour is blackish gray. Phyllite is foliated metamorphic rock. Strike dip reading of the foliation is N256°/65°. Grain size is medium grained. Dominant minerals is an abundance of aluminous minerals like clay minerals, micas and garnet. This fresh outcrop has been found at Salo Lagolla (Figure 4.25).

Petrology description with reference sample number is D2 S8 001, absorption colour is brownish, interference colour is gray, shape is subhedral to anhedral, size of the minerals in between 0.5 to 7.2 mm. Mineral composition composed of clay minerals (30%), muscovite (30%), quartz (20%), garnet (10%) and biotite (10%). **Name of rock: Phyllite** (Travis, 1955) (Figure 4.26).

Figure 4.25 The appearance of phyllite outcrops at Station 14, Salo Lagolla.

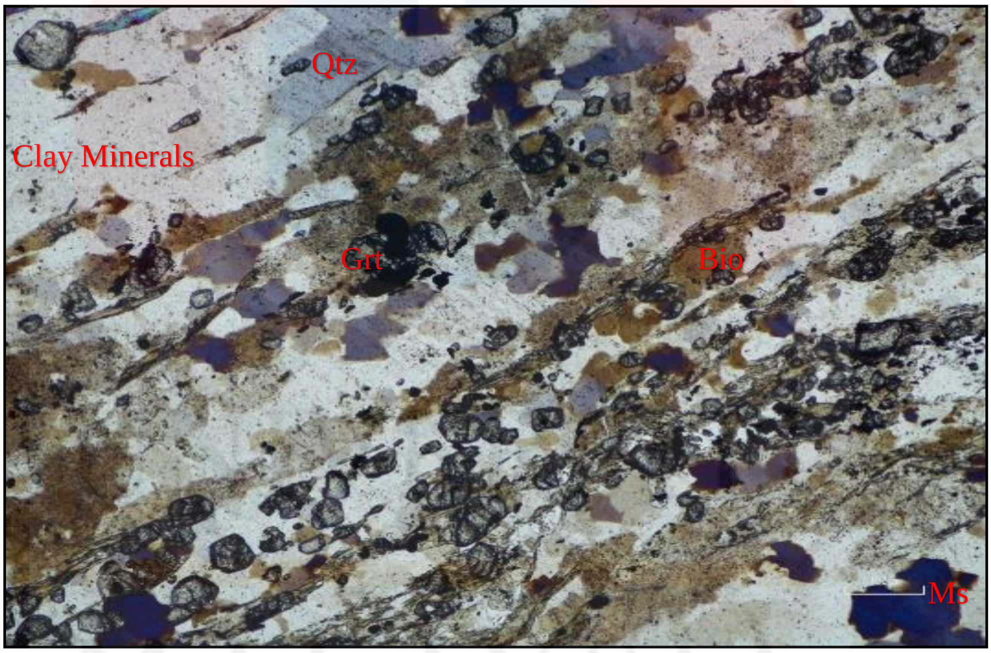


Figure 4.26 Microphotograph of phyllite (D2 S8 001) with mineral composition of clay minerals, muscovite (Ms), garnet (Grt), biotite (Bio) and quartz (Qtz). XPL image, 40x magnification.

d. Depositional Environment and Age of Rock Unit

Depositional environment of schist unit was determined based on texture, structure and composition of the minerals that were found. Petrographic observation shows the main schist unit composed of silica minerals such as chlorite, mica, actinolite, glaucophane and garnet. The structure of rocks was generally have foliation. These rock units formed by regional metamorphism of moderate to high levels with the minerals texture which is lepidoblastic, nematoblastic and general foliation structure (schistose). Based on these indication, it can be interpreted that the depositional deposition of this unit is on the marine environment associated with a subduction zone, where the temperature and pressure ware working together. The age of schist unit was Triassic – Lower Cretaceous (Sukamto R., 1982).

e. Stratigraphic Relationship

Stratigraphic relationship between the schist unit with lithology unit on it was tectonic contact. This is because age between the schist unit with lithology unit on it is aligned, where the age of schist unit is Triassic – Lower Cretaceous (Hamilton, 1979).

4.2.2 Ultramafic Unit

a. Nomenclature

Naming of these unit is based on the appearance of the physical characteristics of lithology. In naming lithological unit's members, there are divided into two ways either megascope or microscope. Megascope observations was determined directly based on physical and mineralogical composition by using Travis classification (1955) for naming it as shown in Table 4.3 below. Besides that, petrography analysis using microscope also used in order to identify minerals optic and specific minerals composition. In field observation, these units composed of lithology such as peridotite, dacite and serpentinite. Based on the dominant lithology in the field, these unit was called as ultramafic unit.

Table 4.3 Classification of Igneous Rock

Essential Minerals		K-FELDSPAR>2/3 Σ FELDSPAR			K-FELDSPAR 1/3 - 2/3 Σ FELDSPAR			PLAGIOCLASE FELDSPAR > 2/3 Σ FELDSPAR						LITTLE OR NO FELDSPAR		SPECIAL TYPES
								K-FELDSPAR>10 % Σ FELDSPAR	K-Spar < 10% Σ FELDSPAR							
									Na- Plagioclase		Ca-Plagioclase					
		Quartz> 10%	Quartz < 10% Feldspathoid < 10%	Feldspathoid > 10%	Quartz> 10%	Quartz < 10% Feldspathoid < 10%	Feldspathoid > 10%	Quartz >10%	Quartz >10%	Quartz < 10% Feldspathoid < 10%	Quartz < 10% Feldspathoid < 10%		Feldspathoid >10% Pyroxene > 10%	Chiefly Pyroxene and/or Olivine	Chiefly Ferro-Magnesian Minerals and Feldspathoids	
Characterizing Accessory Minerals		**Chiefly:** Hornblende, Biotite, Pyroxene, Muscovite **Also:** Sodic Amphiboles, Aegirine, Cancrinite, Sodalite, Tourmaline			**Chiefly:** Hornblende, Biotite, Pyroxene **Also:** Sodic Amphiboles, Aegirine			**Chiefly:** Hornblende, Biotite, Pyroxene(in Andesite) **Also:** Pyroxene, Feldspathoid, Sodic Amphiboles			**Chiefly:** Pyroxene, Uralite, Olivine **Also:** Hornblende, Biotite, Quartz, Analcite, Aegirine, Sodic Amphiboles			**Chiefly:** Serpentine, Iron Ore **Also:** Hornblende, Biotite	Hornblende, Biotite, Iron Ore	
Colour Index		10	15	20	20	25	30	20	20	25	50		60	95	55	
PHANENERITIC	**Equigranular** Batholiths, lopoliths, stocks, large laccoliths, thick dikes, and sills	GRANITE	SYENITE	NEPHELINE SYENITE	QUARTZ MONZANITE (ADAMELLITE)	MONZANITE	NEPHELINE MONZANITE	GRANODIORIT E	QUARTZ DIORITE (TONALITE)	DIORITE	GABBRO	DIABASE (DOLERITE)	THERALITE	PERIDOTITE, HARZBURGITE, PICRITE, DUNITE, PYROXENITE, SERPENTINE	MISSOURITE, IJOLITE, FERGUSITE, UNCOMPAHGRITE (MELILITE PYROXENITE)	PEGMATITE, APLITE, LAMPROPHYRE
PORPHYRITIC	**Phaneritic Groundmass** Laccoliths, dikes, sills, plugs, small stocks, margins of larger masses	GRANITE PORPHYRY	SYENITE PORPHYRY	NEPHELINE SYENITE PORPHYRY	QUARTZ MONZANITE PORPHYRY	MONZANITE PORPHYRY	NEPHELINE MONZANITE PORPHYRY	GRANODIORIT E PORPHYRY	QUARTZ DIORITE PORPHYRY	DIORITE PORPHYRY	GABBRO PORPHYRY		THERALIT PORPHYRY	PERIDOTITE PORPHYRY (KIMBERLITE)		
	Aphanitic Groundmass Dikes, sills, laccoliths, surface flows, margins of larger masses, welded tuffs	RHYOLITE PORPHYRY	TRACHYTE PORPHYRY	PHONOLITE PORPHYRY	QUARTZ LATITE PORPHYRY	LATITE PORPHYRY	NEPHELINE LATITE PORPHYRY	DACITE PORPHYRY		ANDSITE PORPHYRY	BASALT PORPHYRY		TEPHERITE PORPHYRY	LIMBURGITE PORPHYRY		TRAP, FELSITE
APHANITIC	**Microcrystalline** Dikes, sills, surface flows, margins of larger masses, welded tuffs	RHYOLITE	TRACHYTE	PHONOLITE	QUARTZ LATITE (DELLENITE)	LATITE (TRACHY-ANDESITE)	NEPHELINE LATITE	DACITE		ANDESITE	BASALT		TEPHERITE	LIMBURGITE	NEPHELINITE, LEUCITITE, MELILITITE, OLIVINE NEPHELINITE (NEPHELINE BASALT),ETC.	
	Glassy Surface flows, margins of dikes and sills, welded tuffs	OBSIDIAN, "PITCHSTONE", VITROPHYRE, PERLITE, PUMICE, SCORIA														

Source : Russell B. Travis, 1955.

b. Distribution and Thickness

The distribution of this unit occupying approximately 20 percent (%) of the research which is around of 7 kilometre square (km^2). The distribution of these rocks exposed at north to north northwest of the study area and lithology constituents unit was exposed very well in area of Bulu Palaka and Bulu Lasitae. The thickness of this rock unit based on the calculation of the geological cross section A – B is 500 meters (m) (View Geological Map).

c. Lithology Characteristic

i. Peridotite

Dominance lithology in ultramafic unit was peridotite which is located at Station 32, 33, 34, 36, 37, 38, 39, 40, 41, 42, 43, 44, 46 and 48 in Bulu Palaka and Bulu Lasitae area. Peridotite is dominant rock of the upper part of earth's mantle. Based on field observation Station 39, the lithology is peridotite. Fresh colour is light gray while weathered colour is dark brown. Peridotite have phaneritic texture. Grain sized is coarse grain. Dominant minerals is serpentine minerals. This peridotite was classified as kimberlite due to contained dominant serpentine minerals in composition of minerals. This outcrop have been found at Bulu Palaka (Figure 4.27).

Based on petrology description, absorbtion colour is colourless, interference colour is blackish white, size of minerals in between 0.75 to 7.15 mm. It consisted of serpentine minerals mostly 70%, pyroxene 17% and olivine 13%. **Name of rock : kimberlite** (Travis R. B., 1955) (Figure 4.28).

Figure 4.27 The appearance of peridotite outcrops at Station 39, Bulu Palaka.

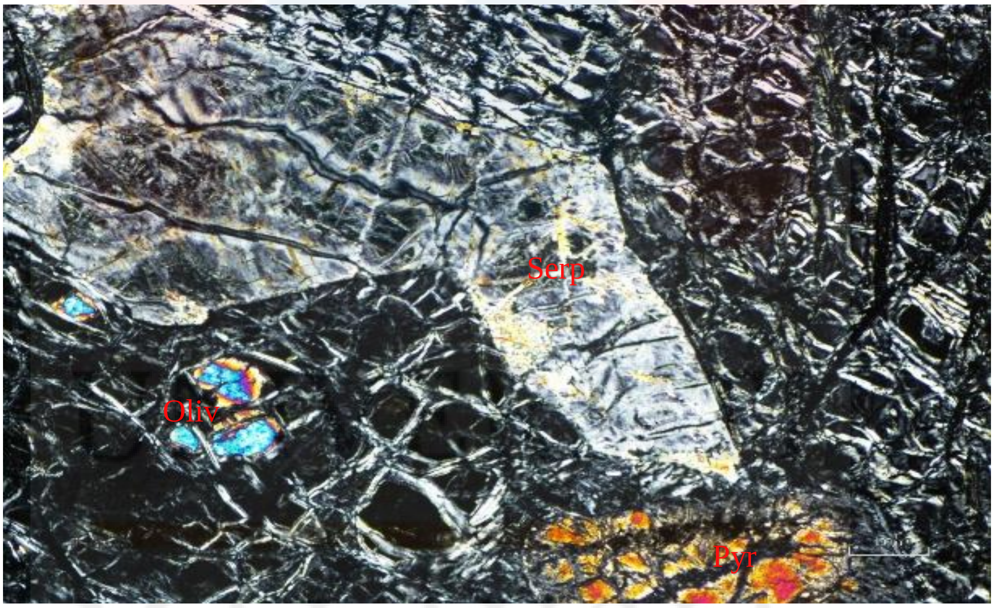


Figure 4.28 Microphotograph of kimberlite (D3 S1 001) with minerals composition of serpentine (Serp), pyroxene (Pyr) and olivine (Oliv). XPL image, 40x magnification.

ii. Serpentinite

The distribution of serpentinite was located at Station 35 and 45. This lithology exposed very well in area of Bulu Palaka and Bulu Lasitae. Serpentinite was founded in Ultramafic Unit which is dominance peridotite area. At Station 35, the outer surface was gray in colour, while the fresh inside part was greenish gray. Non foliated rock and fine grained size. These form by hydrothermal metamorphism of ultrabasic igneous rocks. Minerals in this group are formed by serpentinization, a hydration and metamorphic transformation of ultramafic rock from the earth's mantle. This outcrop have been found at Bulu Lasitae (Figure 4.29).

Based on petrology description with reference sample no D3 S14 001, absorbtion colour is colourless, interference colour is brownish gray, size of minerals in between 0.5 to 2.5 mm, texture is schistose. Minerals composition is consisted of serpentine (80%), actinolite (15%) and opaque mineral (5%). **Name of rock : Serpentinite** (Travis, 1955) (Figure 4.30).

Figure 4.29 Handspeciment of serpentitie outcrops from Station 35, Bulu Lasitae.

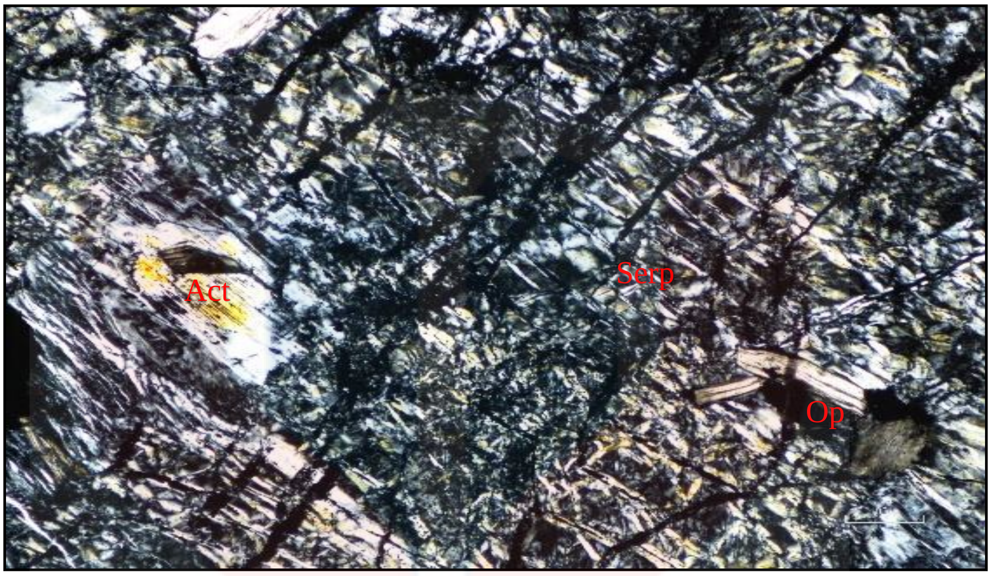


Figure 4.30 Microphotograph of serpentinite (D3 S14 001) with minerals composition of serpentine (Serp), actinolite (Act) and minerals opaque (Op). XPL image, 40x magnification.

iii. Dacite

Based on field observation at Station 39, the lithology that had been found is dacite. Based on physical characteristic, the fresh colour is light gray while weathered colour is blackish gray. This outcrop have been found at Bulu Lasitae (Figure 4.31). Based on petrology description with reference sample no D3S20001, absorbtion colour is brown, interference colour is blackish gray, size of minerals in between 0.025 to 3 mm, texture is porphyritic, shape is euhedral to anhedral. Minerals composition is consisted of groundmass (59%), nepheline (16%), plagioclase (12%), pyroxene (10%) and olivine (3%). **Name of rock : Serpentinite** (Travis, 1955) (Figure 4.32).

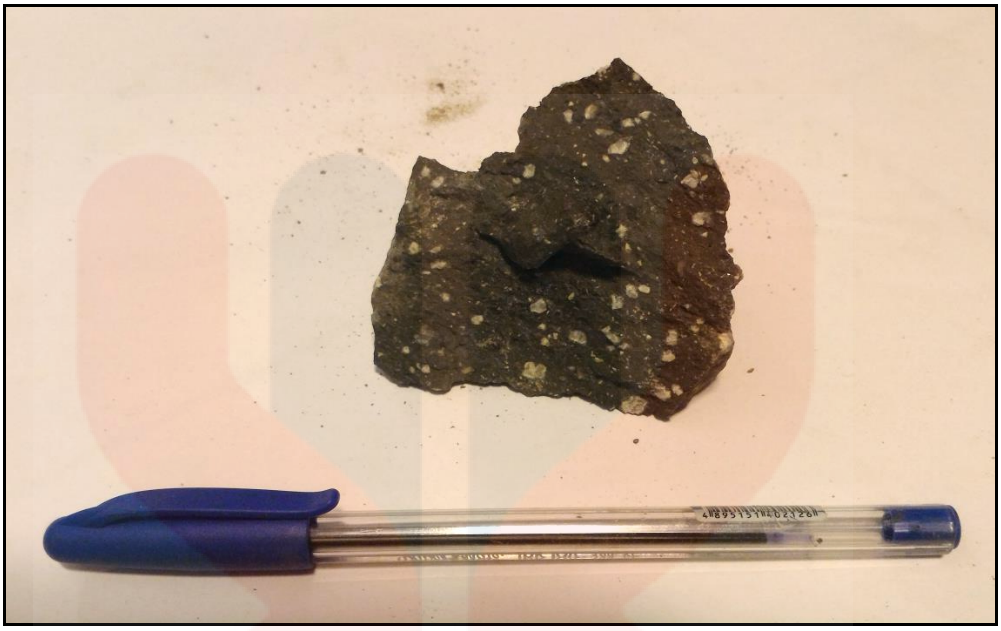


Figure 4.31 The appearance of hand speciment dacite outcrops from Station 43, Bulu Lasitae area.

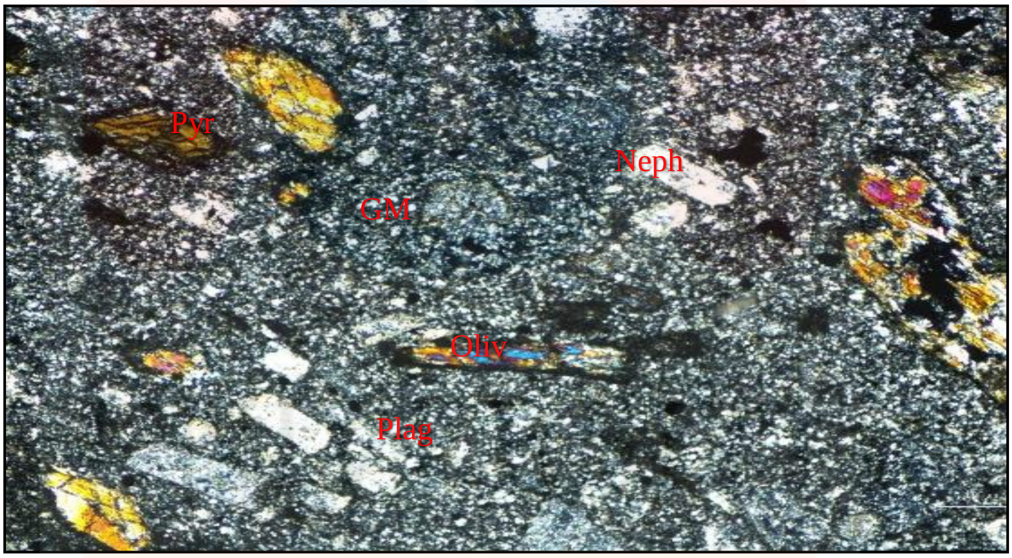


Figure 4.32 Microphotograph of dacite (D3 S20 001) with minerals composition of groundmass (GM), Nephelin (Neph), plagioclase (Plag), pyroxene (Pyr) and olivine (Oliv). 40x magnification of cross polarized

d. Age of Rock Unit

Age of ultramafic unit was determined based on the physical characteristics, position of stratigraphy, geographical position, field data, data from regional stratigraphy of the research area and previous study based on their basis similarity of lithology characteristics in the field as well as petrographic observation. Based on the description in physical characteristics of rock type and location, mostly peridotite was serpentinized (dark green to blackish green). This units also has a touch of the fault with the surrounding rock units. Based on Sukamto (1982), the age of ultramafic unit was Triassic age.

e. Stratigraphic Relationship

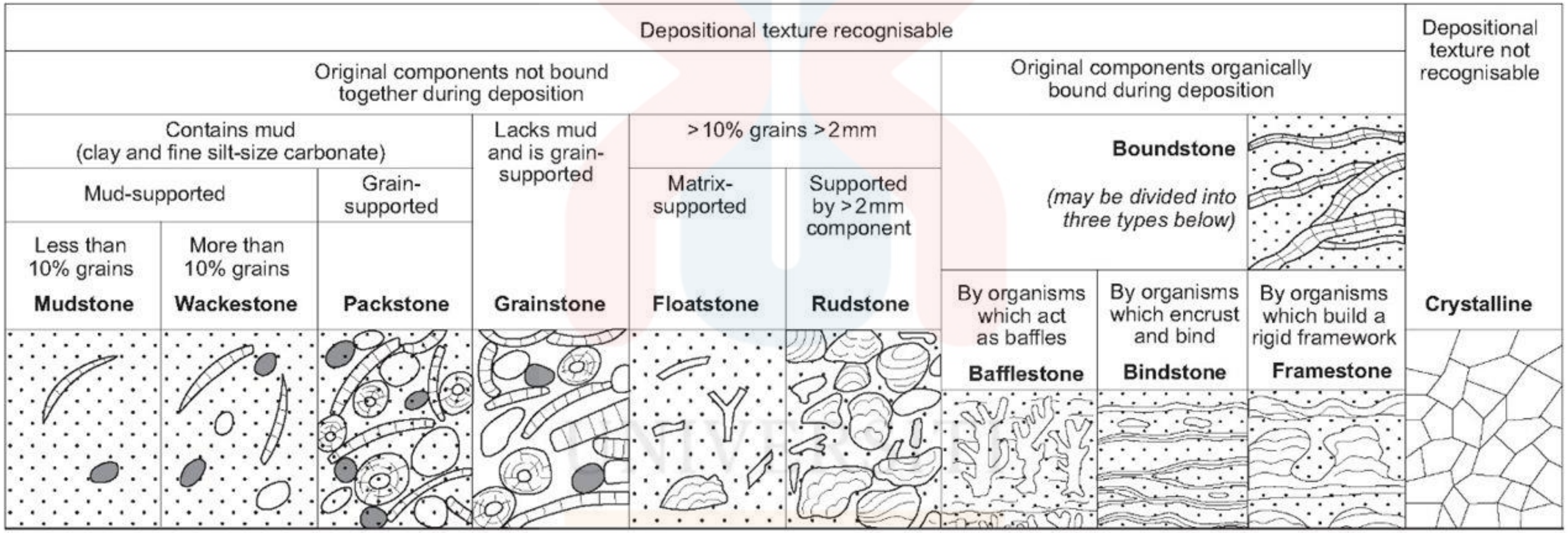
Based on stratigraphic relationship between ultramafic unit and schist unit, this relationship was determined as tectonic contact and this thickness unit is less than 2500m (Sukamto, 1982).

4.2.3 Limestone Unit

a. Nomenclature

Naming of these unit is based on megascope observations which is determined directly based on physical and mineralogical composition by using Dunham classification (1962) in Table 4.4 for naming it.In field observation, these units composed of lithology such as limestone and claystone. Based on the dominant lithology in the field, these unit was called as limestone unit.

Table 4.4 The Dunham classification of carbonate sedimentary rock.



Source : After Dunham, 1962.

b. Distribution and Thickness

The distribution of this unit occupying approximately 40 percent (%) of the research which is around of 10 kilometre square (km^2). The distribution of these rocks exposed at north northeast to south southeast of the study area and lithology constituents unit was exposed very well in area of Palaka to Daccipong. This limestone unit was exposed with fresh condition in this area. The thickness of this rock unit based on the calculation of the geological cross section A – B is 340 meters (m) (View Geological Map).

c. Lithology Characteristic

i. Limestone

Dominance lithology in limestone unit was limestone which is located mostly at Salo Barru, Baruga, Bangabange, Bulu Bottosuwa, Salo Lagolla and Daccipong.area. Limestone is a sedimentary rock consisting of more than 50% calcium carbonate (calcite, $CaCO_3$). Some of the limestone secreted by marine organisms such as algae and coral (biochemical limestone) and the others have foraminifera fossil.

Based on field observation Station 1 at foothill of Bulu Bottosowa, fresh colour is grayish white while weathered colour is blackish brown. Clastic texture. Generally, it composed mainly of large foraminifera and algae microfossils. Bedding structure is N85°E/45°. Based on classification of Dunham (1962), this limestone was named as bioclastic limestone (Figure 4.33).

Based on petrology description, with referance sample D1 S1 001, absorbtion colour is brownish gray, interference colour is blackish brown, size of minerals in between 0.05 to 35 mm. It composed of Skeletal grain (77%) which is consisted of *Calcareous Algae* (Horowitz & Potter, 1971) and *Nummulites* sp. (Peter & Dana, 2003), calcite (10%), muscovite (8%) and quartz (5%). **Name of rock : Grainstone** (Dunham, 1962) (Figure 4.34).

Figure 4.33 The appearance of Limestone outcrops at Station 1, Bulu Bottosuwa.

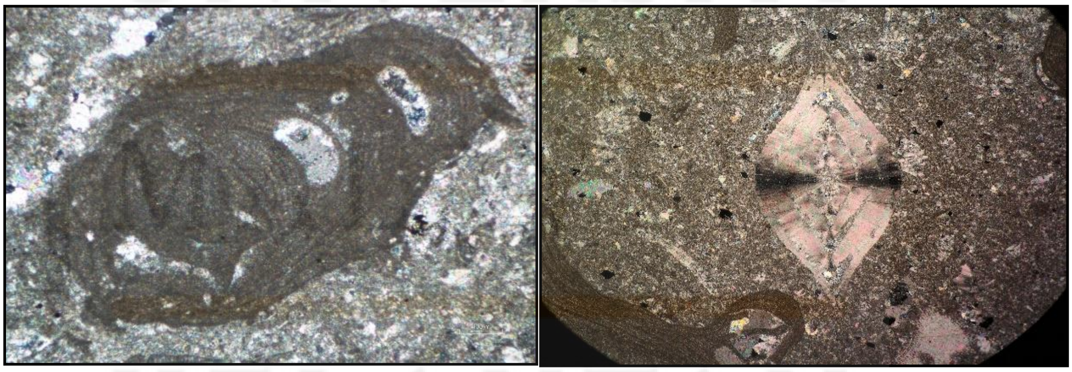


Figure 4.34 Microphotograph of limestone with the composition of the foraminifera fossil *Nummulites* sp. (left) and algae fossil Calcareous Algae (right). XPL image, 100x magnification.

Field observation Station 61, fresh colour is milky white while weathered colour is blackish brown. Clastic texture. Bedding structure is N340°E/60°. This outcrop have been found at Bangabange (Figure 4.35).Based on petrology description, with referance sample D4 S1 001, absorbtion colour is brown, interference colour is brownish green, size of minerals in between 0.675 to 20 mm. It composed of Skeletal grain (92%) which is consisted of *Coralline Algae* (Horowitz & Potter, 1971), foram fossil such as *Amphistegina* sp., *Globigerina* sp. *and Miogypsina* sp. (Peter & Dana, 2003) and Mud (8%). **Name of rock : Packstone** (Dunham, 1962) (Figure 4.36).

Figure 4.35 The appearance of Limestone outcrops at Station 61, Bangabangae.

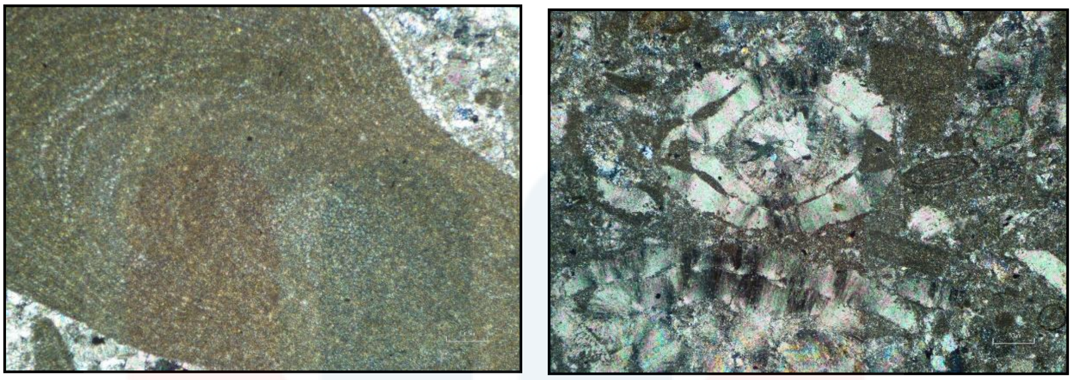


Figure 4.36 Microphotograph of limestone with the composition of the foram fossil *Amphistegina* sp., *Globigerina* sp. and *Minogypsina* sp. (right) and algae fossil Coralline algae (left). XPL image, 100x magnification.

Based on field observation Station 68, fresh colour is milky white while weathered colour is blackish brown. Clastic texture. Bedding structure is N310°E/20°. This fresh outcrop have been found at Salo Barru (Figure 4.37).

Based on petrology description, with referance sample D4 S6 001, absorbtion colour is grayish brown, interference colour is dark brown, size of minerals in between <0.025 to 0.5 mm. It composed of Skeletal grain (40%) which is consisted of *Miogypsina* sp. (Belford D.J., 1968), *Parafusulina schucherti* sp. (Peter & Dana, 2003) and sparite (calcite) (60%). **Name of rock : Crystalline Limestone** (Dunham, 1962) (Figure 4.38).

Figure 4.37 The appearance of Limestone outcrops at Station 68, Salo Barru.

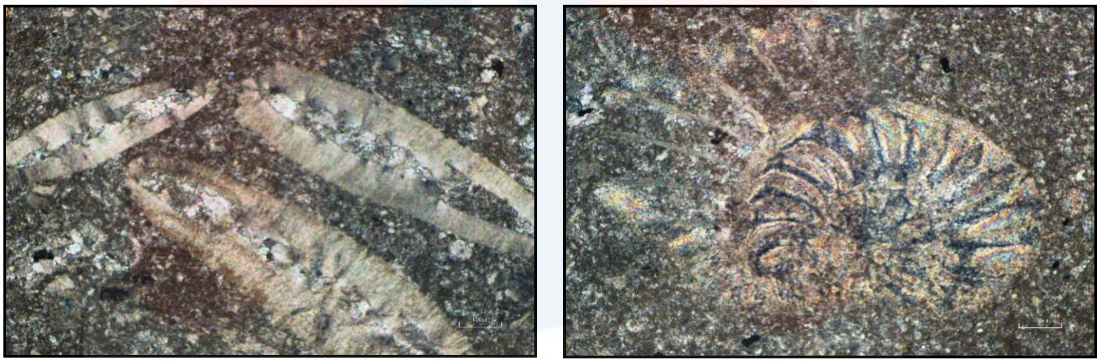


Figure 4.38 Microphotograph of limestone with the composition of the foram fossil *Miogypsina* sp. (left), *Parafusulina schucherti* sp. (right). XPL image, 100x magnification.

ii. Claystone

Claystone is lithified and non fissile mudrock. It consist of up to fifty percent clay, which measure less than 1/256 of a milimeter in particle size. Based on field observation Station 57, fresh colour is white while weathered colour is brownish white. Bedding structure is N300°E/10°. This fresh outcrop have been found at mostly at Salo Lokae (Figure 4.39).

Based on petrology description, with referance sample D4 S7 001, absorbtion colour is brownish gray, interference colour is blackish brown, size of minerals in between 0.05 to 1.55 mm. It composed of Skeletal grain (87%) which is consisted of coral fossil *Octocoral* (Peter & Dana, 2003), foram fossils such as *Discocyclinid* sp. *and Globigerina* sp. (Horowitz & Potter, 1971) and mud (13%). **Name of rock : Claystone** (Dunham, 1962) (Figure 4.40).

Figure 4.39 The appearance of claystone outcrops at Station 57, Salo Lokae.

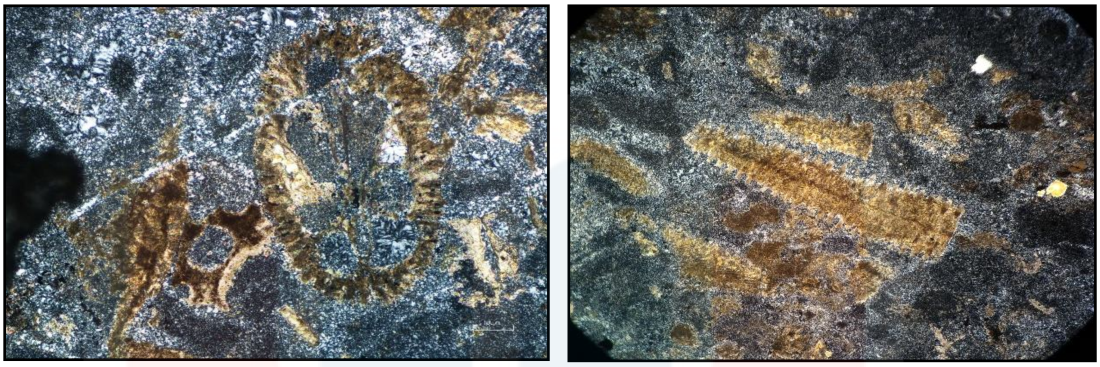


Figure 4.40 Microphotograph of claystone with the composition of the coral fossil Octocoral (right), foram fossils such as *Discocyclinid* sp. and *Globigerina* sp. (left) and mud.. XPL image, 100x magnification.

d. Depositional Environment and Age of Rock Unit

Determination of the depositional environment of limestone was determined based on the physical characteristics and the type of fossil existed. It shows the depositional environment of this unit was shallow marine. Based on Sukamto (1982) the age of this unit was Early Eocene to Middle Miocene.

e. Stratigraphic Relationship

Based on stratigraphic relationship between ultramafic unit, this relationship was determined as unconformity.

4.2.4 Melange Unit

Some part of this these rocks in schist unit and ultramafic unit were chaotically mixed of igneous (basalt), metamorphic (schist, garnet mica schist, blueschist, greenschist, phyllite, serpentinite and quartzite) and sedimentary rocks (chert and sandstone).

a. Nomenclature

Melanges are mappable but discontinuous, often chaotic rock units and the distribution of this unit occupying some part of the research area. It composed of mixtures of often pervasively sheared, weak matrix enclosing a variety of stronger blocks of different lithologies and size. Nomenclature of these unit was based on the physical characteristic of lithology.

b. Distribution and Thickness

The distribution of these rocks exposed at north northwest to south southwest of the study area and lithology constituents unit was exposed very well in area of Salo Dengenge, Salo Lagolla and Bulu Palaka.

c. Lithology Characteristic

i. Breccia

Based on field observation at Station 5, the lithology is breccia or also known as fault breccia. Fresh colour is greenish gray while weathered colour is brownish black. Texture is clastic, structure is non-foliated (cataclastic). Fragment composition consisted of calcite, quartzite, schist and clay cement. This fresh outcrop have been found at Salo Dengenge which is southwest from Bulu Salebbi (Figure 4.41).

Based on petrology description with reference sample number is D2 S2 002, absorption colour is light brown, interference colour is dark brown, shape is subhedral to anhedral, size of mineral in between 0.05 to 3 mm. Minerals composition composed of calcite (85%), muscovite (8%), quartz (5%), garnet (2%). **Name of rock : Schist Breccia** (Higgins, 1971) (Figure 4.42).

Figure 4.41 The appearance of schist breccia outcrops at Station 5, Salo Dengenge.

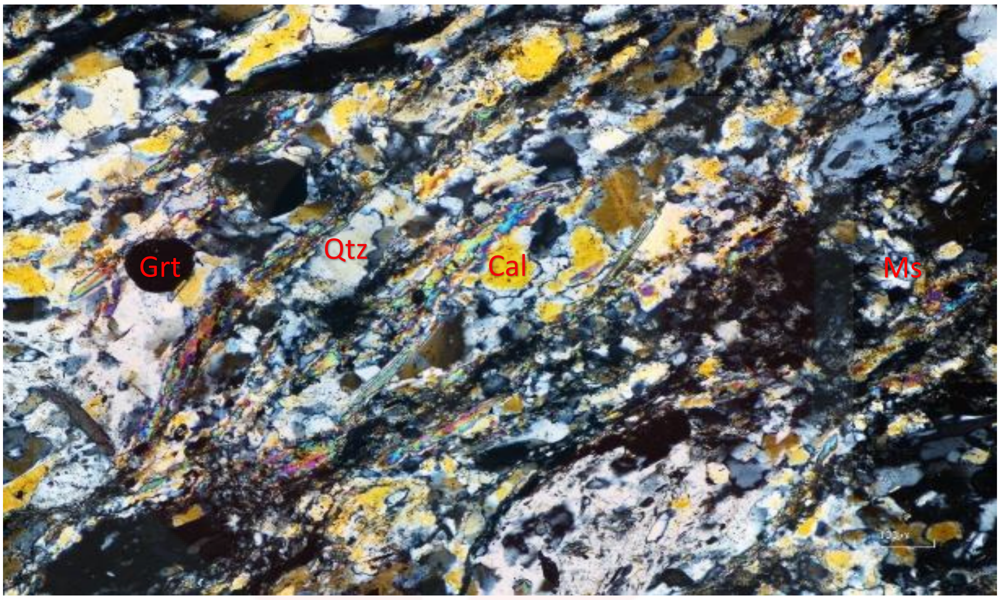


Figure 4.42 Microphotograph of breccia schist (D2 S2 002) with minerals composition of calcite (Cal), garnet (Grt), quartz (Qtz) and muscovite (Ms). XPL image, 40x magnification.

ii. Sandstone

Based on field observation at Station 52, the lithology is sandstone. Fresh colour is brownish while weathered colour is dark brownish. This outcrop have been found at foothills of Bulu Bottosuwa (Figure 4.43). Based on petrology description with reference sample number is D3 S9 001, absorption colour is colourless, interference colour is brownish gray, shape is subhedral to anhedral, size of mineral in between 0.25 to 5 mm. Minerals composition composed of quartz (75%), and garnet (25%). **Name of rock : Quartz Sandstone** (Dunham, 1962) (Figure 4.44).

Figure 4.43 The appearance of quartz sandstone outcrops at Station 52, Bulu Bottosuwa.

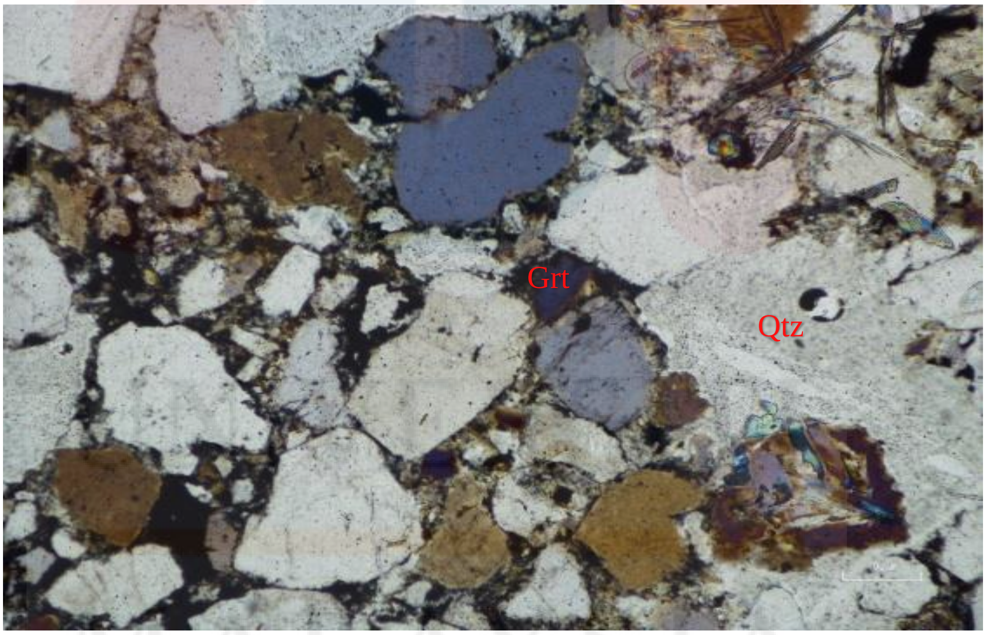


Figure 4.44 Microphotograph of quartz sandstone (D3 S9 001) with minerals composition of quartz (Qtz) and garnet (Grt)\. XPL image, 40x magnification.

iii. Chert

The distribution of chert was located at Station 9 and 25. This lithology exposed very well in area of Salo Dengenge and Salo Batubelang. Based on field observation at Station 9, fresh colour is grayish while weathered colour is reddish gray. This outcrop have been found at Salo Dengenge (Figure 4.45). Based on petrology description with reference sample number is D1 S12 003, absorption colour is reddish brown, interference colour is blackish brown, size of mineral in between <0.025 to 8 mm. Minerals composition composed of silica minerals (68%), and iron oxide (32%). **Name of rock : Chert** (Dunham, 1962) (Figure 4.46).

Figure 4.45 The appearance of chert outcrops at Station 9, Salo Dengenge.

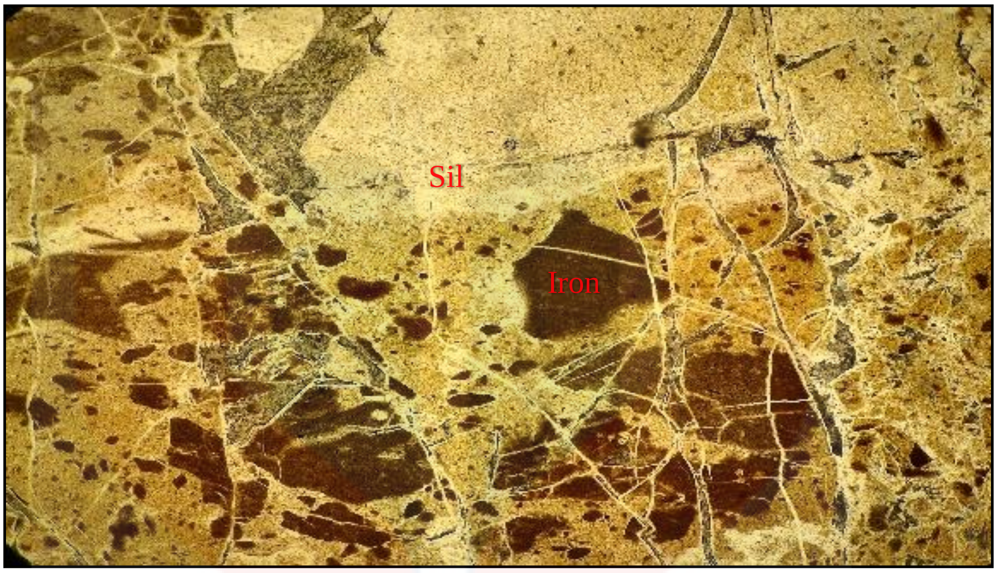


Figure 4.46 Microphotograph of chert (D3 S12 003) with minerals composition of silica minerals (Sil) and iron oxide (Iron). XPL image, 40x magnification.

iv. Basalt

Based on field observation at Station 7, the lithology is basalt. Fresh colour is dark gray while weathered colour is gray. Structure is massive. This basalt have calcite vein. This fresh outcrop have been found at Salo Dengenge (Figure 4.47).

Based on petrology description with reference sample number is D1 S11 001, absorption colour is brownish gray, interference colour is grayish, shape is subhedral to anhedral, size of mineral in between 0.25 to 6.82 mm. Minerals composition composed of calcite (50%), pyroxene (19%), quartz (10%), biotite (6%) and plagioclase (5%). **Name of rock : Basalt (Travis, 1955**) (Figure 4.48).

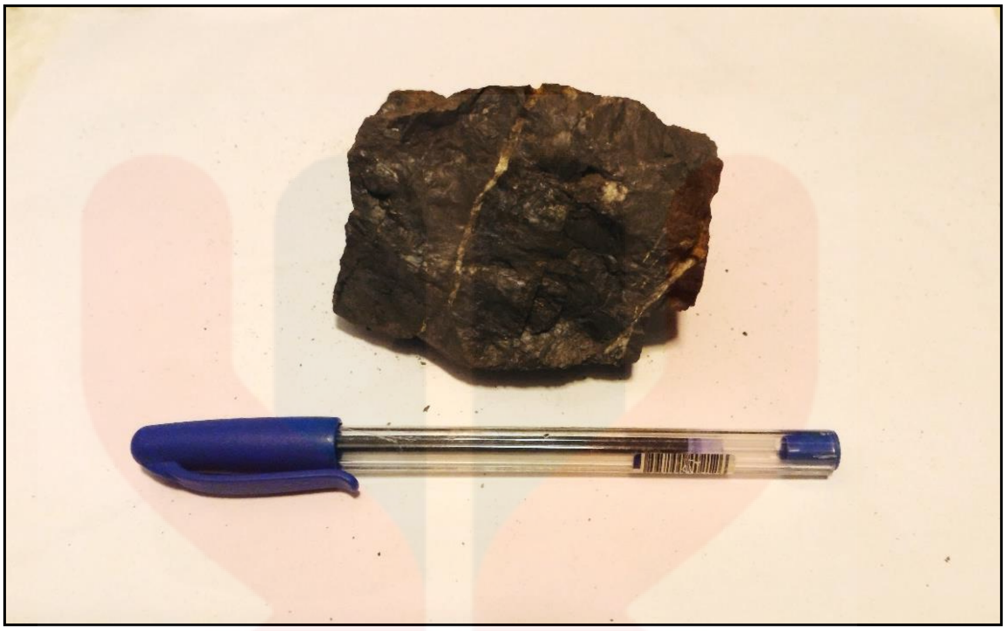


Figure 4.47 The appearance of basalt outcrops at Station 7, Salo Dengenge.

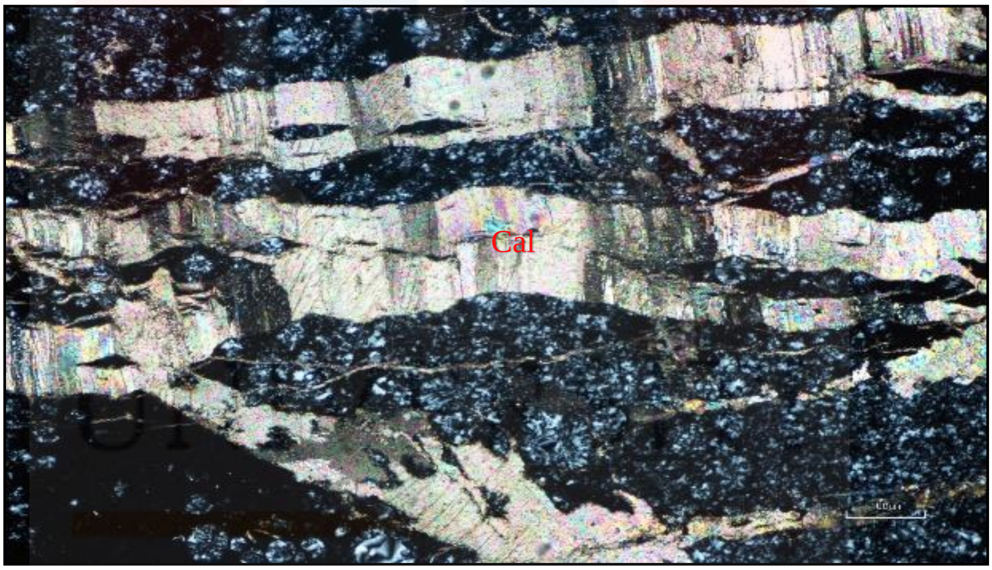


Figure 4.48 Microphotograph of basalt with calcite vein (D1 S11 001) with minerals composition of calcite (Cal), pyroxene (Pyr), quartz (Qtz), biotite (Bio) and plagioclase (Plag). XPL image, 40x magnification.

d. Depositional Environment and Age of Rock Unit

Depositional environment and age of melange unit was determined based on the physical characteristics, field data, data from regional stratigraphy of the research area and previous study based on their basis similarity of lithology characteristics in the field as well as petrographic observation. Based on the description in physical characteristics of rock type and location was relatively close, the melange unit in the research area can be related to Bantimala Melange Complex. According to Wakita et al., (1994), the age of melange unit was Lower Cretaceous age. Besides that, Depositional environment of melange unit was occurred in the zone under pressure due to tectonic which then caused the rocks mixed (Hamilton, 1979).

e. Stratigraphic Relationship

After the formation of schist and ultramafic unit, tectonic activity continues to Lower Cretaceous and lead the deformation, fracture and destruction of this unit at the junction of these two plates, until in some parts it was form a melange which is a jumbled rock consisting of fragments of schist, quartzite, basalt, chert, breccia and sandstone (Miyazaki et al.,1996; Maulana et al., 2010).

4.3 Structural Geology

According to Davis (1984), determining the type of geological structures that developed in the study area, based on the indicative geological structures found in the field, either in the form of primary data and secondary data by using descriptive and analytic methods kinematic. Descriptive method is a method of description directly elements of structure encountered in the field in the form of fault breccia, position of rocks, fault plane, and joints position, while the method of kinematic analysis is a method of analysis which is done by making the image reconstruction based on the data geometry encountered in the field then analyzed it.

The discussion of the geological structure of the research area included geological structure patterns that was found in the field such as identifying the type of structure, regional stratigraphic studies and interpretation formation machanism of geological structure. Based on the above it kind of geological structures developed in the research area consisted of:

- Fold Structure
- Joint Structure
- Fault Structure

4.3.1 Fold Structure

Asikin (1979) stated that fold was formed because of two mechanisms which are buckling and bending. Buckling is fold due to the pressure is parallel to the surface. Bending is a fold that the direction of pressure is vertical to the surface. Based on field observation and measurement made in the field, it can be interpreted that the structure of the folds of the research area in the form of minor drag folds and minor form of anticline folds. With descriptive methods in the field, then encountered minor folds in the form of drag folds at two Stations 14 (Figure 4.49), Stations 50 (Figure 4.50) and anticline fold at Stations 6 (Figure 4.51).

Figure 4.49 Minor drag fold of the schist encountered at Station 14 with strike dip reading N140°E/32°.

Figure 4.50 Minor drag fold of the blueschist encountered at Station 50 with strike dip reading N105E/10.

Figure 4.51 Minor anticline fold of the schist encountered at Station 6 with strike dip reading N140°E/38°.

4.3.2 Joint Structure

Joint is a fracture in the rock where there is no or very little shifting. Things that were identified in the field observation was joints characteristic such as position of joint on outcrop, measure position of joint, distance of joint and photo of joints (Billing, 1968).

Joints that was found at the study area is nonsystematic joint on schist outcrop at Station 5. This joints was classified as tectonic joints as seen in Figure 4.52. Tectonic joints was formed when the relative displacement of the joint walls was normal to its plane as the result of brittle deformation of bedrock in responds to regional or local its plane as the result of brittle deformation of bedrock in responds to regional or local tectonic deformation of bedrock. As a result from tectonic process that occurred at this area, such joints formed when directed tectonic stress causes the tensile strength of bedrock exceeded as the result of the directed tectonic stress.

The result of measurement, processed and analyzed the joints was interpreted by using the method Georose Diagram (Figure 4.53) which was used to determined the direction of the general force direction and magnitude of the main force direction ($\sigma1$, $\sigma2$ and $\sigma3$). The result of joints measurement at Station 5 joints space 20 – 40 cm, wide opening 1 – 2 mm. Measurement on this Station 5 was carried out 50 times (Table 4.5).

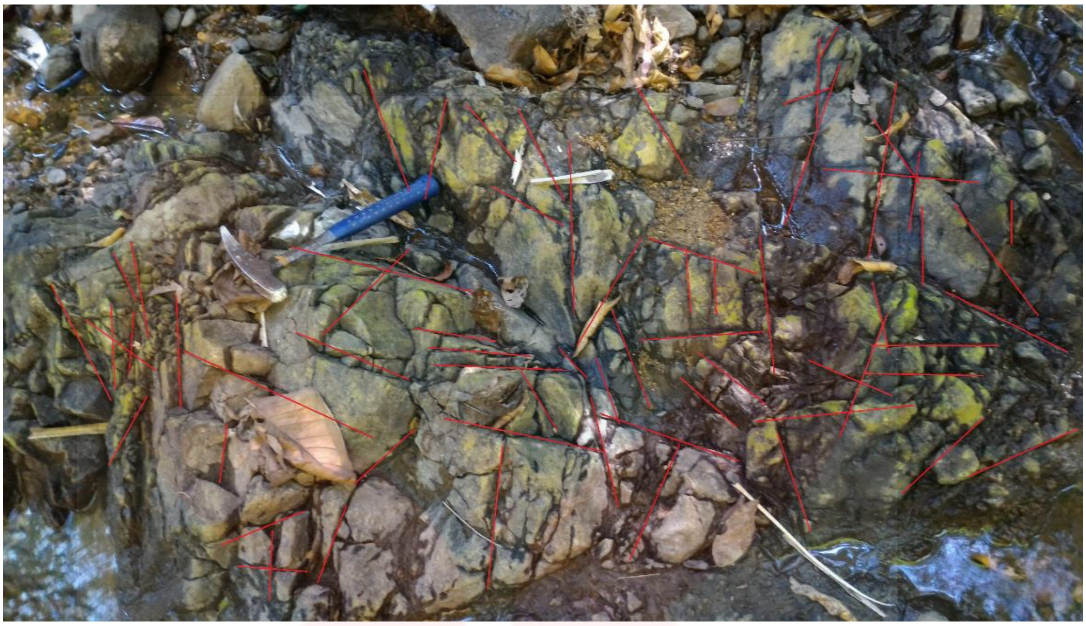


Figure 4.52 Non systematic joints (tectonic joints) of the schist encountered at Station 5.

Table 4.5 Joints measurement data at Station 5 on schist outcrop.

No	Strike (NE)	Dip (…)	No	Strike (NE)	Dip (…)	No	Strike (NE)	Dip (…)	No	Strike (NE)	Dip (…)
1	330	55	14	232	70	27	30	22	40	330	55
2	55	40	15	226	71	28	235	61	41	55	75
3	55	70	16	355	88	29	335	80	42	52	72
4	52	74	17	186	71	30	71	72	43	30	20
5	270	16	18	52	68	31	30	61	44	125	66
6	240	60	19	50	66	32	230	65	45	234	61
7	85	60	20	75	60	33	354	80	46	88	65
8	32	62	21	99	58	34	50	67	47	55	65
9	30	74	22	55	84	35	75	55	48	10	30
10	55	64	23	172	70	36	90	58	49	227	75
11	50	30	24	54	74	37	335	75	50	172	74
12	35	61	25	70	46	38	36	62			
13	2	26	26	125	65	39	55	83			

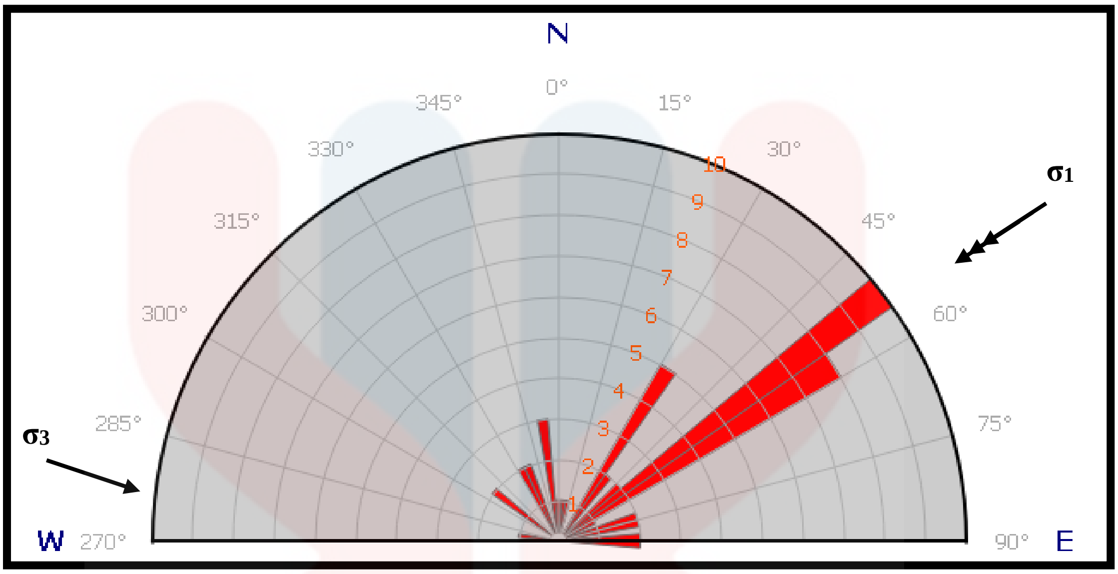


Figure 4.53 Georose diagram of the joints on schist rock.

Based on rose diagram, joints direction was northeast to southwest (N30°E – N60°E), relatively joints slope 45° - 60° (Table 4.5). The result of data analysis using rose diagram obtained direction of major force (σ1) is N50E and minimun force (σ3) is N275°E.

4.3.3 Fault Structure

Billing (1968) asserted that, fault is known as fracture occurred along the rock because of the relatively movement of one block to another block of rock. In the study area, indication of fault found in the fault zone and its surrounding was fault breccia and spring. Fault breccia was fractured zone and destruction zone which is located at fault plane. This fault breccia and spring were the one of primary characteristic of fault. This feature have been founded at Station 4 (fault breccia) and Stasion 5 (spring) of the study area. Figure 4.54 and Figure 4.55 below show both the fault breccia and spring was located along the Salo Dengenge.

Based on data and geological structure in the research area, it can be concluded that type of faulting occurred was reverse fault. Tectonically, the older unit (schist unit and ultramafic unit) unconformity overlain by younger rocks (limestone unit). The older rocks undergo deformation time by time through a number of thrust faults, brecciated, eroded and partially blended into melange.

Figure 4.54 The existence of fault breccias that indicate the occurrence of fault at Salo Dengnge in Station 4.

Figure 4.55 The existence of springs that was found in schist at Stasion 5.

4.4 Historical Geology

The geological history of the research area were initiated in the Triassic Era where the era of Basement Complex was formed and comprising schist unit consisted of green schist, mica schist and blue schist. This unit was formed in subduction zones which was a collision between the continental plates and oceanic plates (Hamilton, 1979).

At the Jurassic age, the sequence unconformably overlying and tectonically intercalated with the metamorphic lithological units consisted of serpentinized peridotite and peridotite. After the formation of this unit, tectonic activity continues to Lower Cretaceous and lead the deformation, fracture and destruction of this unit at the junction of these two plates, until in some parts it was form a melange which is a jumbled rock consisting of fragments of schist, quartzite, basalt, chert, breccia and sandstone (Miyazaki et al.,1996; Maulana et al., 2010).

The Tonasa Formation unconformably overlies the basement complex and ultramafic unit. The age of the Tonasa formation is Eocene to middle Miocene (Van Leeuwen, 1981; Sukamto, 1982). This formation consisted of limestone and claystone. This unit composed of foraminifera in marine sediments, bioclastic limestone and packstone.

After the occurrence of the tectonic activity, the research area undergoes young geological processes such as weathering, denudasional and sedimentation processes. The process continues until now.

CHAPTER 5

RESULT AND DISCUSSION

This research study was presents the results petrographic analysis of samples of metamorphic rocks collected as part of a mapping in the Desa Anabanua area with scale of 1:25000, Barru, Sulawesi Selatan. The objective of the report was to provided petrographic descriptions of the metamorphic rocks and discussed the characteristic of metamorphic rock based on thin section. The samples was detailed in Table 5.1.

Table 2.1 Summary of petrography metamorphic rocks studies result.

No	Reference No. Sample	Station / Location	Dominant Minerals Assemblage	Rock Name
1	D1 S10 001	Station 8 Location : Salo Denngenge	Quartz, Muscovite, Garnet	Quartz – Muscovite Schist
2	D1 S2 001	Station 3 Location : Salo Dengenge	Garnet, Muscovite and Quartz	Garnet Mica Schist
3	D1 S8 001	Station 10 Location : Salo Dengenge	Quartz	Quartzite
3	D2 S8 001	Station 14 Location : Salo Lagolla	Muscovite, Quartz, Biotite and Garnet	Phyllite
4	D2 S11 001	Station 22 Location : Salo Birubiru	Chlorite, Actinolite, Muscovite, Quartz and Sericite	Chlorite - Actinolite Schist
5	D2 S12 001	Station 23 Location : Salo Birubiru	Glaucophane, Chlorite, Muscovite and Garnet	Glaucophane – Chloride Schist
6	D3 S14 001	Station 35 Location : Bulu Palaka	Serpentinite	Serpentinite

The changes in mineral assemblages was due to changes in the pressure and temperature conditions of metamorphism. Thus, the mineral assemblages that was observed be an indication of the pressure and temperature environment that the rock was subjected to. As the pressure and/or temperature increase on a body of rock, that means the rocks undergoes prograde metamorphism or that the grade of metamorphism increases.

When rocks was subjected to high pressures and temperature, due to deep burial occur in orogenic zones when two continental collide, they become metamorphosed. They remaining in the solid state through slowly recrystallize. This takes thousands of millions years. Metamorphism was basically an isochemical process which is less unchanged from the original rock and the bulk chemical composition of a rock body is more. But he minerals will largely recrystallized into a new mineral assemblages as shown in Figure 5.1. below. Besides that, new structural features was frequently transmitted to the rocks such as slaty cleavage, phyllitic foliation and schistosity.

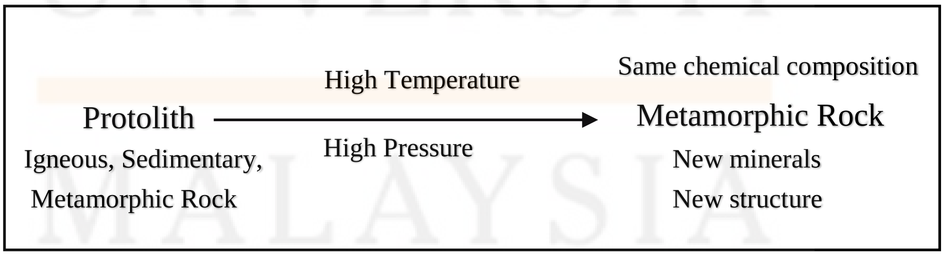


Figure 5.1 Metamorphism process.

Low-grade metamorphism occurred at temperature between 200 to 320°C and approximately low pressure. Low grade metamorphic rocks was generally characterized by the existence of an abundance of hydrous minerals (minerals that contain water (H_2O) in their crystal structure) such as clay minerals, chlorite and serpentine. Meanwhile, high-grade metamorphism occured at temperatures greater than 320°C and relatively high pressure (Anthony and Jay, 1990).

As the grade of metamorphism increases, hydrous minerals will become less hydrous by non-hydrous minerals become more common and losing H_2O. Example of less hydrous minerals and non-hydrous minerals that characterize the high grade metamorphic rocks like muscovite (hydrous minerals that finally disappears at the highest grade of metamorphism), biotite (a hydrous minerals that was stable to very grade of metamorphism), pyroxene (a non-hydrous mineral) and garnet (a non-hydrous mineral).

The sampling on the Salo Dengenge, Salo Batubelang, Salo Birubiru and Bulu Lasitae was conducted with observing the physical characteristic of these rocks in form of fresh colour, texture and mineral composition.

a. Schist

Schist was the dominance rocks in Schist Unit. The distribution of schist was located at Station 8, 13, 17, 18, 19, 20, 25, 26, 27, 28, 29, 30, 47, 49 and 50. This lithology exposed very well in area of Salo Dengenge, Salo Lagolla and Salo Batubelang.

Based on reference sample no. D1 S10 001 at Stasion 8, fresh colour of schist was light gray and have medium to course grained as seen in Figure 5.2. Figure 5.3 shows the irregular planar foliation at this stage was called as schistosity. This foliated textures was developed in the sequence listed below as temperature and pressure increases during metamorphism. It developed lepidoblastic textures in schist (Figure 5.4). This resulting of this texture was due to the parallel orientation during recrystallization of minerals with a flaky or scaly habit of muscovite. Main minerals composition of schist consisted of quartz, muscovite and chlorite. Other minerals such as garnet and opaque mineral also presented.

Schist was formed by regional metamorphism of a wide range of protolith including argillaceous and arenaceous sediments, igneous rocks, mixed siliciclastic and carbonate sediments (David S., 1983). Schist was a medium grade metamorphic rock which is higher grade than slate and can be distinguishing from high-grade gneiss by the lack of significant isolation into compositional bands and usually has a smaller grain size.

Figure 5.2 Sample of schist, 10cm.

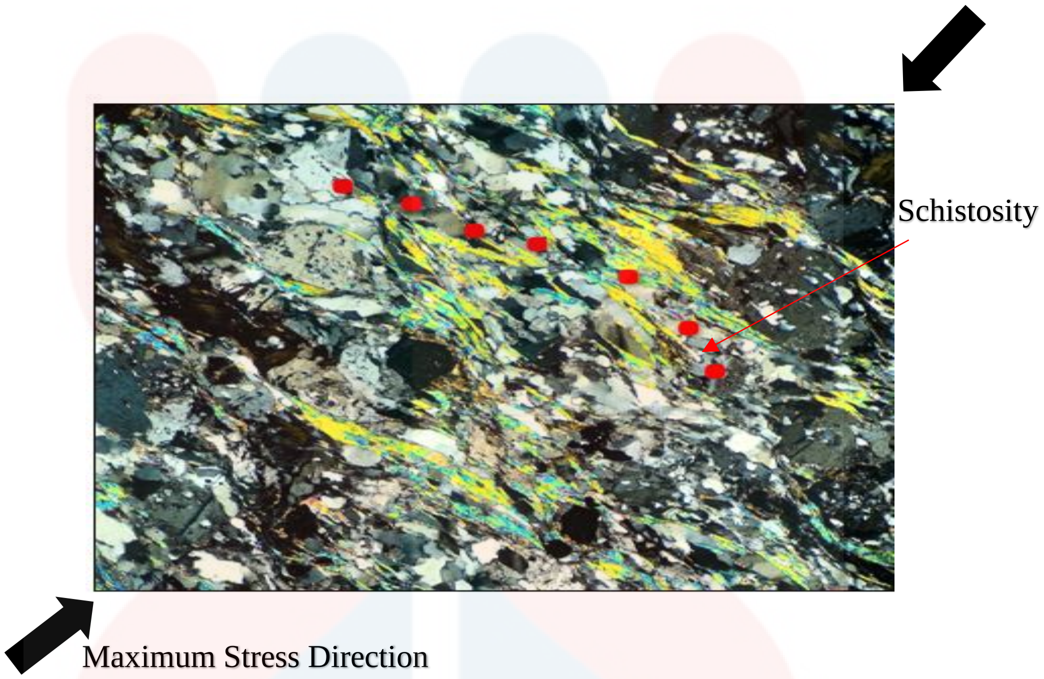


Figure 5.3 Schistose foliated structure in a schist. XPL image, 40x magnification.

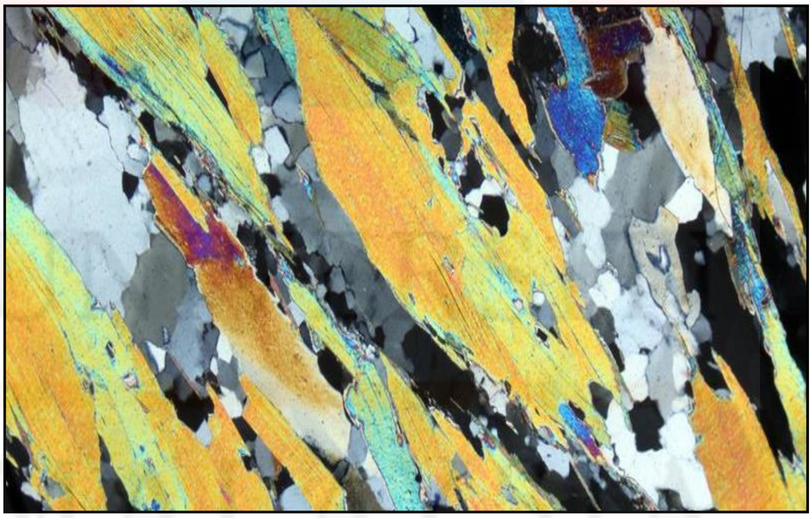


Figure 5.4 Lepidoblastic muscovite layer. XPL image, 100x magnification.

b. Garnet Mica Schist

Garnet mica schist was a part of Schist Unit. The garnet mica schist was located at Station 3 with the outer surface was gray in colour, while the fresh inside part was light gray. Texture foliated and have fine to medium grained. This lithology exposed very well in Salo Dengenge area (Figure 5.5).

This mica schist was naming as garnet mica schist because on referring to rich in garnet minerals presence when observed under microscope . According to interpretation on reference sample number D1 S2 001, at higher temperature of metamorphism, new mica flakes grow larger. Parallel mica flakes show up in bright colour and rounded garnet crystals appear black as seen in Figure 5.6. Commonly it produced by regional metamorphism of clay-rich sedimentary rocks and produced by intermediate-grade metamorphism.

Type and environment of this metamorphic rock was middle regional contact along a convergent plate boundary which is subjected to high degrees of deformation under differential stress. This garnet mica schist does not have lepidoblastic texture because it texture were not aligned to produce a planar fabric compared to schist lithology at Station 8 above. Parent rock of garnet mica schist like Shale, Mudstone or Felsic Igneous Rock.

Figure 5.5 Sample of Garnet Mica Schist, 8cm.

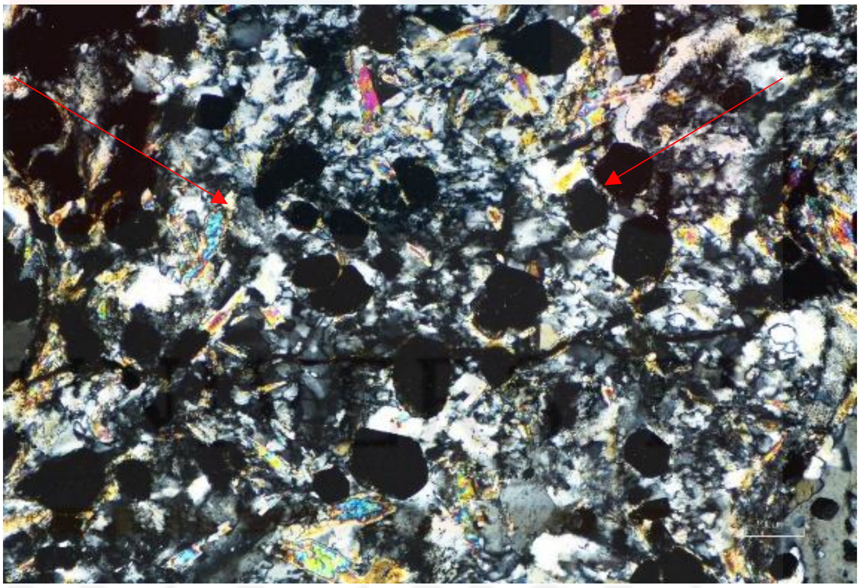


Figure 5.6 Garnet bordered by mica minerals and quartz layers in a garnet mica schist. XPL image, 40x.

c. Phyllite

Phyllite was a fine-grained, phyllitic foliation and type of pelitic metamorphic rock. The distribution of phyllite was located at Station 6, 14 and 51. This lithology exposed very well in area of Salo Dengenge and Salo Lagolla. Pelitic means that these rocks was derivatives of aluminous sedimentary rocks like shale and mudstone. Because of their concentration of alumina, they were recognized by an abundance of aluminous minerals like clay minerals, micas and garnet.

The outer surface was blackish gray in colour, while the fresh inside part was grayish. It have a sheen on its surface due to tiny plates of micas. Phyllite also has a fissility (a tendency to split into sheets) as seen in Figure 5.7 due to the parallel alignment of platy minerals. Its grain size smaller than that of schist. Based on field observation Station 14 located at Salo Lagolla with reference sample no. D2 S8 001, main minerals of phyllite consisted of muscovite, garnet, quartz and biotite. In phyllite, the crystals like biotite and muscovite was large enough to give the rock its sheen and slaty cleavage but not large enough to be visible to the unaided eye.

Phyllite typically was formed along the edges of regional metamorphic belts where clay-rich, marine sedimentary rocks have been cought between colliding continental plate or scraped off the seaflorr into an accretionary wedge above a subduction zone (Jacques, 2002). It was an intermediate grade metamorphism. During metamorphism, the clay minerals have crystallized into tiny micas such as biotite and muscovite as shown in Figure 5.8 As the intensity of heating and compression increases, the mica minerals align themselves perpendicular to the direction of stress and they grow larger. Phyllite was in between slate and schist.

With increasing metamorphic grade, increases in mica grain size will transforms phyllite into schist. Parent rock : Shale or Mudstone.

Figure 5.7 Appearance of phyllite with sheen on its surface and fissility, 10cm.

Figure 5.8 The mica minerals align themselves perpendicular to the direction of stress.

d. Serpentinite

The distribution of serpentinite was located at Station 35 and 45. This lithology exposed very well in area of Bulu Palaka and Bulu Lasitae. Serpentinite was founded in Ultramafic Unit which is dominance peridotite area. At Station 35, the outer surface was gray in colour, while the fresh inside part was greenish gray. Non foliated rock and fine grained size (Figure 5.9).

Based on reference sample no. D3 S14 001, serpentinite was a metamorphic rock that is mostly composed of serpentine group minerals (Figure 5.10). Serpentine group minerals was produced by the hydrous alteration of ultramafic rocks. These was igneous rocks that are composed of olivine and pyroxene (peridotite). Serpentinite form as a result of serpentinization. This was chemical reaction which convert unhydrous silicate minerals (pyroxene and olivine) into hydrous silicate minerals (serpentine). Dark colour of serpentine usually cause by containing iron in the form of magnetite.

As reported by David S. (1983), this serpentinite was formed by the process of serpentinization of peridotite into serpentinite. Serpentinization was a processes whereby ultramafic rock was changed, with the addition of water into the crystal structure of the minerals found within the rock. Serpentinization was a geological low-temperature metamorphic process involving heat and water in which low silica mafic and ultramafic rocks were oxidised and hydrolysed with water into serpentine. Peridotite at and near the seafloor was converted to serpentine minerals. In the process large amounts of water were absorbed into the rock increasing the volume and destroying the structure. It was a low grade metamorphism. Parent rock : Peridotite.

Figure 5.9 Serpentinite from Station 35, Bulu Palaka (8cm).

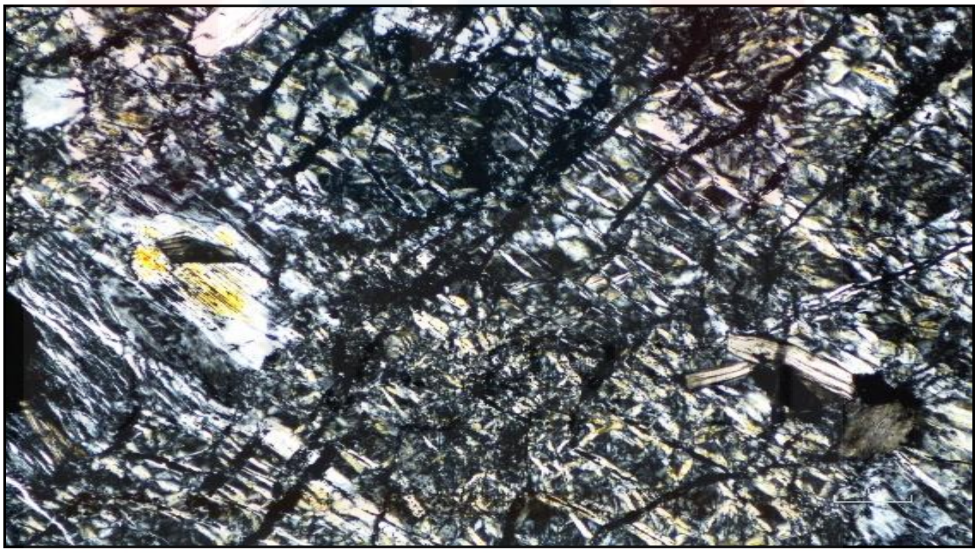


Figure 5.10 Serpentinite where mostly made up of serpentine minerals.

XPL image, 40x magnification.

e. Quartzite

Quartzite was a part of Schist Unit. Quartzite was located at Station 10 with the outer surface was dull white in colour, while the fresh inside part was white. Quartzite was a hard, non-foliated metamorphic dominated by quartz and medium grained size (Figure 5.11). Accessory minerals include opaque minerals. Quartzite also have a sugary appearance and glassy lustre. This lithology exposed very well in Salo Dengenge area.

Based on reference sample no. D1 S8 001, quartzite was a metamorphosed quartz sandstone. Quartz-rich sandstone was composed mostly of SiO_2. Quartzite containing up to 99% quartz and was the largest purest concentrations of silica in the Earth's crust. Since quartz was stable over a wide range of pressures and temperatures, metamorphism of quartz-rich sandstone will result only in the recrystallization of quartz forming a hard rock with interlocking crystals of quartz as seen in Figure 5.12.

Quartzite can be distinguish from quartz sandstone based on a fresh broken surface of quartzite show breakage across quartz grains while sandstone will break around quartz grains. Metamorphic grade and environment of quartzite was variable grade regional or contact metamorphism aong a convergent plate boundary. Parent rock : Quartz Sandstone.

Figure 5.11 A fresh broken surface of quartzite sample show breakage across quartz grains, 6cm.

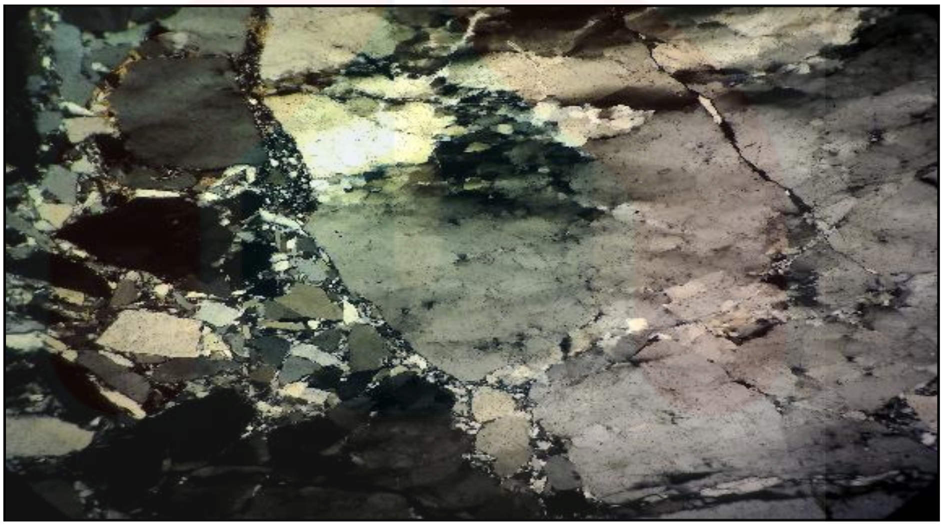


Figure 5.12 Quartz crystals in a Quartzite. XPL image, 40x maginification.

f. Greenschist

The distribution of greenschist was located at Station 22 and 24. This lithology exposed very well in area of Salo Birubiru and Salo Batubelang. The outer surface was greenish black in colour, while the fresh inside part was greenish gray. Greenschist was a fine to medium grained and foliated metamorphic rock. (Figure 5.13). Based on reference sample no. D2 S11 001 at Station 22, greenschist dominated by chlorite, actinolite with quartz and calcite. The name comes from commonly having an abundance of green minerals such as chloride and actinolite. Texture was lepidoblastic (Figure 5.14).

As reported by Miyazaki et al, (1996); Parkinson et al., (1998) in Wakita (2000), greenschist formed by regional metamorphism of mafic igneous rocks usually basaltic rocks, under greenschist facies metamorphism (usually produced by regional metamorphism, typically 300 - 450°C and 1 – kilobars). The foliation in greenschist was resulting in minerals alignment, especially of chlorite and actinolite. Greenschist was metamorphic rocks that formed under the lowest temperature and pressure by regional metamorphism.

Referring to Barrovian Facies Sequence by David S., (1983), the equilibrium of mineral assemblages of rocks subjected to greenschist facies conditions depends on primary rock composition (Figure 5.15). It can be conclude that this greenschist can be classified as Mafic Protolith due to consisting of minerals chloride and actinolite (Figure 5.16).

Figure 5.13 Greenschist sample, 13 cm.

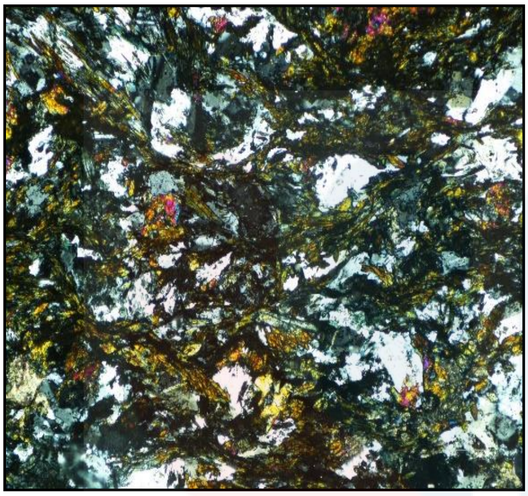


Figure 5.15 Abundance of green minerals in Greenschist. XPL image, 40x magnification.

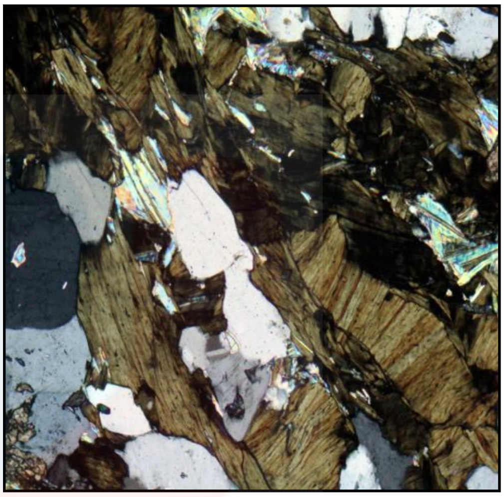
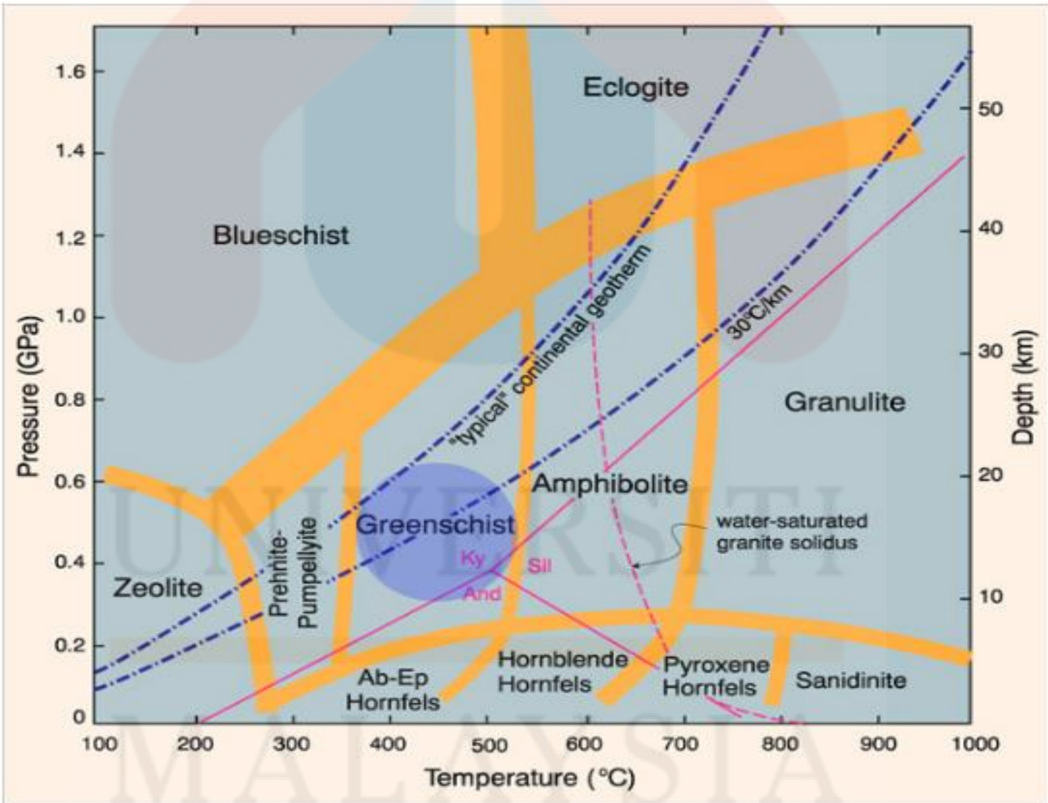


Figure 5.14 Lepidoblastic layers and chloride in a greenschist. XPL image, 100x magnification.



P/T

Figure 5.16 Diagram for Metamorphic Facies (Sources : David S.,1983).

g. Blueschist

Blueschist was located at Station 23. This lithology exposed very well in area of Salo Birubiru. The outer surface was dark grayish in colour, while the fresh inside part was grayish blue. Greenschist was a fine to medium grained, foliated and have schistose texture (Figure 5.17). Based on reference sample number D2 S12 001, blueschist dominated by glaucophane. It also have chlorite, muscovite and garnet (Figure 5.18).

Miyazaki et. al., (1996) stated that blueschist was formed by low temperature, high pressure regional metamorphism of basaltic protoliths. Blueschist forms by the metamorphism of basalt and rocks with similar composition at high pressure and low temperatures, approximately corresponding to a depth of 15 to 30 kilometres and 200 to 500°C. Usually this blueschist was associated with subduction zones. In many cases, the chemical composition of blueschist was characterize the type of metabasalt, therefore they were associated with upper subduction zones correlated to the origin of the oceanic crust (Figure 5.19). Parent rock : Basalt and Seafloor sediments.

Figure 5.17 Blueschist sample, 10cm.

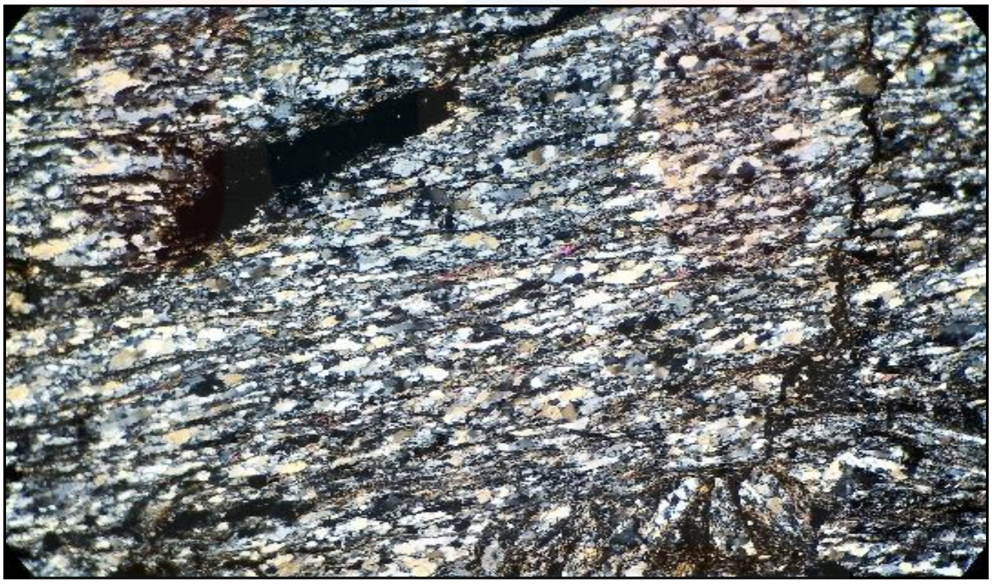
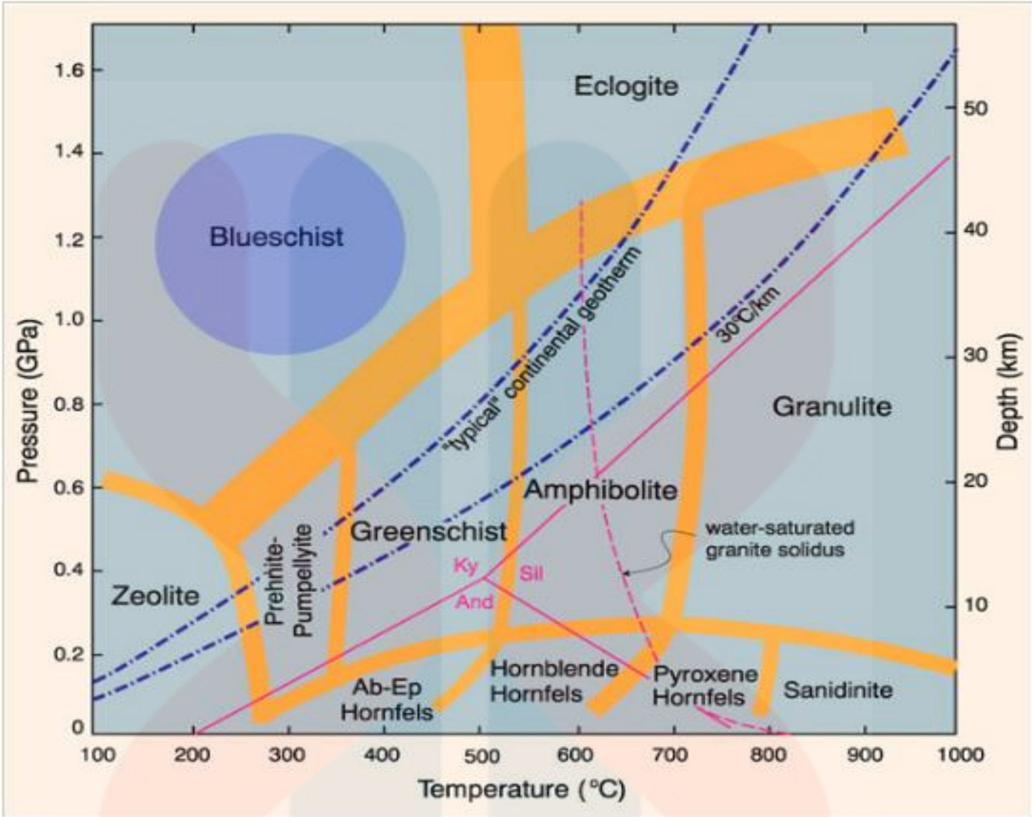


Figure 5.18 Glaucophane (blue) crystals in a blueschist. XPL image, 40x maginification.



P/T

Figure 5.19 Diagram for Metamorphic facies. (Sources : David S., 1983).

CHAPTER 6

CONCLUSION

6.1 Conclusion

The objective of this research were achieved and the results were reported in Chapter 4 and 5. Based on the description in the previous chapters, it can be generally concluded the geological conditions of the study area as follows:

Geomorphology of the study area was divided into two units which is medium relief morphology unit (hill and low hill) and low relief morphology unit (low-lying plain). Mostly type of rivers in the study area was classified as a permanent river. The flow pattern of the river was dominated by a dendritic stream pattern.

There were three types of lithology in the study area consisted of metamorphic rocks, ultramafic rocks and sedimentary rocks. Stratigraphy of the study area was divided into 4 units sequentially from the oldest to the youngest lithology unit as follows schist unit, melange unit, ultramafic unit and limestone unit. Besides that, geological structures developed in the research area are drag fold, minor anticline fold, non-systematics of joint structure and reverse fault due to characteristic of fault such as fault breccia and spring.

Metamorphic rock in the study area known as Schist Unit according to the dominance of schist compared to other type of metamorphic rocks such as phyllite, quartzite, garnet mica schist, greenschist and blueschist. These metamorphic rock was determined based on texture, structure and composition of the mineral content.

Based on these indications, it had been interpreted the depositional deposition of this unit and type of metamorphic grade.

In addition, the Bantimala Block shows a strong tectonic fabric striking which was defined as a deep subduction zone. Therefore, the metamorphic rocks of Barru Block was belong to a range of tectonic environment of the Bantimala-Barru Complexes. Metamorphic rocks in Barru block were slightly younger compared to Bantimala Complex due to different metamorphic environment.

As a conclusion, referring to all the interpretation, it can be concluded that all two objectives of the study area was answered. Firstly, the map of the study area with the scale of 1:25000 was updated. Next, the characteristic of metamorphic rocks based on thin section was identified.

6.2 Suggestion

Based on the field observation in the study area, this area has its own uniqueness in term of geological knowledge. This is because of this study area was located near to the Bantimala Basement Complex. Bantimala Complex and Barru Complex respectively, and separated each other within 30 kilometers (km). The complexes consist of metamorphic, ultramafic and sedimentary rocks, which part of these rocks were chaotically mixed as melange. The recommendation for this research is to explore geological condition chaotic, mixed rocks (melange) and the relationship between distribution of rocks that exposed in Desa Anabanua, Barru Sub-District, Barru Regency.

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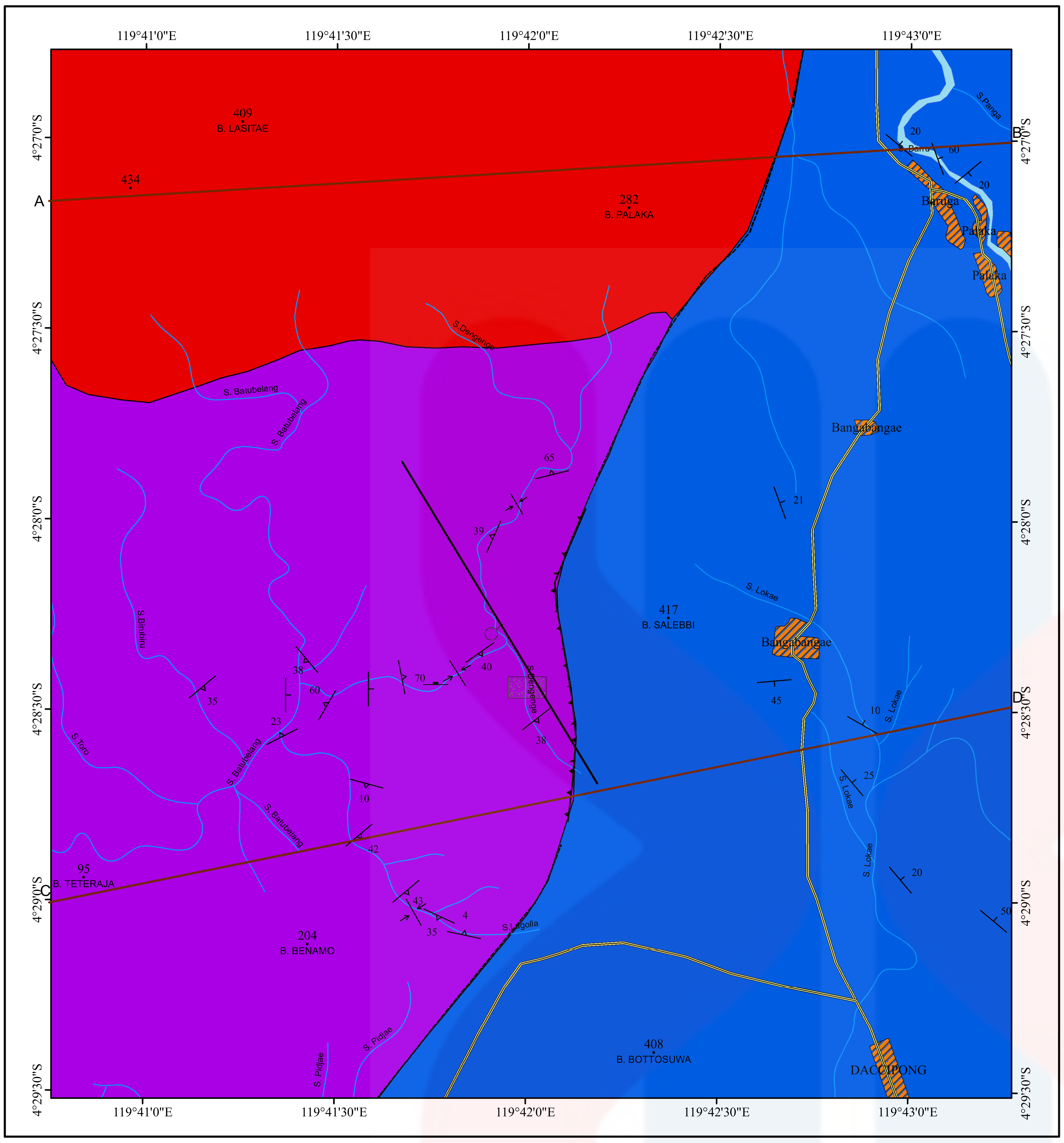
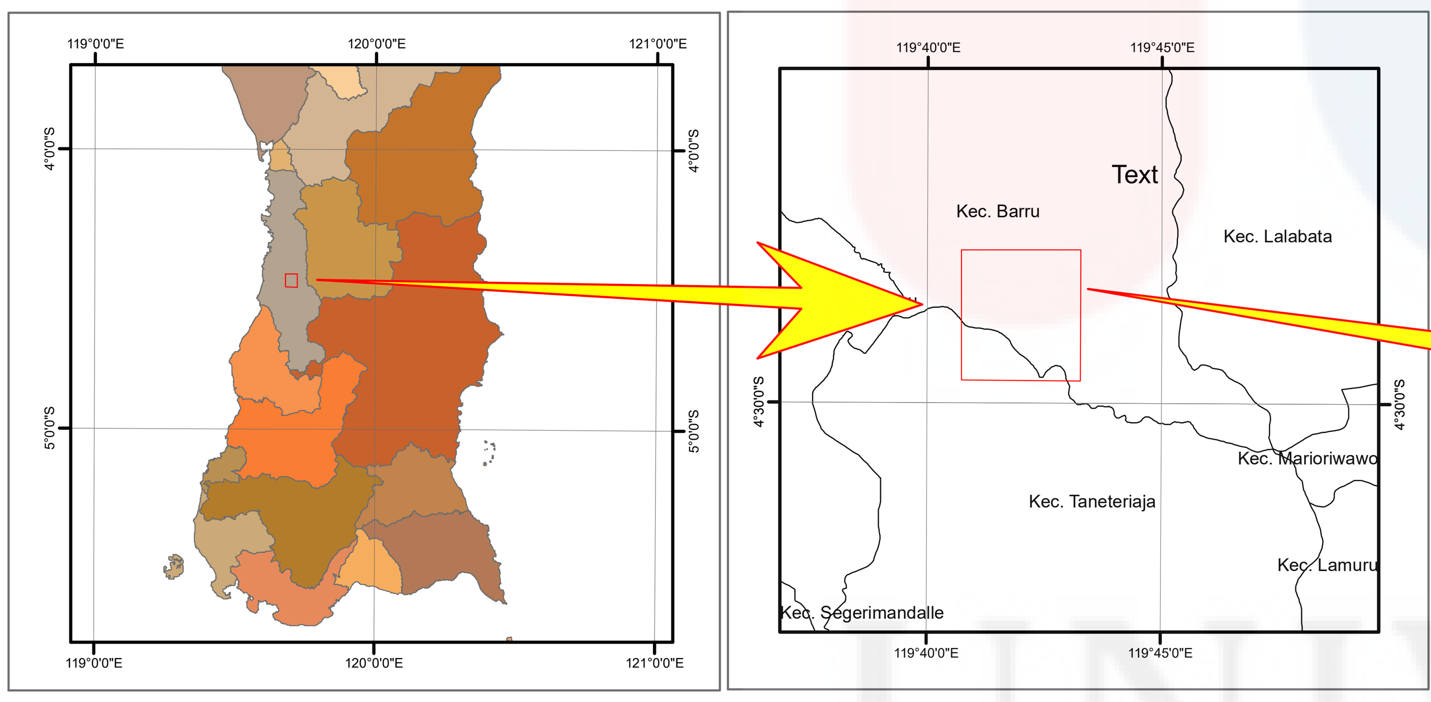
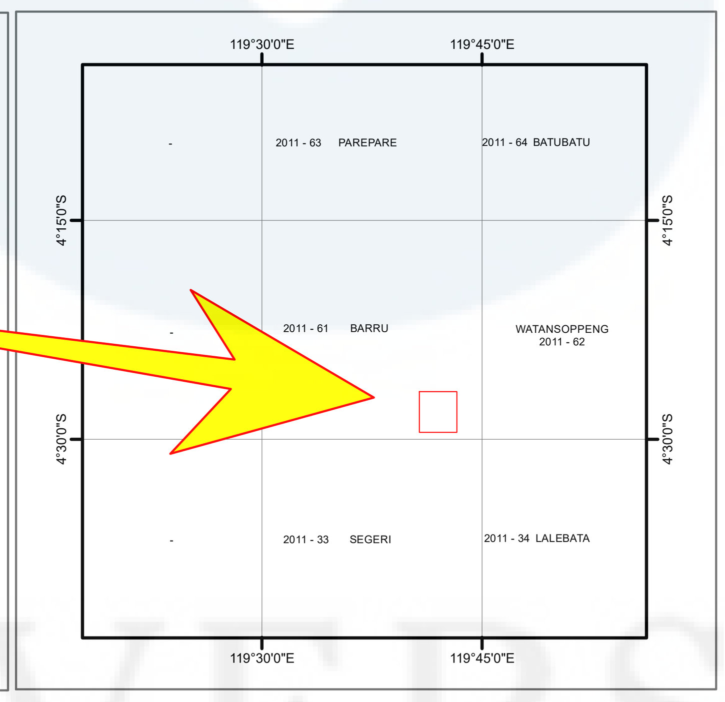


MAP OF STUDY AREA

INDEX MAP





GEOSCIENCE PROGRAMME
FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

GEOLOGICAL MAP

GENERAL GEOLOGY AND PETROGRAPHY OF METAMORPHIC ROCK IN DESA ANABANUA, BARRU SUB DISTRICT, BARRU REGENCY, SOUTH SULAWESI, INDONESIA.

N

0 150 300 600 900 1,200 Meters

Contour Interval = 25

Scale 1: 25000

BY :
AZIRA BINTI AHMAD TAMIZI
E13A031

INDONESIA
2017

Lithology Unit | **Age**

Limestone — Early Eocene - Middle Miocene

Unconformity

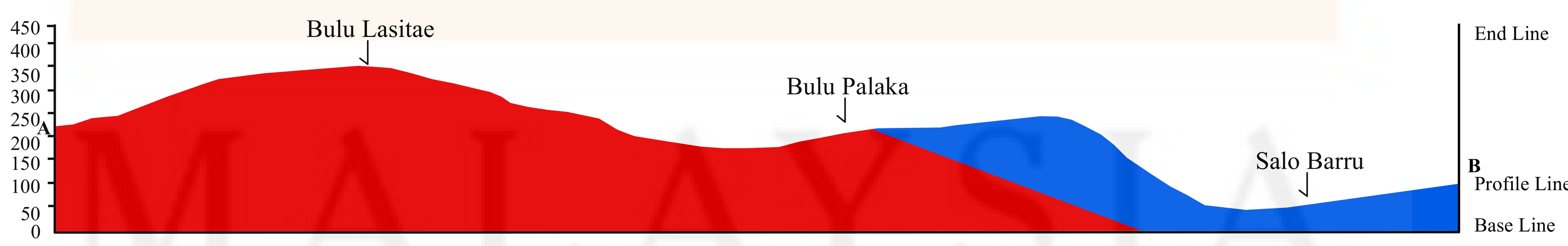
Melange Unit — (Lower Cretaceous)

Ultramafic
Schist — Triassic

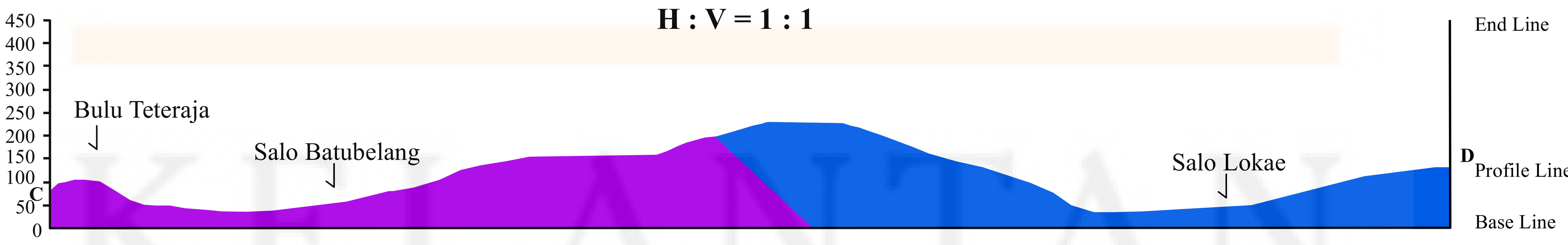
LEGEND

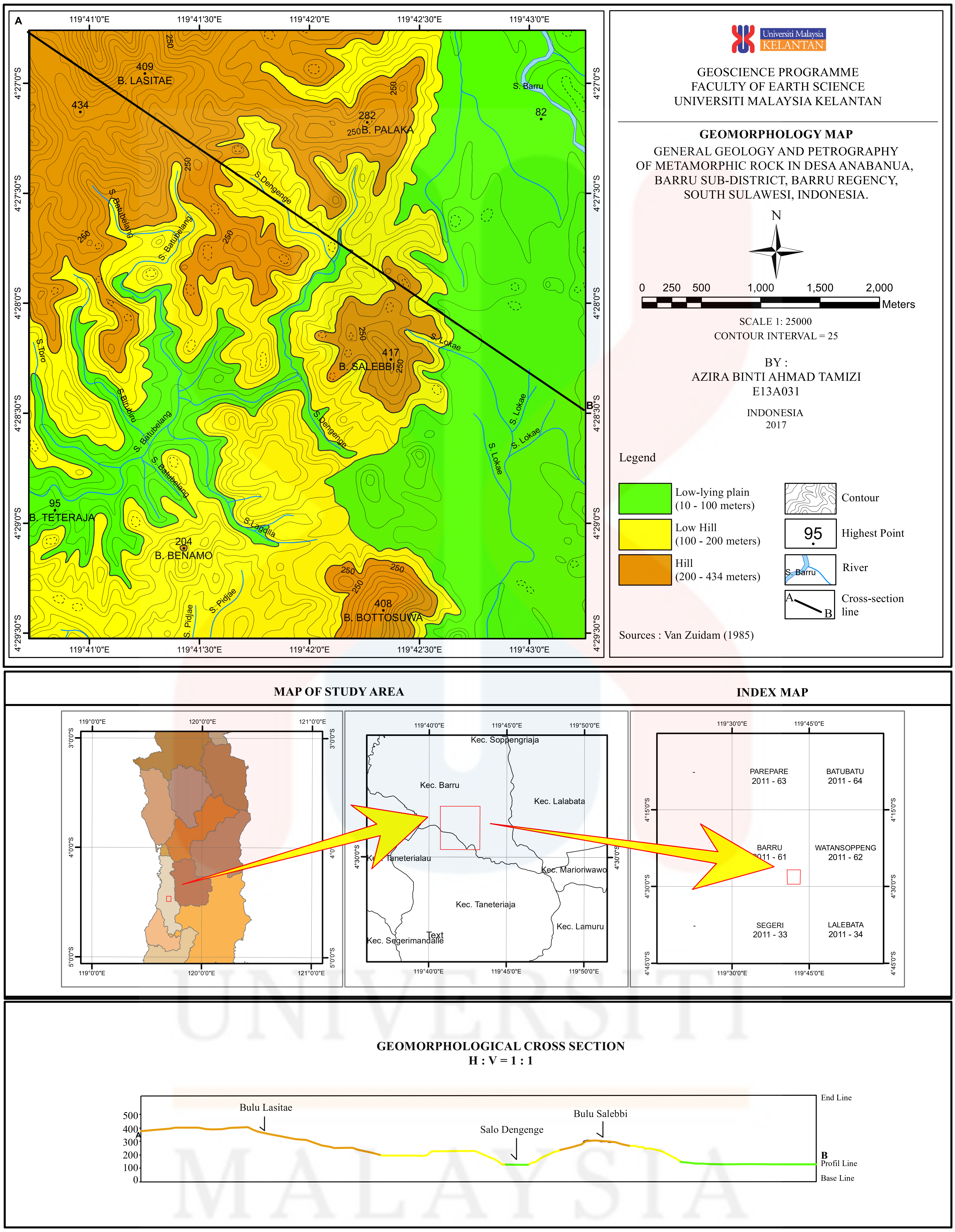
Road
River
Highest Point
Village
Cross Section
Joints
Fault Breccia
Thrust Fault
Strike Dip
Fault
Spring
Folding

GEOLOGICAL CROSS SECTION A - B
H : V = 1 : 1



GEOLOGICAL CROSS SECTION C - D
H : V = 1 : 1

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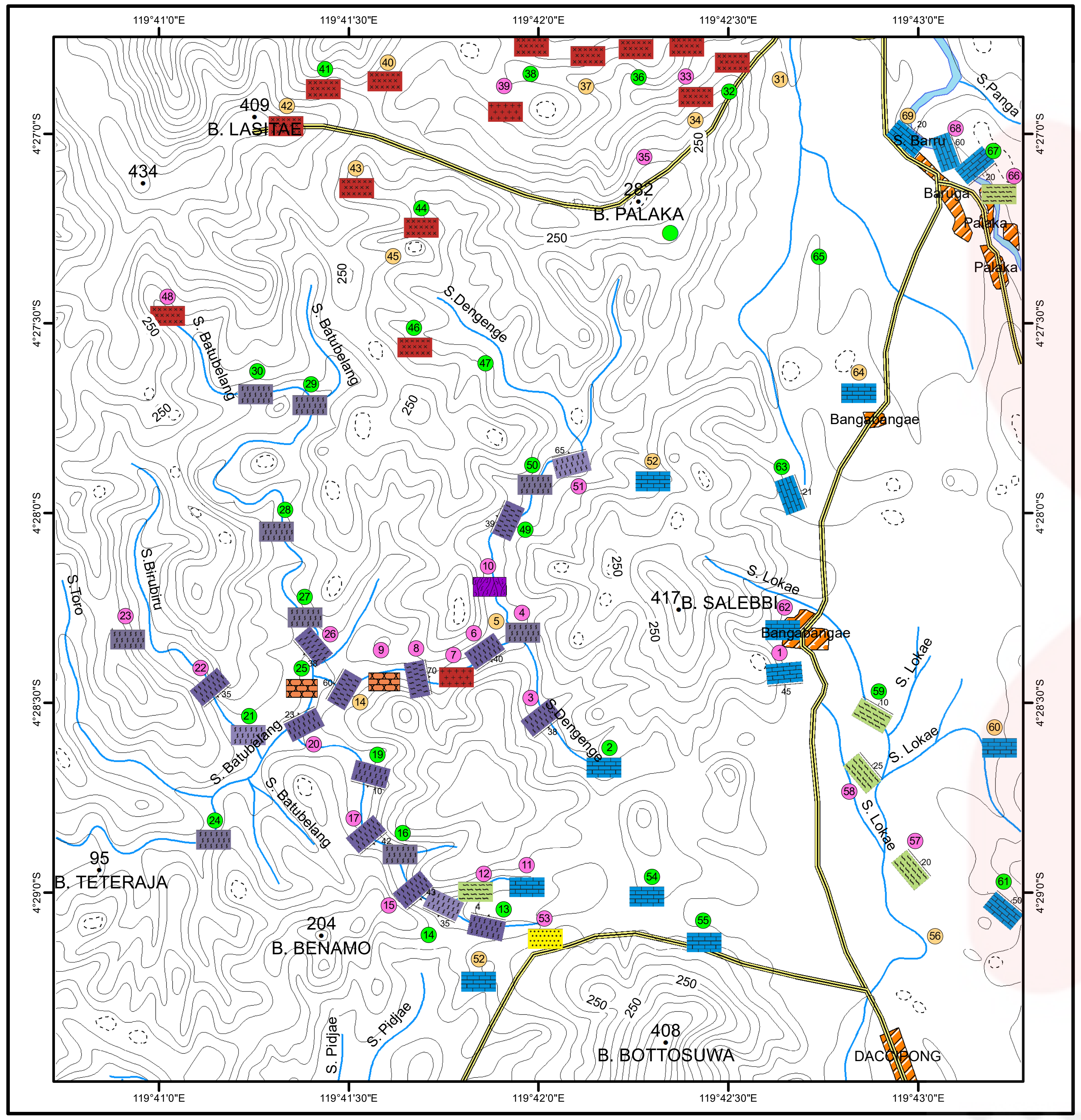
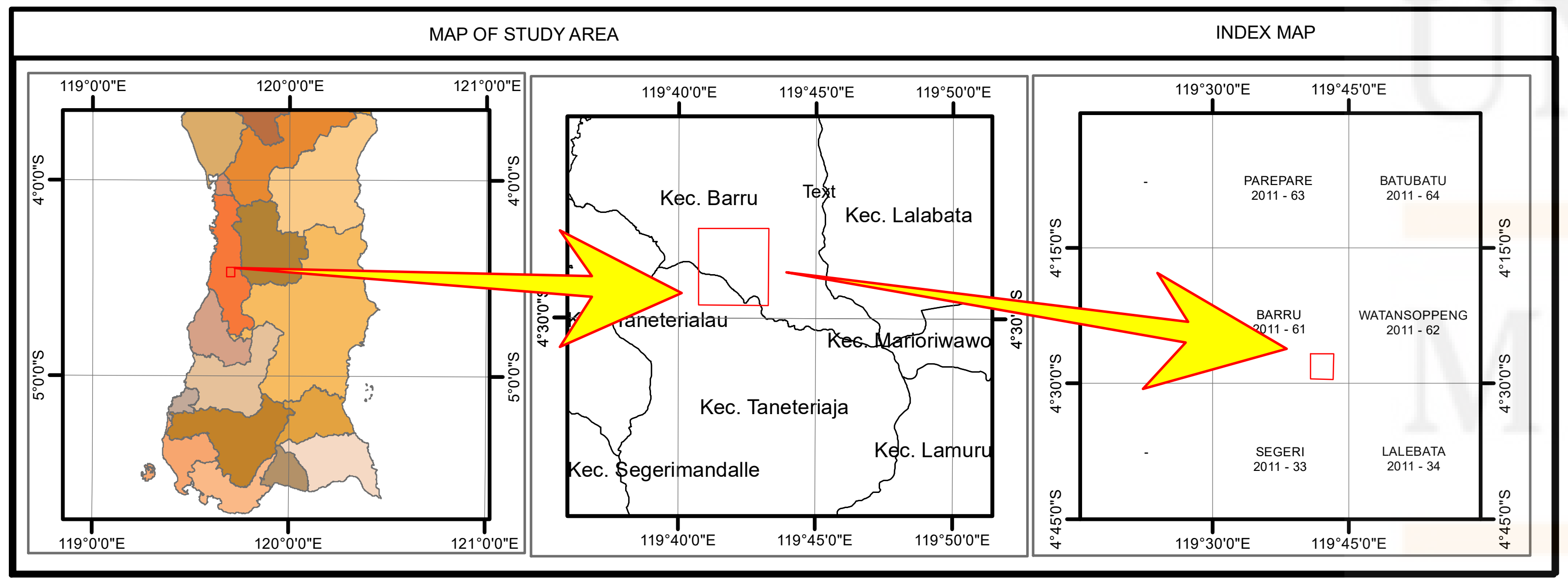
GEOSCIENCE PROGRAMME
FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN
GEOMORPHOLOGY MAP
GENERAL GEOLOGY AND PETROGRAPHY
OF METAMORPHIC ROCK IN DESA ANABANUA,
BARRU SUB-DISTRICT, BARRU REGENCY,
SOUTH SULAWESI, INDONESIA.
N
0 250 500 1,000 1,500 2,000 Meters
SCALE 1: 25000
CONTOUR INTERVAL = 25
BY :
AZIRA BINTI AHMAD TAMIZI
E13A031
INDONESIA
2017
Legend
Low-lying plain (10 - 100 meters)
Low Hill (100 - 200 meters)
Hill (200 - 434 meters)
Contour
95 Highest Point
S. Barru River
A B Cross-section line
Sources : Van Zuidam (1985)
119°41'0"E
119°41'30"E
119°42'0"E
119°42'30"E
119°43'0"E
4°27'0"S
4°27'30"S
4°28'0"S
4°28'30"S
4°29'0"S
4°29'30"S
A
B
409
B. LASITAE
434
282
250 B. PALAKA
82
S. Barru
S. Dengenge
S. Batubelang
S. Toro
S.Bulu
S. Lokae
417
B. SALEBBI
95
B. TETERAJA
204
B. BENAMO
S. Lagolla
S. Pidjae
408
B. BOTTOSUWA
250
MAP OF STUDY AREA
119°0'0"E
120°0'0"E
121°0'0"E
3°0'0"S
4°0'0"S
5°0'0"S
119°40'0"E
119°45'0"E
119°50'0"E
Kec. Soppengriaja
Kec. Barru
Kec. Lalabata
Kec. Taneterialau
Kec. Mariorawawo
Kec. Taneteriaja
Kec. Lamuru
Kec. Segerimandalle
Text
INDEX MAP
119°30'0"E
119°45'0"E
4°15'0"S
4°30'0"S
4°45'0"S
PAREPARE 2011 - 63
BATUBATU 2011 - 64
BARRU 2011 - 61
WATANSOPPENG 2011 - 62
SEGERI 2011 - 33
LALEBATA 2011 - 34
GEOMORPHOLOGICAL CROSS SECTION
H : V = 1 : 1
Bulu Lasitae
Salo Dengenge
Bulu Salebbi
500
400
300
200
100
0
A
B
End Line
Profil Line
Base Line





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STATION MAP

GENERAL GEOLOGY AND PETROGRAPHY OF METAMORPHIC ROCK IN DESA ANABANUA, BARRU SUB DISTRICT, BARRU REGENCY, SOUTH SULAWESI, INDONESIA.

N

0 250 500 1,000 M

SCALE 1: 25000
CONTOUR INTERVAL = 25

BY:
AZIRA BINTI AHMAD TAMIZI
E13A031

INDONESIA
2017

Legend :

: Observation
: Sample and Petrographic Analysis
: Geomorphology
: Limestone
: Schist
: Phyllite
: Claystone
: Sandstone
: Peridotite
: Chert
: Quartzite
: Contour
417 : Highest Point
: River
: Village
: Road