GEOTECHNICAL PROPERTIES AND CHARACTERISTICS OF METAMORPHIC ROCK MASS ON POBOYA GOLD MINE

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ABSTRACT

Gold pricesrisequite highevery year. Therefore, there are many people gold minings in Indonesia. Poboya gold mine considered as one of the existing people mines where goldstaken from metamorphic rocks. Every day, the miners conduct quarrying to extract gold ores regardless of the slope stability. The slope stability commonly affected by the characteristic and the technical properties of the rock mass. This study aimed at determining the geotechnical properties and the characteristics of the metamorphic rock mass of Poboya gold mine. The study was carried out at Poboya gold mine which is located at Palu city, using two methods of geological survey and laboratory testing. The geological survey resulted that lithological Poboya gold mine area is dominated by the metamorphic rocks of *gneiss* and *schist*. Slope condition at the lithological area of *gneiss* have a relatively high weathering compared to the *schist* lithology, and this is due to that the age of *gneiss* rock older than the age of *schist* rocks. The great weathering affected the geological structure and the strength of the available rocks. The Uniaxial Compressive Strenght test showed the values of 31 MPa for the *gneiss* rocks and the value of 41 MPa for *schist* rocks, and this is due to the weathering condition of *gneiss* rock, and as a result, the compressive strength became smaller. The results of the characteristics and technical properties of rock mass at the Poboya gold mine used as a preliminary data in designing the safe and the stable slopes of the pit.

Keywords:Characteristics, Technical Properties, Gold Mine

A. INTRODUCTION

The features and technical properties of rock mass are essential for the mining activities due to the process of extracting and slope slicing that causes the slope instability. Poboya is one of the gold mines where miners conduct quarrying every day using hammer and betel to extract gold ores. Therefore, it is necessary to identify the characteristics and rock mass properties to maintain the stability while designing rock slopes. If the slope is unstable, there will be a landslide occurring in the future, risking lives of miners, properties, security equipment and the production of the mines as well. Aswegen and Laos (2003) asserted that rock mass characteristic is a requirement for mine design to minimize the dangers occurrence.

The purpose of this study was to determine the features and technical properties of rock mass at Poboya gold mine, Palu. The characteristics and technical properties of the rock mass were determined based on the geological survey and the laboratory testing. The study was carried out at Poboya area, located in Mantikulore district, Palu, Central Sulawesi. Poboya region is a concession area owned by a mining company, PT Citra Palu Mineral. The company has not conducted, up to now, any mining activity in this area, thus, it turned to be a people mine. This mine was opened in 2006. The road to the pit is very bumpy, along with the river as far as four kilometers, surrounded by bare hills on the left and right side. The research site as seen in Figure 1.

B. LITERATURE STUDY

1. The geological condition of Poboya

Poboyais located in the eastern section of the central basin connected to PaluKoro fault, which is part of the Northern Neogen of Sulawesi Island (Kavalieris et al., 1992). This basin associated with the filler conglomerate molassesfrm, which mostly occurs in the southeast of Palu city. The complex local geology is represented by sedimentary and metavolcanic of the Tinombo Formation in west vein and gneissic and metamorphic rocks on the eastern of the compoundToboli (Marten, 1999).

According to Muhardjoand Kaschul (1999), the mineralization at Poboya estimated as a low sulphidation epithermal system that formed at metamorphic rock units. The vein system constructed at the *northwestern*Toboli path at the Eastern Fault of Palu. The Toboli formation consists of gneiss and metamorphic rocks, including *biotite gneiss* interspersed by *schist.*

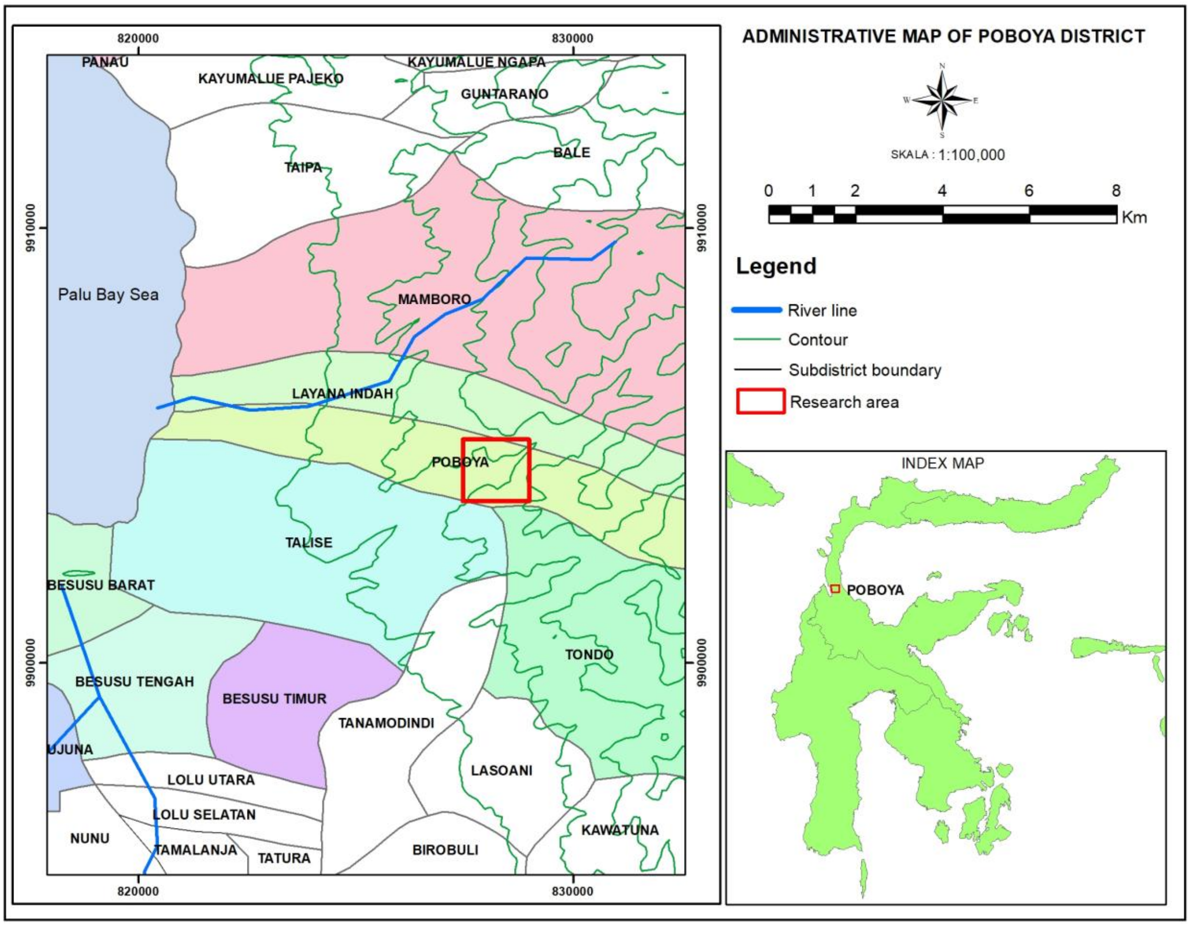


Figure 1 Map of Research Site.

This formation penetrated by *granodiorite, feldspar porphyry* and, *monzonite* for the bedrock forming the highlands along the back of the north arm of Sulawesi.

Rocks that formed Poboya areas, according to stratigraphic sequences for old ages to young ages (Sukamto et al. 1973).

a. Metamorphic rocks

These rocks found on the eastern border of the study site, which is also a boundary of Palu with Parimo regions. *Schist* rocks clogged with more intensive surface weathering. The areas composed of these rocks, vegetated in general, thus the intact rock physical conditions can only be observed around the river cliffs in the northeast or upstream of Poboyariver.

b. Intrusion rocks

The intrusion rocks that found in the study area have a relatively small mass or are local intrusive bodies that infiltrate the older rocks. The physical properties of rocks have been fractured, fragmented and partly weathered.

c. The molasses type of sedimentary rock

These rocks consist of conglomerates, sandstones, siltstone, and claystone. They are widespread in the study area and dominant as well with about 90% dominating the distribution of constituent rocks. The irregular coating properties of these rocks in some places can be observed primarily on the cliffs of the Poboyariver.

d. Alluvial rocks

This material is a constituent of Poboya basin which is characterized by terrestrial morphology. The composition of alluvial fragments consists of schist, diorite gneiss, basalt, and granite.

2. Geomechanical characteristics of discontinuity

Wyllie andMah (2004), data collection of discontinuities through geological surveys by classifying discontinuities, including the formation process. Several parameters of discontinuity considered in the geological investigation such as types of rock, types of discontinuity, scale, orientation, spacing, persistence, roughness, wall strength, aperture, infilling, seepage, set a number of discontinuity, shape, block size, and degree of weathering. The parameters used in this study are:

a. Types ofdiscontinuity

Wyllie andMah (2004) described the general standardof discontinuity types as follows.

1. The Faultis the set of discontinuity throughout the movement that occurs larger or less which are usually parallel or subparallel.
2. Beddingis the surface aligned with the sediment surface. The bedding field should not be assumed as horizontal.
3. Foliationis the parallel orientation of the mineral or metal in the metamorphic rocks.
4. Jointis the discontinuities that do not have a relative movement to be observed, generally cut first surfaces such as bedding, cleavage, and schistosity. The sequence of parallel joints called a series of joint, which two or more sets of intersecting produce the joint system. Two sets of the vertical joint are called orthogonal.
5. Cleavageis the parallel discontinuities that formed in the non-competent layers in a series of bedding of the competence level. In general, the cleavage fields not controlled by mineral particles in a parallel orientation.
6. *Schistosity*, foliation in schist orcrystal rocks with coarse grains due to the parallel structure of platy mineral grains or prismatic type such as mica

b. Discontinuity spacing

Devkota et al. (2009) clarify that discontinuity spacing is one of the important parameters to determine the rock mass quality.

c. Discontinuity Persistence

Discontinuity persistence is a parameter to measure the length or the extent of the present discontinuities of the rock mass (Park, 2005; Wyllie andMah 2004).

d. Roughness

Ge et al. (2015) explainthat roughness is one of the most important parametersin understandingthe behavior and characteristics of permeability of the rock mass.

e. Wall strength

Wyllie andMah (2004) classifythe rock wall strengthin particular into seven gradesas shown in Table 1, this classification is based on the value of uniaxial compressive strength (UCS), ranging from the strongest rock with UCS values greater than 250 MPa, until very weak rocks with UCS values from 0.25 to 1.0 MPa.

Table 1the Classification of Rocks Wall Strength Based on Uniaxial Compressive Strength Values (Wyllie danMah, 2004).

Grade	Description	Field Identification	UCS (MPa)
R6	Very strong rocks	Using geological hammer	> 250
R5	Very strong rocks	Needs a lot of geological hammer strikes to break it.	100-250
R4	Strong rocks	Needs more than one geological strike to break it.	50-100
R3	Medium strong rocks	Can be broken by a single strike of geological hammer	25-50
R2	Weak rocks	can be exfoliated using a knife carefully, the point of shallow indentation using a geological hammer	5,0-25
R1	Very weak rocks	Crushed by a geological hammer and can be exfoliated by a knife	1,0-5,0
R0	Very weak rocks	Can be stabbed using fingernails	0,25-1,0

f. Aperture

Giani (1992) explainsthat aperture can be distinguished based on the initial size of discontinuities, as shown in Figure 2.

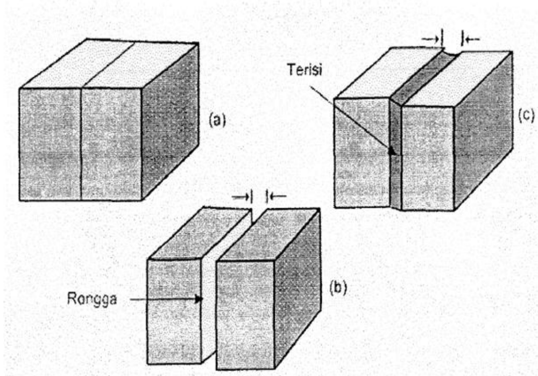


Figure 2 Rock blocks withdiscontinuities (Giani, 1992): a) closed, b) opened, c) filled

g. Infilling

PluijmandMarshak (2004) deliberatethat base on the pattern, there are two types of infillings can be found on discontinuities and also can be used to predict the direction of fracture opening and the speed formed as well as shown in Figure 3.

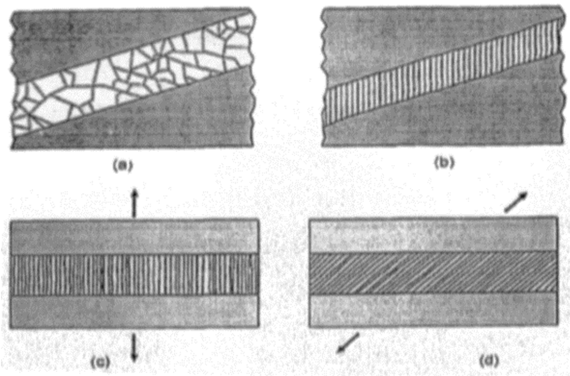


Figure 3 Types ofvein infillings (PluijmandMarshak, 2004): (a) blocky vein, (b) fibrous vein, (c) and (d) direction of fracture openings of discontinuities are equal to the direction of an arrow.

h. Weathering

Hack and Price (1997) assertthat weathering is the in-situ damage of the intact rocks and rock mass as well as a result of physical and chemical processes under the influence of atmospheric and hidrosfer factors, this shows that the decay and changes from the original conditions to the new ones.

3. Technical properties of rocks

Rai et al. (2010) explainthat rocks have particular properties need to identify, namely physical and mechanical properties.
General parameters on the physical properties are a weight of content, specific gravity, porosity, absorption and pore numbers, while the standard mechanical properties known as static and dynamic mechanical properties. In addition to the standard mechanical properties are also known mechanical properties and cuttability obtained from the index test. Physical and mechanical properties tests were conducted to determine the strength of rocks.

C. RESEARCH METHOD

1. Geological survey

The geological survey conducted at a research site to determine the rock lithology, to collect the discontinuities data and to take samples of rocks. The slope discontinuity data obtained from field survey are:

a. Slope azimuth measured usinga geological compass,
b. Orientation of the geological structure in the form ofdip and dip direction measured using a compass,
c. Types of the geological structureare in the shapeof solidity, faults, and rock types,
d. Spacing shows the degree of geological structure density,
e. Presence or absence of water seepage,
f. Roughness degrees of geological structure surfaces,
g. The infilling material of geological structure and thickness,
h. Rocks name,
i. Rock strength level.

2. Physical and mechanical properties test

In the geological survey, rock samples that taken used for the technical properties analysis in the laboratory are the physical and mechanical properties of rocks. Test of physical and mechanical properties of rocks accomplished based on American Standard Test Material (ASTM). The properties tests consist of:

a. moisture content (ASTM D 2216-98),
b. specific gravity (ASTM D 854-02)
c. wight content (ASTM D 5030-13a),
d. uniaxial compressive strength test (ASTM D 2938-95)

The value of cohesion (c) andshear angle (^{o}) obtained by using aRocData 5.0 software to correlate the laboratory data.Paramaters included into RocData as mentioned in Table 2.

Tabele 2 Input Paraemeters of RocData

Lithology	σ_{ci} (MPa)	GSI	mi	D	Ei (MPa)	λ (MN/m^3)	Slope High (m)
Gneiss	31	49	5	0,7	4.853	0,0023	61
Schist	41	43	5	0,7	15.594	0,0025	33

D. RESULT AND DISCUSSION

1. Lithology condition

Methamorphic rocks dominate the lithology that formedthe research site. The metamorphic rocks found in the study area are gneiss and schist.

2. Discontinuity mapping results

After the results of measurement and observations at Poboya gold mine has been obtained, then discontinuity mapping is conducted. The mapping carried out in two locations based on the types of rocks (*lithology*).The results of discontinuity mapping in location 1 (*gneiss lithology)*can be seenin Table 3.While the results of location 2 (*schist*lithology) can be seen as well in Table 4.

Table3 Results of discontinuity mapping at location 1 (*gneiss lithology)*

No.	Type	Dip	Dip Direction	Spasi	Persistence	Aperture	Roughness	Infilling	Weathering	Ground Water
		(o)	(N……..°E)	(cm)	(cm)					
1	Joint	84	130	0	17	0	Slighty Rough	None	Highly weathered	Dry
2	Joint	50	215	60	24	0.1	Slighty Rough	None	Highly weathered	Dry
3	Joint	81	146	21	17	0.1	Slighty Rough	None	Highly weathered	Dry
4	Joint	81	144	32	70	0	Slighty Rough	None	Highly weathered	Dry
5	Joint	80	121	26	95	0.1	Slighty Rough	None	Highly weathered	Dry
6	Joint	83	169	19	76	0.1	Slighty Rough	None	Highly weathered	Dry
7	Joint	78	101	20	116	0.1	Slighty Rough	None	Highly weathered	Dry
8	Joint	89	114	26	210	0.1	Slighty Rough	None	Highly weathered	Dry
9	Joint	89	127	46	100	0.1	Slighty Rough	None	Highly weathered	Dry
10	Joint	89	220	12	93	0	Smooth stepped	None	Highly weathered	Dry
11	Joint	89	221	11	98	0.1	Smooth stepped	None	Highly weathered	Dry

Table4 Results of discontinuity mapping at location 2(*schist lithology)*

No.	Type	Dip	Dip Direction	Spasi	Persistence	Aperture	Roughness	Infilling	Weathering	Ground Water
		(o)	(N…….°E)	(cm)	(cm)					
1	Joint	27	115	0	70	0.5	Slighty rough	None	Slightly weathered	Dry
2	Joint	74	205	30	49	0.1	Slighty rough	None	Slightly weathered	Dry
3	Joint	55	115	29	40	0.1	Slighty rough	None	Slightly weathered	Dry
4	Joint	42	65	24	133	0.1	Slighty rough	None	Slightly weathered	Dry
5	Joint	64	72	43	28	0.1	Slighty rough	None	Slightly weathered	Dry
6	Joint	41	72	100	60	0.2	Slighty rough	None	Slightly weathered	Dry
7	Joint	76	282	20	120	2	Slighty rough	soft	Slightly weathered	Dry
8	Joint	50	105	60	98	0.1	Slighty rough	None	Highly weathered	Dry
9	Joint	78	296	11	40	1	Slighty rough	None	Highly weathered	Dry
10	Joint	46	109	45	180	0.1	Slighty rough	soft	Highly weathered	Dry
11	Joint	81	313	7	40	0.1	Slighty rough	None	Highly weathered	Dry
12	Joint	39	91	15	64	0.2	Slighty rough	soft	Highly weathered	Dry
13	Joint	60	297	20	9	0	Slighty rough	None	Highly weathered	Dry
14	Joint	29	109	105	53	0	Slighty rough	None	Highly weathered	Dry
15	Joint	71	295	26	32	0.1	Slighty rough	None	Highly weathered	Dry
16	Joint	82	119	137	37	0	Slighty rough	None	Highly weathered	Dry
17	Joint	78	173	143	15	0	Slighty rough	None	Highly weathered	Dry
18	Joint	26	45	20	35	1	Slighty rough	soft	Highly weathered	Dry
19	Joint	79	32	300	24	1	Slighty rough	None	Highly weathered	Dry
20	Joint	82	196	5	28	1	Slighty rough	None	Highly weathered	Dry
21	Joint	39	130	220	120	1.5	Slighty rough	soft	Highly weathered	Dry
22	Joint	72	325	60	209	7	Slighty rough	soft	Highly weathered	Dry
23	Joint	39	117	90	119	0.5	Slighty rough	None	Highly weathered	Dry
24	Joint	68	340	29	50	3	Slighty rough	soft	Highly weathered	Dry
25	Joint	41	155	73	20	0.5	Slighty rough	soft	Highly weathered	Dry

A. Location 1 (*Gneiss lithology)*

Based on results of discontinuity mapping in Table 3, it obtained average *dip* value of 81°, *spacing*average is 37 cm, *persistence*average is 83 cm,and*aperture*average is 1 cm.Condition of roughness parameteris predominantly slightly rough, and *weathering*condition is predominantly *highly weathered*, grand water condition is mostly*dry*and dominantly with none *infilling*.Result of discontinuity point plot at location 1 of *gneiss*lithology that there is a set discontinuity as shown in Figure 4. It obtained from a set 1 of *gneiss* that the discontinuity orientationshowsthe value*dip*of 84°with the value of*dip direction* N133°E.

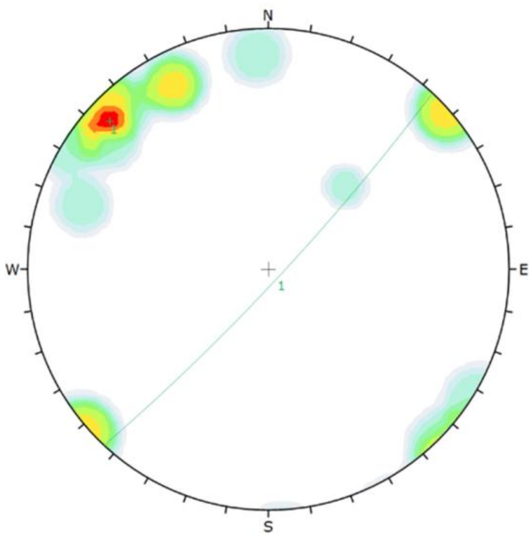
B. Location 2 (*Schist lithology)*

Based on results of the discontinuity mapping in Table 4,it obtained average *dip*value of 58°, *spacing* average is 64 cm, and *persistence*average is 67 cm andthe *aperture*average is 1 cm.

Condition of roughness parameter is predominantly *slightly rough*,and *weathering* condition is mostly*highly weathered*, grand water condition is predominantly *dry*and dominantly with none infilling. Result of discontinuity point plot at location 2 of *schist* lithology that there are two sets of discontinuities as shown in Figure 5. From the set 1 of *schist*, it obtained the discontinuity orientation which shows *dip* value of 51°with*dip direction* value of N119°E. From the set 2 of *schist*, it obtained the discontinuity orientation which shows*dip* value of 74°with*dip direction* value of N307°E.

Slope condition at *gneiss* lithology location has a relatively high weathering compared to*schist* lithology, and it is due to the age of *gneiss* rocks is older than the age of *schist* rocks. Position of *gneiss* rocks are below *schist* rocks without a structural reversal. Asa result, it will affect the visual condition of the geological structure of Poboya gold mine. Structure orientation is in form of geolocial stocks which some can only be observed on slopes that show nonoriented stocky traces.

(a)



Color	Density Concentrations
	0.00 - 2.40
	2.40 - 4.80
	4.80 - 7.20
	7.20 - 9.60
	9.60 - 12.00
	12.00 - 14.40
	14.40 - 16.80
	16.80 - 19.20
	19.20 - 21.60
	21.60 - 24.00
Contour Data	Pole Vectors
Maximum Density	23.34%
Contour Distribution	Fisher
Counting Circle Size	1.0%

	Color	Dip	Dip Direction	Label
User Planes				
1		84	133	

Plot Mode	Pole Vectors
Vector Count	11 (11 Entries)
Hemisphere	Lower
Projection	Equal Angle

(b)

Figure4. Discontinuity patten in location 1*gneiss*litology: Discontinuity view on field, b) Plot of discontinuity point.

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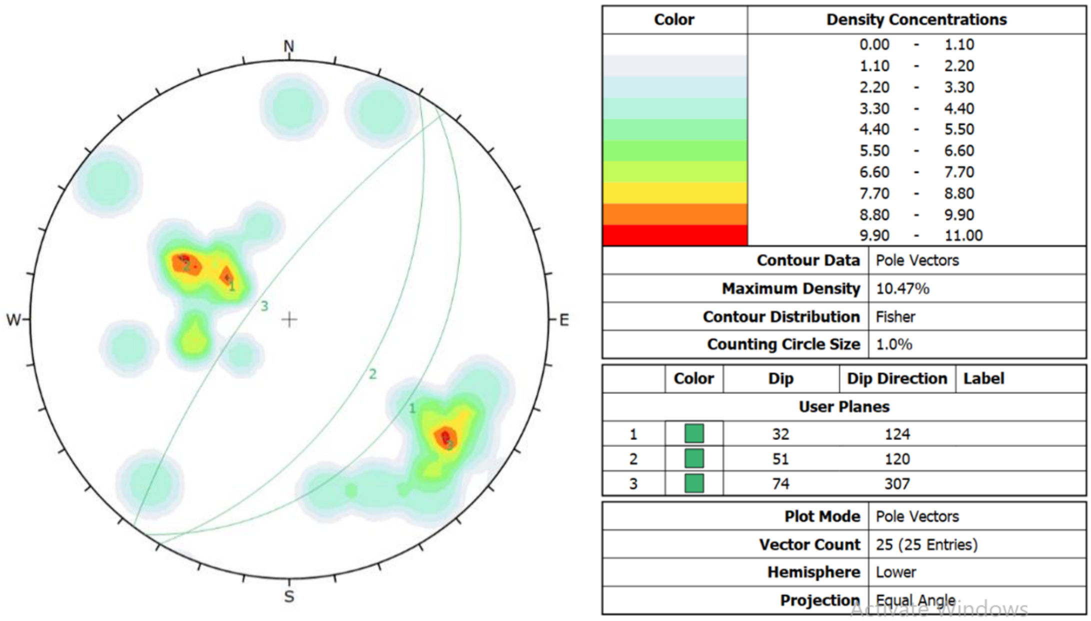
(a)



(b)

Figure 5. Discontinuity patten in location 2*schist*litology: Discontinuity view on field, b) Plot of discontinuity point.

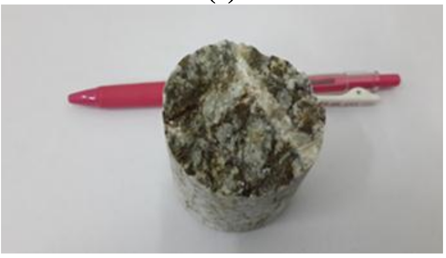
Table 5Test results of rocks technical properties.

Location	Litologi	D (cm)	L (cm)	*Physical Properties Test*				*Uniaxial Compressive Strength* (UCS)			*RocData* 5.0	
				w (%)	γ_b (gr/cm^3)	γd (gr/cm^3)	GS	σ_c (MPa)	E (MPa)	ν	c (MPa)	φ (°)
1	*Gneiss*	5	10	0.89	2.27	2.25	2.64	31	4.853	0,24	0.178	23
2	*Schist*	5	10	0.79	2.47	2.45	2.65	41	15.594	0,25	0.129	25

3. Laboratory test results of technical properties

Test of rock technical properties carried out in the laboratory with diameter (D) of sample size is 5 cm, and rock length (L) is 10 cm in *gneiss* and *schist*lithologiesderived from the study site. The taken sample rocks are in form of chunks. Chunks of rockused for laboratory tests are in form of weathered rocks as shown in Figure 6.

(a)



(b)

Figure 6 Types of rock for laboratory test: a) *gneiss*, b) *schist*

The obtained results show that the value of physical properties of *gneiss* and *schist* rock types tend to be the same, it is because both types of rock classified in a group of metamorphic rocks.

The test results of *Uniaxial Compressive Strength* shows that for lithology *gneiss* uniaxial compressive strength value of 31 MPa and *schist* lithology value for the uniaxial compressive trength of 41 MPa. From the above findings it is known for *gneiss* lithology, the classification of rock strength is at grade R3 which is a strong rock medium (Table 1), and for *schist* lithology, the classification of rock strength is at the grade R4 which is a strong rock (Table 1). The UCS results show that *schist* rock is stronger than *gneiss* rock, this is because the *gneiss* rock has been weathered, and hence the compressive strength value is small.

The parameter of rock material shear strength atPoboya gold mine is obtained through a software of RocData 5.0 analysis and the results then correlated with the laboratory data. Findings obtained from shear strength parameters of rock show the cohesion value (c) of *gneiss* is 0.178 MPa and of *schist* is 0.129 MPa. The value of shear angle (φ)on*gneiss* is 23^{o}and on*schist*is about 25^o.

E. CONCLUSION

Characteristics and technical properties of rock mass in mining activities are needed to minimize dangers occur in the mine slopes. Metamorphic rocks dominate the lithology that formed the study site. The metamorphic rocks found around the study site are *gneiss* and *schist.*

Based on results of discontinuity mapping and the laboratory tests, it can be concluded that the general condition of *gneiss* lithology has a relatively high weathering compared to *schist* lithology, and this is due to the age of *gneiss* rocks is older than the age of *schist* rocks. The high weathering affects the geological structure and strength of rocks as well. Rock strength that resulted from uniaxial compressive strength test, showsthat value of *gneiss* rock strength is lower than value of *schist* rock strength, this is due to the condition of *gneiss* rock has been weathered, and hence the value of strength compressive is small. Results of characteristics and technical properties of rock mass at Poboya gold mine can be used as a baseline data for design safe and stable slopes of mine.

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