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Determination of Rock Slope Stability Using Analysis of Slope Rock Characteristics on Buluri Road, Palu City, Central Sulawesi, Indonesia

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Abstract
The Buluri road section is one of the roads in the trans Sulawesi area of Palu City – Donggala. Sand and rock mining activities by mining companies C, triggered landslides on several slopes that have not been repaired, and without any geotechnical studies. This research was conducted to determine the geological conditions using the analysis of the characteristics of the rocks that make up the slope. The methods used in this research include Geomorphology, Lithology with Weight Content and Rock Compressive Strength, and Geological Structure. The kinematic analysis shows that Geological conditions in the study area have geomorphological data on average it has a slope ranging from 60-70^o with a percentage of the slope angle that is around (56-140%) with an average height difference of 200-500 meters with a valley shape "V" which is classified as a steep slope. geological structure data there are many bridles, which are included in the rock lithology of intermeditated igneous rock types, namely Andesite. Some still look fresh and some are weathered with the condition of the existing material is homogeneous. with physical characteristics of the weight content and compressive strength of rocks at station 1 is 27.35 kN/m3 and 20 Mpa; station 2 28.56 kN/m3 and 19Mpa; station 3 26.97 kN/m3 and 22 Mpa.

Keywords: *Rock Slope Stability, Rock Characteristic, Geology*

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I. INTRODUCTION

Buluri road section is one of the road sections located in the trans Sulawesi area of Palu - Donggala City with a slope steepness of 15-40 degrees and a very steep >40 degrees. The condition of the road section at certain points that have not been repaired, the activity of taking sand and stone by C excavation mining companies on several slopes on the Buluri road section, is considered to have triggered landslides in the area, one of the factors that triggered the occurrence of landslides on some roads is the activity of taking material in the form of sand and stone, and making the surrounding area prone to disasters **[1].**

1.1 Geology Regional

Based on the Geological Map of Palu Sheet, Central Sulawesi Scale 1:250,000 **[8]** the investigation area consists of 3 (three) rock formations, namely Tinombo Ahlburg Formation (Tt), Molasa Celebes Serasin and Serasin (QTms), and Aluvium and coastal deposits (Qap).

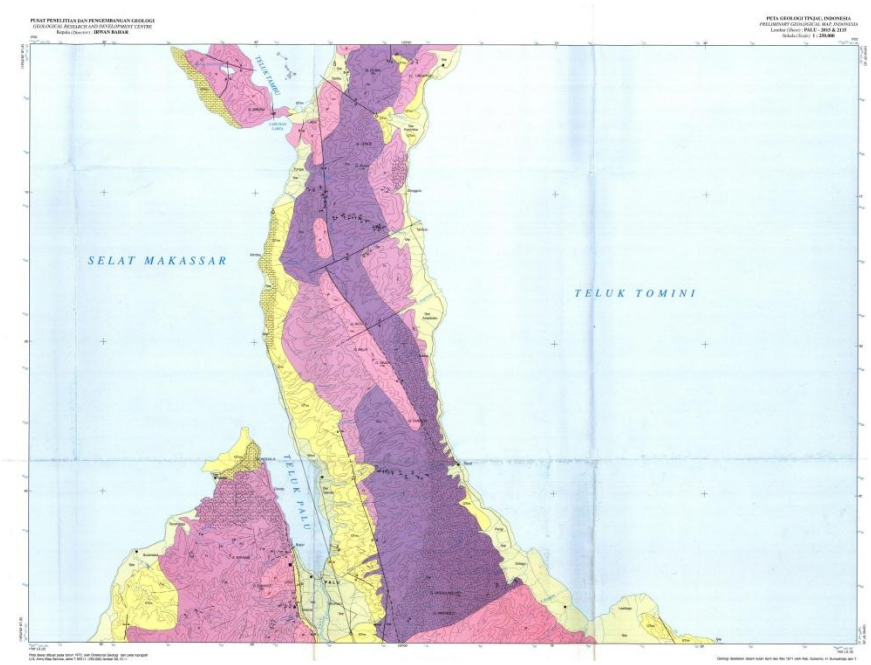


Figure 1: Geologic Map of Palu Sheet, Central Sulawesi [8].

1.2 Engineering Geology of Rocks

The engineering properties of rocks, especially in the field of geomechanics, are an important input in the field of civil engineering. This happens when engineering works start to involve rock bodies such as slope cutting, underground excavation, and surface mining **[3]**. Therefore, rock engineering or geomechanical properties need to be the basis in rock engineering evaluations such as slope stability.

1.3 Engineering Properties of Rocks

Rocks are defined as earth materials that have an axial strength exceeding 1 MPa and have tensile strength **[4]**. Table 1 shows the classification of rock strength based on ISRM **[7]**.

Table 1: Rock Strength Classification [7].

GRADE	TERM	FIELD IDENTIFICATION	Approx. range of σ_c (MPa)
S1	Very soft clay	Easily penetrated several inches by fist.	< 0.025
S2	Soft clay	Easily penetrated several inches by thumb.	0.025-0.05
S3	Firm clay	Can be penetrated several inches by thumb with moderate effort.	0.05 -0.10
S4	Stiff clay	Readily intended by thumb, but penetrated only with great effort.	0.10 -0.25
S5	Very stiff clay	Readily intended by thumbnail.	0.25 -0.50
S6	Hard clay	Intended with difficulty by thumbnail.	> 0.50
R0	Extremely weak rock	Intended by thumbnail.	0.25 - 1
R1	Very weak rock	Crumbles under firm blows with point of geological hammer; can be peeled by a pocket knife.	1 - 5
R2	Weak rock	Can be peeled by a pocket knife with difficulty, shallow identifications made by firm blow with point of geological hammer.	5 - 25
R3	Medium strong rock	Cannot be scraped or peeled with a pocket knife; specimen can be fractured with single firm blow of geological hammer.	25 - 50
R4	Strong rock	Specimen requires more than one blow of geological hammer to fracture it.	50 - 100
R5	Very strong rock	Specimen requires many blows of geological hammer to fracture it.	100 - 250
R6	Extremely strong rock	Specimen can only be chipped with geological hammer.	> 250

The clays in grade S1 - S6 can be silty clays and combinations of silts and clays with sands, generally slow draining.

Although the classification of rock strength uses axial compressive strength values, in general there are only two types of collapse in rock materials, namely shear or tensile **[4]**. Thus, shear strength and tensile strength actually affect the integrity of the rock material. The shear strength of rock material comes from three sources:

cohesion, friction, and dilatancy. The strength of rock material is influenced by mineralogy **[10]**, texture **[8]**, and the structure of the rock material itself. Other factors include water content, load reduction, and the presence of matrix cement in sedimentary rocks. Weathering also plays an important role by reducing the strength of the rock, especially if there is a change in rock-forming minerals **[2]**, Table 2 shows the classification of rock weathering based on ISRM **[6]** recommendations.

Table 2: Classification of Rock Weathering [6].

CLASSIFICATION	DESCRIPTION
Unweathered	No visible signs of weathering. Rock fresh, crystals bright. Few discontinuities may show slight staining.
Slightly weathered	Penetrative weathering developed on open discontinuity surfaces but only slight weathering of rock material. Discontinuities are discoloured and discoloration can extend into rock up to a few mm from discontinuity surface.
Moderately weathered	Slight discoloration extends through the greater part of the rock mass. the rock is not friable (except in the case of poorly cemented sedimentary rocks). Discontinuities are stained and/or contain a filling comprising altered materials.
Highly weathered	Weathering extends throughout rock mass and the rock material is partly friable. Rock has no lustre. All material except quartz is discoloured. Rock can be excavated with geologist's pick.
Completely weathered	Rock is totally discoloured and decomposed and in a friable condition with only fragments of the rock texture and structure preserved. The external appearance is that of a soil.
Residual soil	Soil material with complete disintegration of texture, structure and mineralogy of the parent rock.

1.4 Engineering Properties of Discontinuities

Discontinuity is defined as a general term referring to any discontinuity in a rock body that has a very low tensile strength or no tensile strength at all. Discontinuities can refer to joints, faults, laminated planes, and weak zones **[5].** In general, different types of discontinuities have different size ranges.

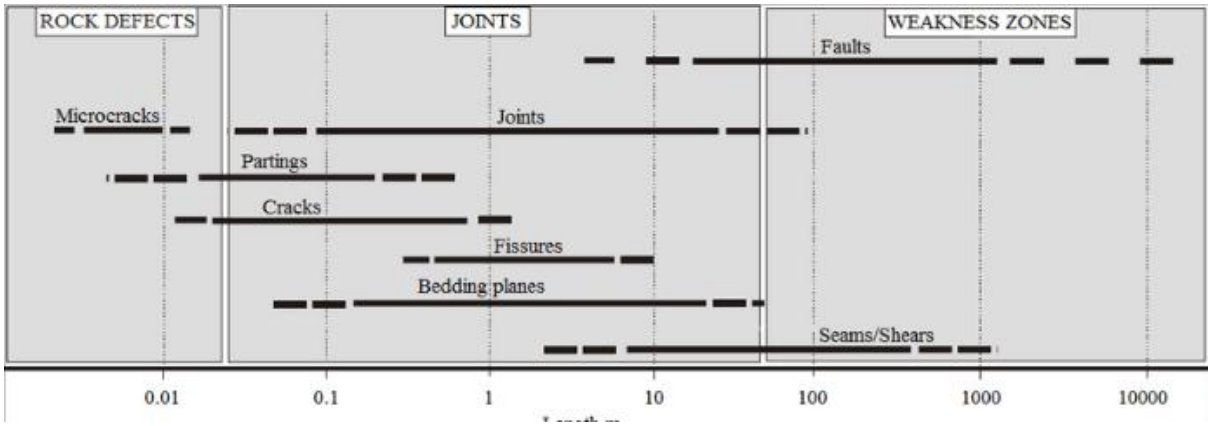
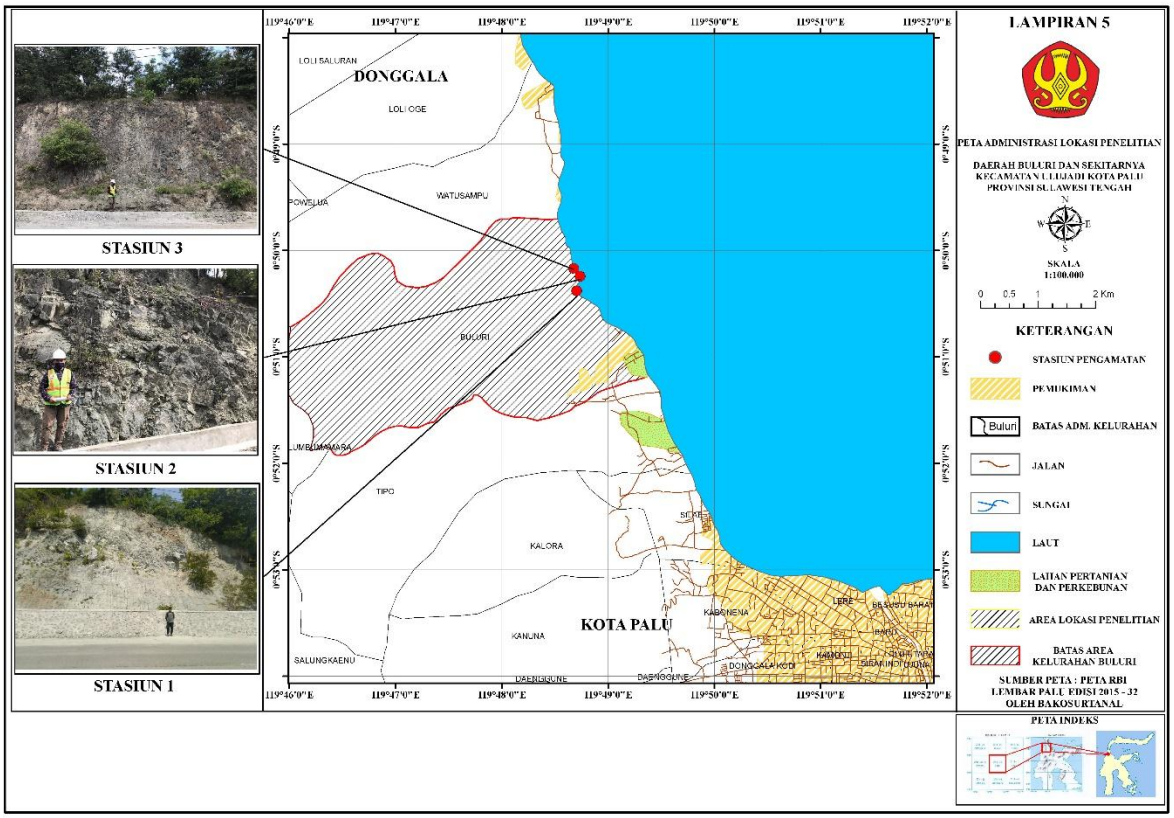


Figure 2: Types of discontinuities defined in engineering geology [5].

II. RESULT AND DISCUSSION

The research site is located on the road section of Buluri Village, Ulujadi Subdistrict, Palu City, Central Sulawesi Province, geographically located at coordinates 00°49'44.2" to 00°51'11.4" South latitude and 119°48'31.4" to 119°49'17.1" East longitude. South latitude and 119°48'31.4" to 119°49'17.1" East longitude. The research area is listed on the RBI map of Palu sheet with a map scale of 1:50,000. The research area is located at km 15+300 from Palu City right around the Palu - Donggala axis road. The research location can be seen in Figure 3.



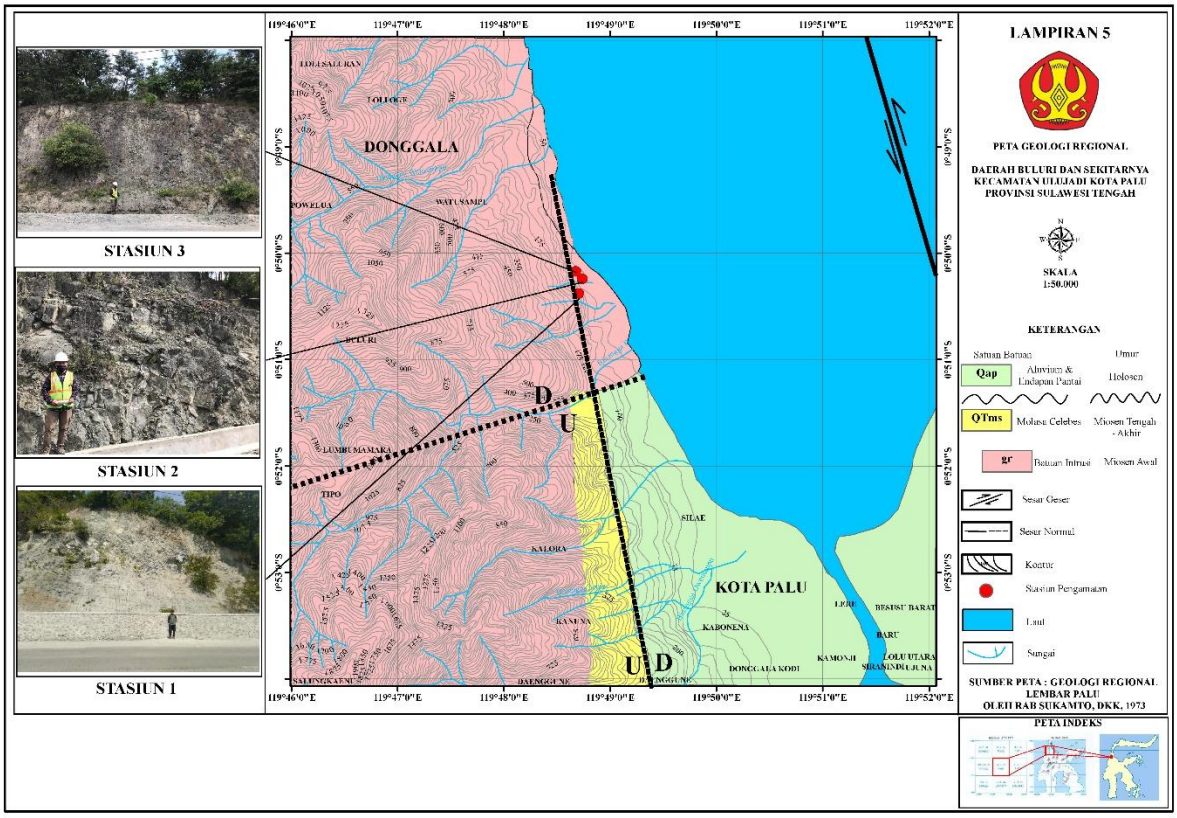


Figure 3: Research Location

Geological conditions in the research area greatly affect the condition of the existing slopes, where the slopes in the research area have an average morphomteri - average slope ranges from 60-70o with a percentage of the slope angle which is around (56-140%) with an average height difference of 200-500 meters with a "V" valley shape which is classified as a steep slope (Van Zuidam, 1989), there are many bridles, with physical characteristics of lithology having constituent minerals of quartz, plagioclase, orthoclase, hornblende, opaq minerals and pyroxine. The appearance of fresh color varies from white to gray and gray rocks, brown weathered color and some blackish brown have a massive structure, have a texture in the form of hypocrystalline crystallinity, afanitic granularity, anhedral shape, and inequigranular relations which are included in the type of intermeditate igneous rocks. So that by looking at this lithological feature, the naming of this rock is Andesite (Fenton, 1940). rock lithology Some of the rocks still look fresh and some are weathered with the condition of the existing material is homogeneous. with the physical characteristics of the weight content and compressive strength of rocks at station 1 are 27.35 kN/m3 and 20 MPa, station 2 28.56 kN/m3 and 19MPa, station 3 26.97 kN/m3 and 22 Mpa.

Figure 4: (a) Morphological appearance of the research area Observation station 1 with a slope of 64°photographed towards 303°E.
(b) Morphological appearance of the research area Observation station 2 with a slope of 71° photographed towards 194°E.
(c) Morphological appearance of the research area Observation station 3 with a slope of 70° was photographed towards 177°E.

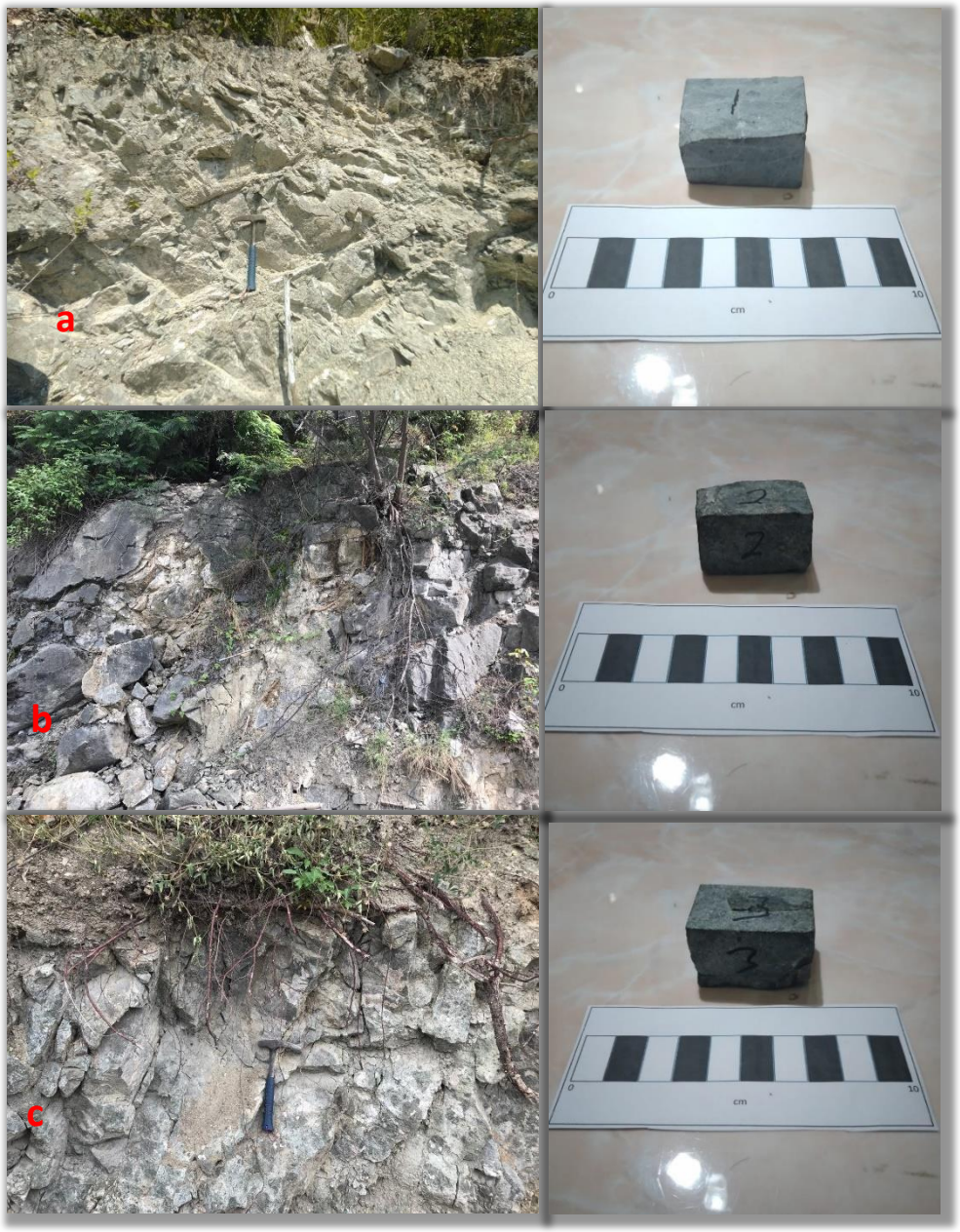


Figure 5: (a) Andesite outcrop with relative photo direction N 320° E at station 1 and Andesite handspecimen.
(b) Andesite outcrops with a relative photo direction of N 273° E at station 2 and the appearance of Andesite handspecimens.
(c) Andesite outcrops with a relative photo direction towards N 312° E at station 3 and the appearance of Andesite handspecimens.

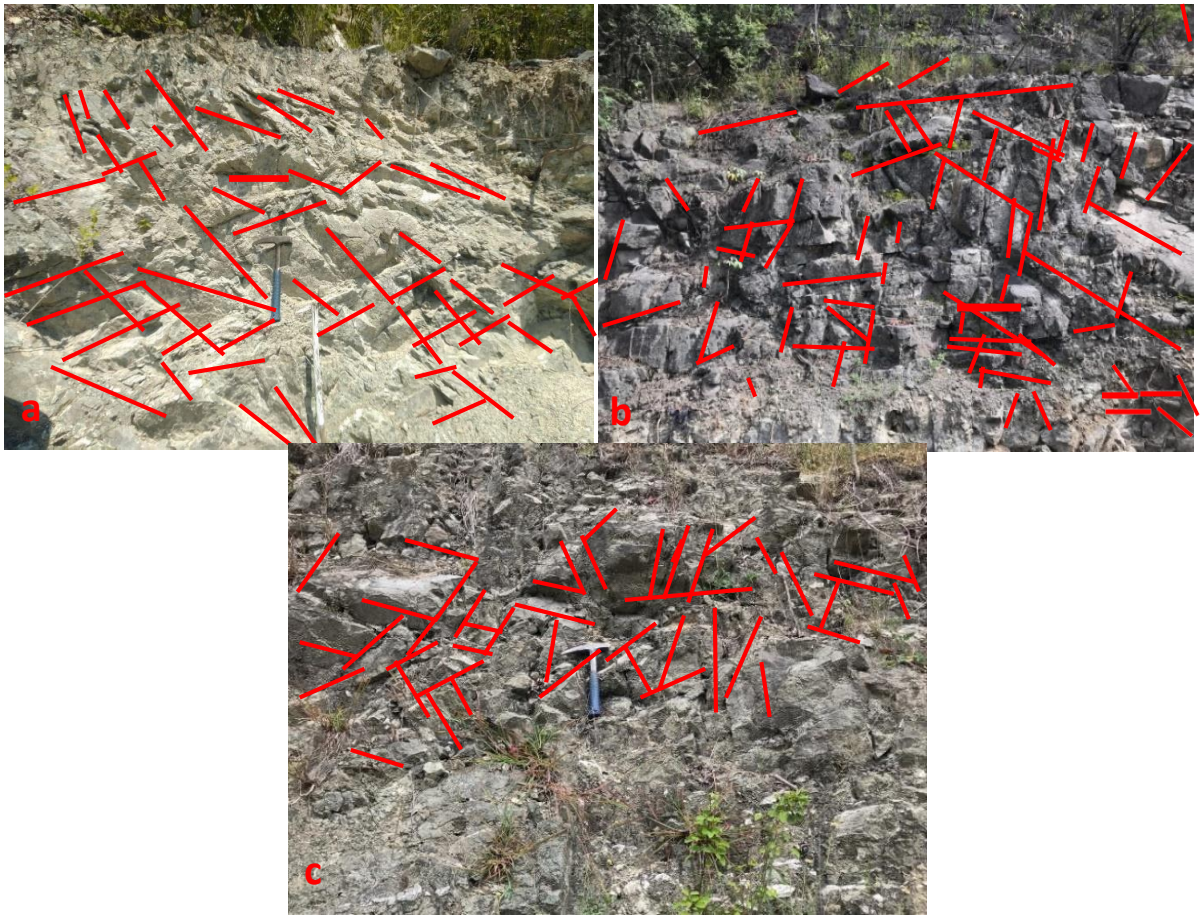


Figure 6: (a) The scouring of fault braces at station 1 was photographed relative to N 320°
(b) The scouring bridle at station 2 was photographed relative to N 279°
(c) The scouring of fault braces at station 3 was photographed relative to N 309°

III. CONCLUSION

Rock characteristics analysis is a good tool to make a preliminary assessment of rock stability to determine the likelihood of collapse, especially when assisted by geomorphology, lithology, geological structure, rock compressive strength, and weight content methods in data collection. A practitioner will be able to identify possible failures before conducting a more detailed assessment. This study can be important to understand the overall slope stability in a short period of time and can provide useful information on possible failures.

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