Analysis of mineral types of clay contained in residual soil
Kulinjang Area, Enrekang, South Sulawesi Province

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Abstract. Kulinjang area is the main access road that connects Enrekang District with Tanah Toraja District. The road cuts through the hills on a steep slope at the west side, where there are several large landslides alongside the road that have been occurred for a while. Meanwhile, on the road surface, irregular cracks occur. This is due to the local deformation of the soil material or bedrock, where one of the influencing factors is the clay mineral content of the soil. However, not all clay minerals have negative impacts. The formation genesis of clay minerals as rock-forming minerals that can determine the engineering properties is very complex so that the type and amount of clay minerals that formed from weathered origin rock and the weathering factors will have a huge impact on the engineering properties. This study entitled Analysis of Mineral Types of Clay Contained in Residual Soil at Kulinjang Area aims to identify the characteristics of mineral types of clay in the residual soil layer, identify the morphology and thickness of the soil and analyze the stratigraphic distribution of the clay minerals. The methods used in this study are consist of taking surface sample data and subsurface sample data by manual drilling (hand auger), analyzing samples using petrography and analyzing the chemical content in the soil by XRD method (X-Ray Diffraction).

1. Introduction

Distribution of marl rock, which is interbedded with limestone and volcanic rock as a forming rock, is often found in the study area, which is a hilly and mountainous region. In the east, there are mountain ranges with steep slopes, extended west-southeast from Latimojong to the mountainous region of Sidrap.

The Kulinjang area is an important access road to connect between Enrekang District and Tanah Latimojong District. In some places, landslides occurred alongside the road, which damaged the road and caused cracks on the road surface so that it becomes irregular. Also, the steep slope is used as a residence, rice fields and plantations by local citizens [1].

Marl rock is a clastic sedimentary rock with a silt-clay size (0.0625-0.002 mm) composed of clay minerals in which each structure has a different crystal structure. Clay minerals can be formed from almost every type of rock [2], as long as there are enough alkaline and alkaline earth compounds to create a chemical reaction (decomposition). Meanwhile, limestone with a layered structure is bioclastic sediment from the Latimojong Formation and tuff consisted of orthoclase minerals [3].

Weathering results from sedimentary rocks that are influenced by climate and type of sedimentary rocks can affect the mineral content as a forming mineral in residual soil. Thus, if the clay minerals contained are clay minerals that have high swell and shrinkage properties, then this will affect the engineering properties of the soil.
Genesis formation of clay minerals is very complex. The forming factors will determine the specific characteristic that is plastic and dry shrinkage due to temperature changes. The varying ion exchange capabilities and types of bonds between atoms create various classifications of the types of clay minerals.

Minerals that form clays are extremely fine that they cannot be measured macroscopically. Subsurface drilling and identification of clay minerals by using X-ray diffraction analysis is one method that can provide detailed information.

2. Research Objective
The research objectives of Analysis of Mineral Types of Clay Contained in Residual Soil at Kulinjang Area are:
- Analyze the types of clay minerals that form residual soil and its stratigraphic distribution in each rock layer.
- Analyze the morphological relationship with the types of clay minerals to improve the understanding of the types of clay minerals that can be formed from weathering rocks that interbedded between marl, limestone, and breccias.
- It was analyzing the possible causes of landslides that are induced by the clay minerals differences that form residual soil.

3. Research Method
The method used in conducting this research is the experimental method by doing rock testing, groundwater testing and chemical analysis on subsurface soils.

Data is collected by purposive sampling. 15 samples were taken in the central area of the landslide, while in the north, south, west and east of the landslide 10 residual soil samples were taken using a block diagram system. The residual soil sample is taken based on the assumption of soil movement which is adjusted to the geomorphology, topography and estimation of local groundwater flow.

Data collection techniques used are adjusted to the data needs, including:
- Measurement of parameters consisting of soil and forming a rock parameters in the study area and topographic data collection (height, slope and distance), including the area of land allotment.
- Direct observation of the physical condition of rock outcrops and residual soils which include color, texture, mineral composition and rock structure. Observations were also made to see the distribution and relationship of rock outcrops and residual soils with other nearby rocks or minerals. Geological elements found in the field are recorded visually using a digital camera.
- The subsurface data is collected at two points. Besides that, rock samples were also taken consisting of a sample of marl rock, a sample of limestone, and fragments and matrices of breccias, which will be used to make thin incision samples.
- The sampling of weathered marl rock is conducted by using a hand auger as many as two samples, which then will be analyzed for its mineral content and chemical composition.

4. Result And Discussion
The Geomorphology of Research Area is divided into three morphological units:
- Sharp relief mountain morphology unit occupies about 25% of the total research area in volcanic breccia lithology spread in the east extending to the south of the study area, including the Bulu Maladewa and Bulu Malando area.
- Medium relief hill morphology unit occupies about 15% of the total area of the study, is composed of the lithology of limestone and tuff rock, which covers the northern and western regions of the Kulinjang area.
- Low relief hill morphology unit occupies about 60% of the total area of the study, is composed of volcanic rocks in the form of tuffs covering the western region extending from the north to the south of the Kulinjang area.
The river that develops in the study area is a dendritic river in which the main river is Saddang river in the west and Mataallo river in the eastern Kulinjang area.

Figure 1. Geomorphological Map of Kulinjang Area, Enrekang District, South Sulawesi Province.

4.1. Stratigraphy of Research Area
The rock unit of the study area consists of: 1. Limestone unit; 2. Tuff Unit; and 3. Volcanic breccia unit.

4.1.1. Limestone units consist of limestone and marl, generally composed by fossilized limestone and carbonaceous claystone inserts. The appearance of the limestone in the field is gray in fresh, blackish-brown in weathered, clastic texture, fine-medium grain size, good sorting, clast-supported, layered structure, composed of calcite material, consist large Foraminifera fossils such as Nummulites and Discoyclina. The direction of the strike is N 270° E - N 356° E and dip 25° - 32°.

Figure 2. Limestone appearance at Malauwe packstone, red area with azimuth N 245° E
The microscopic appearance of limestone in cross-nicol (Fig. 4.3) shows a bioclastic texture with material composition consisting of grains (skeletal grains and non-skeletal grains) (65%), lime mud (20%), sparrycalsite (10%) and pores (5%). Skeletal grains consist of small foraminifera fossil, red algae and quartz minerals. Material sizes of 0.02 - 3 mm, the name of the rock is Packstone [4].

The physical characteristics of carbonate clay are gray in fresh, brownish-yellow in weathered, clastic texture, clay grain size, good sorting, clast-supported, layered structure, composed of clay material and carbonaceous. The orientation of strike is N 270° E - N 356° E with dip 25° - 32°.
Figure 5. Thin section appearance of marl, foraminifera, fossil, mud and opaque mineral

The microscopic appearance of clay carbonate on cross-nicol (Fig. 4.5) is blackish gray. Bioclastic rock texture with material composition consists of grains in the form of skeletal grains (25%), small foraminifera, as well as lime mud (60%), sparry calcite (10%) and pores (5%). Material size 0.02 - 1.4 mm, the name of the rock is Wackstone [4]. Age and the deposition of limestone units are Lower Eocene to Upper Eocene [5]. Whereas the depositional environment is shallow marine [6].

Tuff units, fine tuff units spread about 15% of the total area of the study area or about 6.06 km². The distribution of this unit is in the middle between the coarse tuff unit and the limestone unit and extends from the north to the southern end of the study area, in Tuara Village to Kulinjang Village. Land surface (N 225° E) - northeast (N 45° E) with a relative slope to the northwest with a large angle between 9° - 15°. The unit of fine tuff found in the study area consists of coarse tuff lithology. The field outcrop is found winter layering these two lithology. As can be seen at Station 78, the interlayer of fine tuff with coarse tuff in the middle of the study area, Kulinjang village.

Figure 6. Interlayering of fine tuff and coarse tuff at
Microscopic appearance of fine tuff alters the blackish-brown nature of the parallel-nicol, brownish-gray on cross-nicol, fine pyroclastic texture, 0.03 - 0.6 mm grain size, angular - surrounded angularity, good sorting, composition quartz (10- 20%), pyroxene (5-10%), plagioclase (5-10%), biotite (5-10%), opaque minerals (0-5%), carbonate minerals (5-20%) and volcanic glass (50 -55%). Based on the physical properties and mineral composition, the name of the rock is *Vitric crystal tuff* [7].

4.1.2 Volcanic breccia unit. Occupies 40% of the area of the study area, showing physical characteristics gray in fresh, brown in weathered, clastic texture, pebble - medium sand grain size, poor sorting, matrix-supported, layered structure, composed of boulder rock fragments - sand, matrix, and ash. The direction of a strike is N 348° E – N 358° E with dip 28° - 31° [8].

Microscopic appearance of breccia fragments is brownish yellow in cross-Nicoll, gray interference color, hypocrystalline crystallinity texture, porphyritic granularity, grain size <0.01 - 0.84 mm, euhedral-subhedral mineral shape, mineral composition pyroxene (30%) (aegirine), plagioclase (55%) (labradorite), opaque mineral (5%), a base mass of volcanic glass (10%), name of volcanic breccia is *Porphyritic Basalt* [9].
Figure 9. Thin section appearance of volcanic breccia fragment that shows carbonaceous mineral, microlite plagioclase and opaque mineral plagioclase,

Age and the depositional environment are Middle Miocene - Upper Miocene and deposited in shallow marine.

4.2. Geological Structure of Research Area
The structure that developed in the study area is the fault structure in the form of Palakka strike-slip fault with the dextral relative shifting direction, and the age of the fault predicted after the youngest rock (limestone) is Post Eocene age.

Figure 10. Geological Map of Kulinjang Area, Enrekang District, South Sulawesi Province
5. Characteristics of clay mineral types

The results of data analysis (Table 1) from the XRD test at point 1, samples were taken at an altitude of 630 m above sea level and at a slope of 35°, soil thickness is 2.5 meters.

| Depth (m) | Illit (%) | Kaolinit (%) | Halloysit (%) | Vermiculite (%) | Chlorite (%) |
|-----------|-----------|--------------|---------------|-----------------|--------------|
| 0 - 1     | 8.7       | 20.7         | 40.1          | 24.5            | 2.1          |
| 1 - 1.5   | 31.2      | 16.4         | 13.6          | 17.4            | 23.2         |
| 1.5 - 2   | 43.7      | 19.1         | 21.7          | 6.5             | 9.2          |
| 2 - 2.5   | 42.6      | 19.2         | 15.6          | 8.7             | 16.5         |
| 2.5 - 3   | 48.2      | 20.3         | 13.3          | 11.9            | 2.1          |

In the most constant amount of kaolinite, the physical properties of kaolin are plastic when contacted with water but not iner solid which affects viscosity and density but does not provide hydration in water [10].

Illite is a clay mineral that shows the highest percentage of other clay minerals. If potassium dissolves because it reacts with water, then osteoclasts (potassium feldspar) will form kaolinite [11].

\[
2 \text{KAlSi}_3\text{O}_8 + 3 \text{H}_2\text{O} \rightarrow \text{Al}_2\text{Si}_3\text{O}_10(\text{OH})_2 + 4 \text{SiO}_2 + 2 \text{KOH}
\]

And illite also can be formed from orthoclase (potassium feldspar), if potassium doesn’t dissolve completely:

\[
3 \text{KAlSi}_3\text{O}_8 \rightarrow \text{KAl}_2(\text{Al}_2\text{Si}_3)\text{O}_{10}(\text{OH})_2 + 6 \text{SiO}_2 + 2 \text{KOH}
\]

Illite has a stronger bond so it is more stable, but there is an octahedral gibbsite layer between two layers of tetrahedral silica, this bond causes greater illite activity than kaolinite, and shows a pattern that is getting more towards the direction in the form of numbers. This is influenced by random rocks and is found tend to decrease in numbers at a depth of 3 meters.

Halloysite genesis and also Vermiculite which is type 2 : 1, has a weak crystal bond, which contains Ca⁺ and Mg⁺ so that this mineral has the potential to swell and shrink.

| Depth (m) | Illit (%) | Kaolinit (%) | Halloysit (%) | Vermiculite (%) | Chlorite (%) |
|-----------|-----------|--------------|---------------|-----------------|--------------|
| 0 - 1     | 13.8      | 22.1         | 4             | 56.3            | 13.2         |
| 1 - 1.5   | 26.1      | 23.4         | 42.2          | 6.4             | 8.6          |
| 1.5 - 2   | 72.3      | 25.3         | 0             | 0               | 8.6          |
Samples taken at point 2, soil thickness, is 2 meters, altitude 540 meters above sea level, slope 55°, the morphology is steeper than 54°, this will increase at the Halloysite genesis while rainwater will flow faster, so at the same depth the surface is smaller than point 1.

On the geological map, it can be seen that the point 2 is in normal fault line causing the area included in the weak zone, it can be seen on the surface of the destroyed rocks which can affect the weathering processes both in mechanical or chemical, and can alter the type and percentage of clay minerals in the research area.

The results of the further analysis showed that the clay mineral originating from the same claystone, but at the location of the elevation and in different reliefs would show the difference of color and the percentage of the type of clay mineral.

The existence of Vermiculite, Illite and Halloysite gives their own character on the soils, and the intensity of rainfall is quite high, as well as the measurement of the position of rock layers in the same direction as the slope, can affect greater mass movement.

6. Conclusion
- The results of the X-RD analysis showed that in the study area the clay minerals from the top to bottom layers were the illite mineral, kaolinite, vermiculite, halloysite and chlorite. The results also show that the spread of illite minerals is getting bigger in the direction, which is inversely proportional to vermiculite minerals, while kaolinite minerals are relatively constant at every depth.
- In the areas that have a slope angle morphology of 35 °, clay mineral content is found from ground level to a depth of 3 meters where the percentage changes gradually. While in areas that have a slope angle morphology of 54 °, vermiculite and halloysite are no longer found at a depth of 2 meters.
- The thickness of soil on a steep slope is smaller than the thickness of soil on a sloping slope.

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