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CLAY MINERAL VARIATIONS IN AN ACTIVE FAULT ZONE AND THEIR IMPACT ON LANDSLIDES

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ABSTRACT: Clay minerals are a common material of the earth, which are formed in soil and rock. This research aims to investigate variations in the characteristics and physical properties of clay minerals in an active fault zone and assess their impact on landslide occurrence in the southern part of the Cianjur-Garut region. The morphotectonic approach is applied as an indicator of the location of the active fault zone. The Cilaki river valley has a unique wine glass-like shape, indicating active fault control on its formation. Tertiary sedimentary rocks and Quaternary volcanic deposits compose the strata in this area. Rock samples were collected from the active fault zone. Petrographic analysis was carried out on these samples, including optical microscopic (OM), Scanning Electron Microscopy (SEM), and X-Ray Diffraction (XRD). Six rock samples have clay minerals of about 32% to 60% and are characterized by the presence of saponite, a mineral of the Smectite group. Illite and kaolin were not indicated in XRD analysis but were recognized by SEM analysis. The clay assemblages in fault zone are the result of gradual mineral alteration processes under low temperatures and pressure. Smectite is the group of clay minerals with the highest swelling index. High swelling clays tend to have low strength,h which is very relevant in areas vulnerable to landslide occurrence. The analysis of variability and physical properties of clay minerals can be used to know the characteristics of soils and their impact on landslides.

Keywords: Cianjur-Garut region, Cilaki river, Clay mineral, Fault zone, Landslide

1. INTRODUCTION

The research is concerned on the relationship between tectonic deformation processes and some aspects of clay mineral properties. In particular, the role of clay mineralogy in the lithological characteristics in a region. The research area is dominated by Quaternary volcanic deposits, while the downstream area has exposed Tertiary sedimentary rocks (Fig.1;Fig.2). The scope of study is using clay minerals to identify and explore the processes that may occur in active faults zones.

Active faults have controlled the research area [1] but their genesis and importance in deformation processes are poorly understood. A clay mineral approach can be used to recognize the deformation condition according to their physical properties [2]. Clay minerals have essential relevance to geological studies such as fault gouge, weathering, landslides and geotechnical engineering [3-8]. Clay minerals can be produced by weathering and hydrothermal alteration [9,10]. These minerals are widespread in soils, fine-grained volcanic rock, sedimentary rock and metamorphic rock. Clay minerals can occur in fault zones and their formation are affected by fault strength [7], and the formation of fault gouge in faults [8]. Generally, clay mineral classifying into three groups: 1) Illite group 2) Smectite group and 3) Kaolinite group.

An active fault is concerned with tectonic geomorphology, which used to evaluate tectonic activity [11]. This work focuclay minerals' variation and physical properties nerals in the active fault zone. Identification and analysis of these materials can use petrographic, Scanning Electric Microscopy (SEM), and X-Ray Diffraction (XRD) methods [12].

It is related to the occurrence of faults and landslide that is affected by deformation processes by tectonic activity on the Quarternary period. The following reason is rather difficult to recognize a geological structure development in a mountainous volcanic area.

The research area includes the Garut and Pameungpeuk geological map [13] and Sindang Barang and Bandarwaru geological map [14] in the geological mapping system of Java Island sheet.

Human settlements and tourism activities have crowded the Talegong-Cisewu area. On the other side, this area is a lot of landslides, flash floods, and earthquakes. It is necessary to do further research to study the detail of geological conditions in specific lithology.

2. RESEARCH SIGNIFICANCE

Research on variations in clay minerals in the active fault zone is very important as an effort to reduce the risk of landslides that often occur in the

Talegong-Cisewu area which is the main transportation route from Bandung to the southern part of West Java. An in-depth understanding of the presence of clay mineral variations in the active fault zone can explain the massive landslide occurrence in this region. By knowing the characteristics of clay minerals that are present in this active fault zone, it can then be used to carry out technical engineering related to infrastructure development on this transportation route. This research can also provide significant benefits for other studies related to development in areas that have similar geological setting.

3. GEOLOGICAL SETTING

The regional tectonic setting of Southern West Java is an island arc model. The rise of volcanoes can recognize the characteristic, uplift, and geological structures exist in the region with the main stress direction from South to North [14].

The study area is physiographically included in the southern mountainous zone [15]. Volcanic mountainous and hills landforms dominate the Talegong-Cisewu area with moderate to the high slope. Minewhile, the plains landform occupied the southern coastal. The lithology of the research area composed of Tertiary and Quaternary rocks [13]. Using the time scale from the Geological Society of America [16] and base on field survey data, various rock unit has arranged stratigraphy of the research area.

The lithology are sedimentary rock, Quaternary volcanic deposits, and alluvium (Fig.2). From old to young, the stratigraphic units are Jampang Formation (Tomj), Quarzt diorite (Tmi), Bentang Formation (Tmpb), Koleberes Formation (Tmk), Undifferentiated old volcanics (QTv), Pyroxene andesite (Pa), Waringin-Bedil andesite (Qwb), Undifferentiated efflata deposits of old volcanics (Qopu), Malabar-Tilu volcanics (Qmt), Kancana lava (Qkl), Huyung lava (Qhl), Young volcanics of Mt. Wayang (Qyw), Young volcanics of Mt. Cikuray (Qyc), and alluvium (Qha).

Source: https://www.google.co.id/maps

Fig.1 The research area at Cianjur-Garut border, southern part of West Java, Indonesia

Active faults in West Java are known, such as the Baribis fault, the Cimandiri fault, and the Lembang fault [14,15,17]. Meanwhile, the active status of the faults in the South West Java region has not been widely published. There are more five faults, which influence the morphology dimension and landform of the southern part of Cianjur-Garut region (Fig.2). Fault zone material assumed that these rocks are a result of brittle fragment deformation processes as cataclasis. It is essential in forming clay mineral in the fault zone, which is known as clay gouge [18]. Understanding of natural clay minerals is still limited. There is still a great need for detailed research on this matter.

This article reveals clay minerals diversity in fault zone. Furthermore, it is expected to be a reference in finding critical data showing the relationship between active faults and landslides in the Talegong-Cisewu area.

4. METHODS

The identification of clay mineral physical properties by various methods. Several methods used in this research are petrographic analysis using polarization microscope, SEM, and XRD.

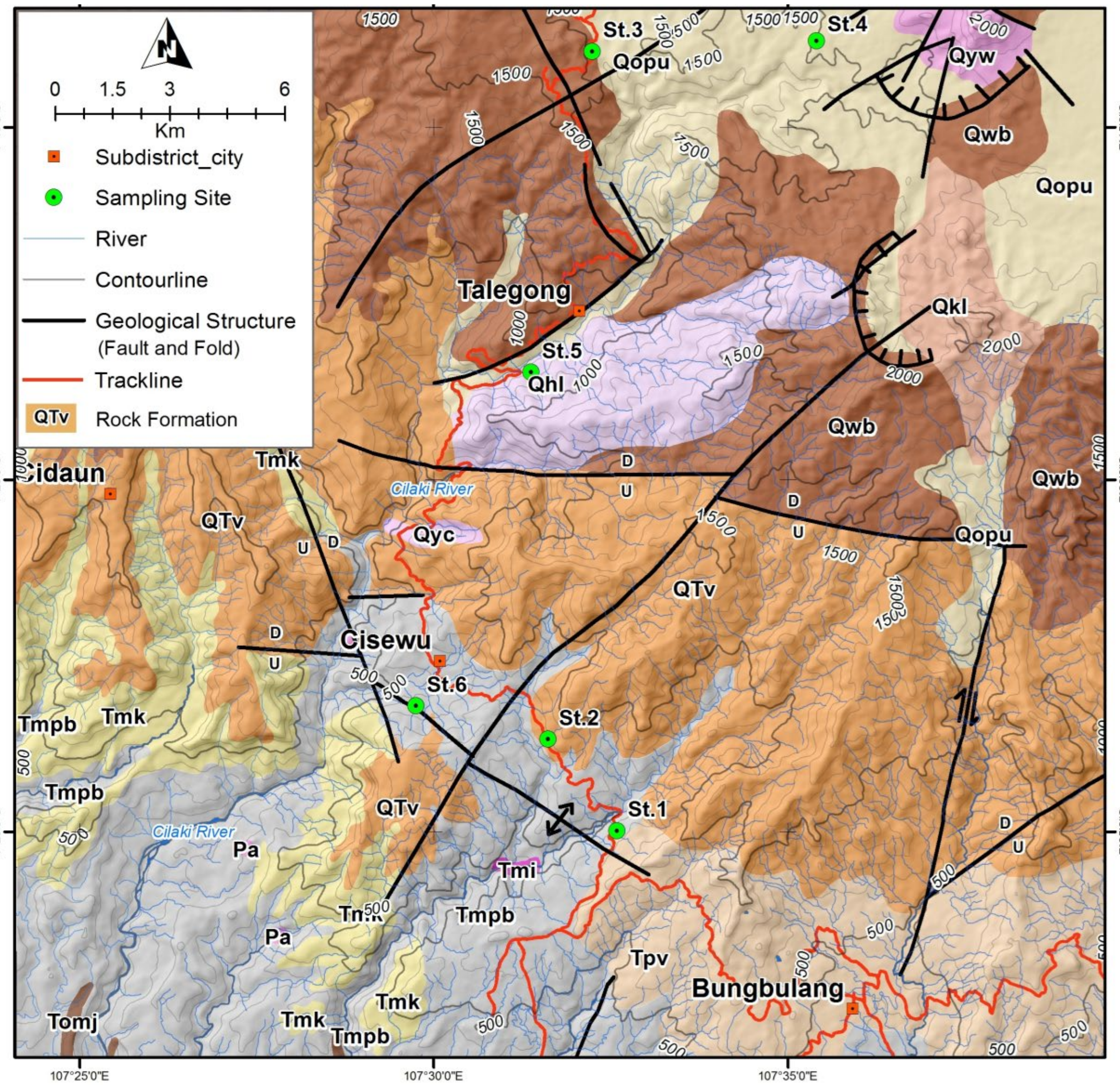

Fig.2 The rock sampling site on the geology map of research area [13,14]

Samples were taken systematically from the field survey which were considered to be representative of each rock unit in the study area. All samples are located near the surface of the fault zone associated with the deformation process.

The six samples represent the five rock formations displayed in parentheses, namely (1) tuff sandstone (Tmpb), (2) tuff (QTv), (3) andesite (Qwb), (4) tuff (Qopu), (5) andesite (Qhl), and (6) tuff sandstone (Tmk). The sampling locations are shown on the map in Fig.2. The preparation and analysis of rock samples and acquisition data of remote sensing conducted in the laboratories of Geology Agency, Republic of Indonesia.

Various geological structure analysis is adjusted with the condition of the research area, respectively. This work can use to determine the occurrence of the deformation process in the research area. Several measurements of geological structural elements in the field were also carried out, especially for the Talegong-Cisewu area. For ease in understanding landform deformation of the study area, topographic maps (1: 25,000 scale) and regional geological maps (1: 100,000 scale) made in digital format. The combining of the remote sensing method and field survey held to determine the rock sampling area.

Morphotectonic analysis was carried out to determine the presence of active faults. Two geomorphic index variables used in this study are mountain-front sinuosity (Smf) and valley floor – valley height ratio (Vf). Using Smf index formulation provided the following classification [11,17,19]: Class 1 active tectonism (1.2-1.6), Class 2 moderate to slightly active tectonism (1.8-3.4), and Class 3 tectonically inactive (2.0-7.0). The Smf value approaches 1.0 with increasing straightness, that used as an indication of recent uplift [20]. While, refer to Vf index provided the following classification [21]: Class 1 high active tectonism (< 0.5), Class 2 moderate to low active tectonism (0.5-1.0) and Class 3 tectonically inactive to slightly (> 1.0).

Six samples of rock have chosen representatives of each rock unit in the fault zone (Table 1). An in-depth analysis of rock uses an optical microscopic analytical in laboratory petrology that provides essential equipment and information of vary mineral contain on their mineral composition.

Table 1 Rock samples for OM, SEM and XRD analysis

Station	Nama of rock	Rock formation
St.1	Tuff sandstone	Bentang (Tmpb)
St.2	Tuff	Undifferentiated old volcanics (QTv)
St.3	Andesite	Waringin-Bedil andesite, old Malabar (Qwb)
St.4	Tuff	Undifferentiated efflata deposits of old volcanics (Qopu)
St.5	Andesite	Lava of Mt.Huyung (Qhl)
St.6	Tuff sandstone	Koleberes (Tmk)

This study utilizes a polarization microscope E 600 POL Eclipse model by Nikon. Moreover, SEM (JEOL JED-2300 Series) analysis is essential to study of shape, texture, and other physical properties of clay mineral by grain method.

The characteristic of clay mineral applied to recognize a region affected by the deformation process and landslide occurrence type. The XRD bulk analysis (PA. Nalytical X'pert PRO PW 3040/x0) used to determine a type and composition of clay mineral in each rock sample. This method is essential to understand the background of mineral assemblages and the types of the clay mineral.

5. RESULT

5.1 Fault Zone Evidence

Infield study have found several surface outcrops as such Quaternary volcanic deposits, Tertiary sedimentary rock, shear joint and fault scarp which are proven to be the result of deformation processes due to tectonic activities.

The exposure of the structures shows that rock units have undergone a tectonic deformation process. It is rather challenging to determine evidence of geological structure in volcanic mountainous which was covered by high weathering, erosion process, land use transformation, and deformation processes. Therefore, a field survey was conducted to find the evidence of faults and other indications.

Fig.3 Joints outcrop (left) and stereographic projection analysis show N-S and NW-SE trending faults (right)

There are 32 joints measurement and several fault indications such as fault planes, waterfalls, hot springs, fault escarpments, offset morphology, and minor faults. Fig.3 is showing the result of joint analysis by the Dip Program. This is one of the results of the joint analysis which identified two dominant directions (N-S and NW-SE). The analysis can recognize spatial variation and types of geological structures within the fault zone of this study area. There are more than five faults in the Talegong-Cisewu area where samples were taken in that zone which is considered to be representative of each rock unit

5.2 Clay Mineral Characteristic

The study concerned with fault zone materials, which are identified by the physical properties of clay mineral analysis. Clay mineral has a critical environment application in land use and living organism. The availability of clay mineral can occur in faults zone and landslide areas. By using Wentworth grain-scale classification [22], clay is defined as fine-grain material in which grain size is less than 1/256 or 0.002 millimeter. Understanding the physical properties of clay minerals requires further analysis. The petrology analysis step by step, as follows: hand specimen, petrography, SEM, and XRD. It is essential to find an overview of clay mineral and the implication of the landslide occurrences.

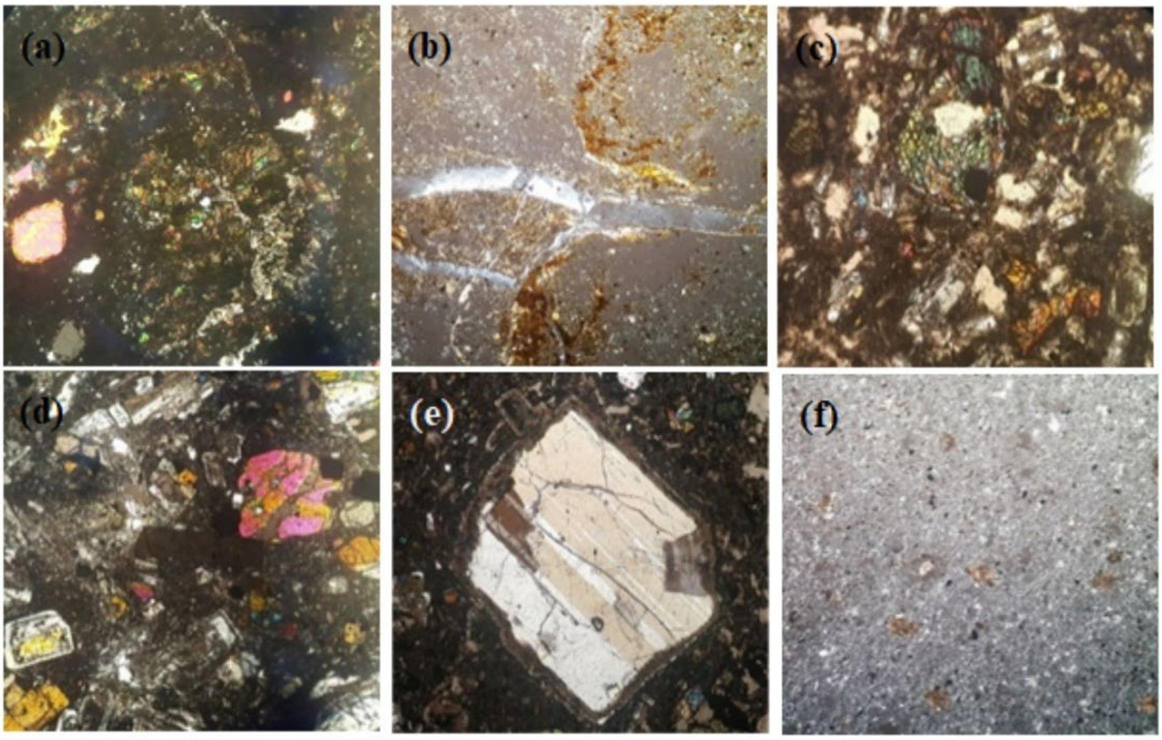

Fig.4 Optical microscopic images of rock in the fault zone. (a) Tuff (Tmb), (b) Tuff (Qtv), (c) Andesite breccia (Qwb), (d) Andesite (Qhl), (e) Tuff lapilli (Qopu) and (f) Tuff sandstone (Tmk).

Clay mineral can recognize by hand specimen description. Its slick and fine-grain material. Furthermore, petrographic analysis is used to determine the percentage of clay mineral content. The resulting of petrography analysis shows the six optical microscopic images in cross nikol of a rock sample in the fault zone (Fig.4;Table 2). The results of optical microscopic analysis showed that the rock samples were dominated by clay mineral content ranging from 32 to 60%. The exposure of clay mineral is rather tricky to recognize that needs more experience in petrographic observation. Clay minerals a common smooth component of vary mineral alteration, which can be formed by many causes. In Fig. 4a-f, clay mineral indicating by appearance fine-grain mineral fragments with a black-brown-yellow dark color that is around large mineral fragments and fills with the cracks. The occurrence of clay mineral is most affected by the type of source rock. The thin section is a method that can not determine the type of clay mineral but is a simple way and cheap for recognizing clay mineral contain.

Details of the physical properties appearance of clay mineral show in Fig.5, which is a result of the SEM identification with magnification object to 650 times and 3,000 times. Other observation with different magnification objects has been done but chosen the best representative images of clay mineral for this article. Several articles describe the name or nomenclature of the physical properties of clay mineral in different ways. This study follows the morphological characteristics of clay mineral descriptions [12] to observe and identify physical properties such as (1) micromorphology, (2) textures, (3) structures (4) particle size, and (5) mineral identification.

Six samples of rock identify in the smectic group (Table 3). The SEM images of clay mineral in the study show the webby structures, sheets form, cornflake material, and melting origin texture (Fig.5a1/a2-f1/f2). It refers to the smectite group.

Table 2 Mineral composition in each rock sample based on petrographic analysis

Material (Rock)	Mineral (%)						
	Px	Pl	Af	Qz	Ca	Gs	Cy
Tuff (Tmpb)	-	-	10	10	25	3	32
Tuff (QTv)	-	-	-	25	-	15	60
Andesite (Qwb)	20	30	-	10	-	5	35
Tuff (Qopu)	15	20	-	5	-	5	55
Andesite (Qhl)	10	25	-	-	-	15	50
Tuff sandstone (Tmk)	-	5	5	5	-	40	45

Px: pyroxene; Pl: plagioclase; Af: alkaline feldspar; Qz: quartz; Ca: calcite; Gs: glass; Cy: clay.

Table 3 Mineral composition using SEM analysis

Material (Rock)	Physical properties (size < 2 mm)		
	Texture & Structure	Morphology	Mineral
Tuff (Tmpb)	flake & webby	cornflake	smectite, quartz
Tuff (QTv)	smooth & webby	cornflake	smectite, quartz, chlorite
Andesite (Qwb)	Flake & webby to rounded	melt flake	smectite, quartz
Tuff (Qopu)	crude & webby	cornflake	smectite, feldspar
Andesite (Qhl)	Flake & layer sheet	cornflake	smectite, feldspar, quartz
Tuff sandstone (Tmk)	Flake & webby to layer sheet	massive flake	chlorite, mica, feldspar

Anomaly feature appears in Fig.5 (f2), which is characteristic of the flake sheet of mica with magnification 3000 times. Clay mineral image is typical of illite properties, and Fig. 5 (a2) is also shown the characteristic of Kaolin mineral with layers texture and massive structure by magnification 3000 times. However, each clay mineral exhibits a different exposure, which depends on the origin of rocks. In Table 3 explained the variety of physical properties description of clay mineral as a result of observation SEM images. However, this method can not use to determine the specifics of the clay mineral. Recently this method is the best method to find information on the type, composition, and dimension of clay mineral and its implication.

The rock samples are described in six samples, and their XRD samples disperse by ultrasonic, < 2 mm; < 1 mm; and < 0.5 mm particle size fractions separated by centrifugation.

The results show that all samples of the main mineral phase identified informed of the fault zone are similar. The presence of clay mineral in the research area is the product of heat-induced alterations possibly generated by active fault mechanisms**.** In general, existing publications state that most clay minerals are altered minerals due to hydrothermal activity that occurs after the formation of the rock or at the same time as the formation of the rock, for example the volcanism process. In others, there is a role for rock weathering. The reaction of elements or compounds in rock with water and aeration to form altered minerals that are generally fine in size [23].

In Fig.5a, Fig.5b, Fig.5c and Fig.5e reveals saponite mineral as known as a part of the smectite group. Smectite is absent in the two samples shown in Fig.5d and Fig.5f. Meanwhile, Fig.5d shows the presence of clay minerals, namely traskite and albite minerals. These minerals are concerned with hydrothermal alteration processes and associated with andesite-basalt rock.

Table 4 Clay minerals variety by XRD analysis

Material (Rock)	Group	Mineral	Peak
Tuff (Tmpb)	Smectite	Saponite	16 [Å]
Tuff (QTv)	Quartz	Quartz	4 [Å]
	Smectite	Saponite	15 [Å]
	Chlorite	Clinoclore, Ferroan	7 [Å]
	Dolomite	Ankerite	3 [Å]
Tuff (Qopu)	Smectite	Saponite	15 [Å]
	Silica	Silicon oxide	4 [Å]
Andesite (Qwb)	Quartz	Silicon oxide	4 [Å]
	Quartz	Traskite	15 [Å]
	Feldspar	Albit	6 [Å]
	Quartz	Cristobalite	4 [Å]
Andesite (Qhl)	Smectite	Saponite	15 [Å]
	Feldspar	Albit	6 [Å]
Tuff sandstone (Tmk)	Chlorite	Clinoclore	7 [Å]
	Feldspar	Albit	6 [Å]
	Mica	Eastonit mica	10 [Å]

While clay mineral in Fig.5f represented by Clinochlore, Albite, and Eastonite mica minerals, which is a hydrothermal alteration product and associated with andesite-granodiorite rock. Using the XRD method of clay fraction, tuff lapilli of undifferentiated efflata deposits of old volcanics (Qopu) and Tuff of Koleberes Formation (Tmk) in bulk analysis, indicate that the main types of clay mineral in both formed of the fault zone are subordinately illite to smectite (Table 4).

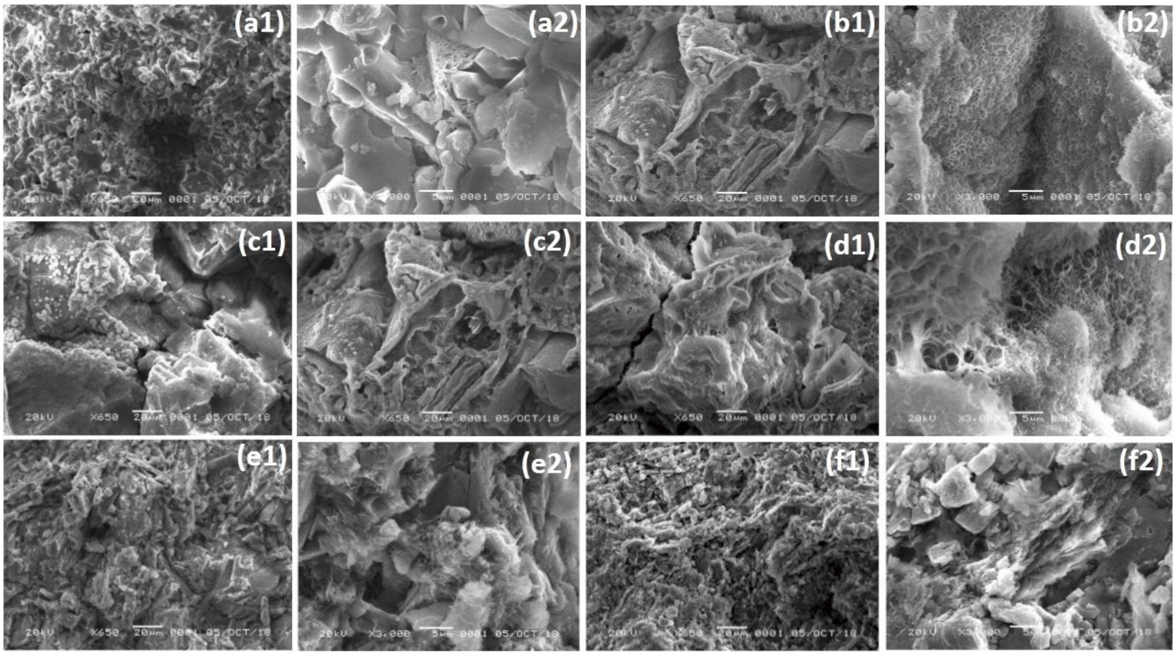

Fig.5 The SEM of clay mineral with the image (1) 650 times and (2) 3,000 times. The SEM of (a) Tuff-Tmpb; (b) Tuff-QTv; (c) andesite-Qwb; (d) Tuff- Qopu; (e) Andesite -Qhl; (f) Tuff-Tmk.

6. DISCUSSION

6.1 Indicators of Active Fault Zones

Remote sensing and field survey methods are used to identify areas affected by active faults. Faults that occur in the Quaternary period and are expected to be active in the future are classified as active faults [21].

Another definition of active faults is that they have moved within the most recent 10,000 years [21]. By using the regional tectonic study of southern West Java, Cisewu is included in the areas which are affected by tectonic activity with main compressive stress direction oriented South to North [1,24]. Also, the lithology is dominated by Quaternary volcanic deposits. The tectonic activity of a region can be predicted by a quantitative geomorphology approach. That is the mountain- front sinuosity (Smf) and valley floor – valley height ratio (Vf) formulas. These parameters can be used as an indicator of active faults. There are several faults in Cisewu area and the fault activity will be discussed as follows.

Accordance with an understanding of the definition [21] provides characteristic of active fault can be applied. The evaluation of the active fault of Cisewu area is determined base on the expand lineament of fault pattern, which cut through the Quaternary volcanic deposits. The area of Cisewu and its surroundings is controlled by several faults that cut the Quaternary age rock units (Table 1).

Also, the stratigraphy of Southern West Java dominated by volcanic deposits with various ages on Quarternary [13,14]. Recently, several active volcanoes are separate in Southern West Java, and the outcrops deposits can quickly found. We assumed the faults that may continue to move in the future. Therefore, the vary of the active fault classes can be determined by smf and Vf formulas as a morphotectonic approach [1,25]. The presence of active faults as part of active tectonics is also indicated by the results of geophysical surveys [24] and the presence of the epicenter of earthquakes on land [26]

The 33 sites of mountain-front sinuosity (Smf) index measurement of Cisewu area have calculated to determine the tectonic activity class. Commonly, Smf values of Cisewu area and surrounding classify into Class 1 as active tectonism with value close to 1. Its associated landform includes elongated watershed, steep slope (30 to 140 %), and narrow valley floors.

In some areas, the Smf value can classify into Class 2 and Class 3. Further, Valley height-width ratio (Vf) is another geomorphic index for identifying relatively young watershed in tectonically active areas. The field survey data of the Vf value obtained that the average value of the upstream area is 1.09, the middle area is 0.23, and downstream is 0.12.

The Vf value in the Cisewu area is included in Class 3 which shows low uplift, but several areas around it are classified as Class 1 and Class 2. By this calculation in Table 5, the morphotectonic of the research area can classify into Class 1 to Class 3, related to the fault activity on the Quaternary period. The origin of clay mineral samples obtained from these areas.

Table 5 The morphotectonic indicators of active fault on the Quaternary and Tertiary periods

Geomorphic index	Quaternary	Tertiary	Total value range
Smf	1.05 – 2.17	1.04–1.13	1.04–2.17
Vf	1.34 – 19.38	1.03–6.05	1.03–19.38

6.2 Clay Mineral Properties and Landslide Occurrence

The rock samples conduct by megascopic description, petrographic thin section, SEM observes, and XRD method. The samples are obtained from the fault zone as clay gouge at Cisewu and surrounding areas, which is concerned with active fault and their implication for the occurrence of the landslide. The clay minerals identify within the fault zone on six samples are characterized by the presence of smectite group, quartz group, feldspar group, chlorite group, and mica group. Clay mineral is a product of alteration mineral by cataclastic, diagenetic, and volcanism processes. Its impact on deformation processes. The active fault, volcanism, and diagenetic processes occur in this area. The physical properties of clay mineral expected to reveal a characteristic of clay mineral as an indicator of the occurrence of active fault at Cisewu and other similar circumstance areas.

The recognizing of clay mineral by hand specimen is common to describe that is specific color (yellow-brown, white-grey and black), soft-slick material, and fine-grain size. The distribution of clay mineral contains in percent can be identified by petrographic observation, as shown in Table 2. In thin-section analysis, the mineral composition is dominated clay mineral with mineral contain between 32% and 60%. The rock unit of Tuff sandstone of Old volcanic deposits (QTv) high contains clay mineral and the lowest in the Tuff rock of Bentang Formation (Tmpb). The circumstance of the clay mineral occurrence concerned with mineral alteration, which influences deformation processes. The physical properties of clay mineral in Quartenary volcanic deposits characterize with dull green color, floating particle, maximum of interference color in violet order III (0.026), and particle size are < 0.005 mm. The exposure of the minerals such as pyroxene, plagioclase, K-feldspar, quartz, and calcite is known as a source of the origin of the clay mineral. In Fig.4b, Fig.4c, Fig.4d, and Fig.4e shows the cracks in a fragment of the mineral origin, which identifies as an influence changing of pressure and temperature.

While in Tertiary sedimentary rock is characterized by green yellow-brown color, floating particle, <0.005 mm fine-grain size, and not clear borders of clay mineral, as shown in Fig. 4a and Fig.4f. The exposure of minerals such as plagioclase, K-feldspar, quartz, and glass mineral is angular to sub-rounded. The presence of clay minerals in samples may be affected by fault activity, but the other processes are considerable. By using cross-section observation, characteristics of physical properties in clay mineral can use to recognize the clay mineral availability and possibilities of the type of deformation processes. Therefore, it can not find the information on the type and composition of the clay mineral.

The more in-depth analysis of physical properties utilizes SEM method. This method is the best real exposure of clay mineral with magnification object until thousands of times. Fig. 5 shows the SEM images with magnification 650 times and 3,000 times. Moreover, all images of clay mineral identify into a smectite group that characterizes base on the physical properties. In Table 3, the clay mineral characterize as follow: 1) texture: flake and parallel cellular 2) structure: webby, layer sheet, and massive pore 3) particle size: < 2 mm 4) morphology: cornflake, melt lake and massive flake. The flake sheet texture, webby structure, irregular shape, and euhedral form with ruggy plates are typical of the smectite group [12]. The characteristic of Quaternary volcanic deposits shows the excellent assemblage of webby structure, as shown in Fig.5b1/b2, Fig.5c1/c2, Fig.5d1/d2, and Fig.5e1/e2. While the Tertiary sedimentary rock is a wrong webby structure even seems random, as shown in Fig.5a1/a2, and Fig.5f1/f2. In this case, the assemblages interpreted that these two difference assemblages represent probably different even: 1) Quaternary period and 2) Tertiary period. The presence of the smectite group can prove by XRD bulk analysis.

The present of saponite characterizes with a peak between 15[Å] to 16[Å]. The physical properties of these minerals are high expanding of the clay mineral. The product of hydrothermal deposits in vein and vesicles basalt, which is associated with formed silicate-serpentinite, amphibole, and skarn. Others of clay mineral are clinochlore ferroan 7[Å], traskite 15[Å], albite 6[Å], and eastonite mica 10[Å]. These predict to subordinate illite group or combinate of the layers illite-smectite. The kaolin group is absent in the samples. It is derivative from illite and smectite mineral alteration. The absence of kaolin mineral may interfere with fault activity, and it indicates the possibility of circulation of hydrothermal fluids only within the fault zone — the reason to suggest that the transformation of clay mineral is hydrothermal rather than diagenetic. However, kaolin can be recognized by SEM observation with magnification 3000 times, as shown in Fig. 5a2. The absent of kaolin may be not identified by the XRD method. The active fault is a term of zones and a short period. According to assemblages of clay mineral in fault zone is produces an alteration material with low temperature and pressure by gradual processes (series in sequence product). This case is not discussing the geochemical properties specific to the pressure and temperature and its derivative.

Fig.6 Landslide on Talegong-Cisewu road, the southern part of Garut, West Java.

The geological features of the area indicate the occurrence of faults and landslides affected by a long history of tectonic activity during the Quaternary period. It has been difficult to recognize the geological structure development in this mountainous volcanic area for the following reasons. The physical properties of clay mineral are significant, which is the implication for landslide investigations [7]. The origin of clay minerals can help in identifying areas prone to landslides. In some cases, the cause of landslides can be identified through this study. The presence of clay minerals in the study area is dominated by saponite type (smectite group). Smectic expand clay mineral with physical properties is the highest swelling index [27]. The cohesion and adhesion properties of smectite are also different from other soil minerals. This property is closely related to landslides, soil creep, and erosion. Soils containing high smectite have the potential for landslides because smectite can absorb large amounts of water [28]. Smectite is also almost always synonymous with soil movement events caused by expansion and contraction due to changes in soil water content. Also, it is a high-water absorption ability. In the rainy season is most soil which saturated water content is. This circumstance can result in a region that is vulnerable to landslide occurrence (Fig.6). The consequence of landslide identification has delineated the regions with assemblages of high clay mineral content — meanwhile, the current fault study concerned with landslide occurrence that still becomes a trending topic. Active fault activity is assumed to play a role in the genetics of landslides, especially in the South West Java region. This is also supported by the results of previous studies [26,29,30,31,32].

7. CONCLUSION

The area of Cisewu and its surroundings, which is on border zone between South Garut and South Cianjur, is an area with high tectonic activity. This is evidenced by the 3 results of the analysis of the geomorphic index (smf and Vf) as well as the geological structures exposed at the surface and those that are still below the surface.

Based on the results of petrographic analysis of samples from 6 rock formations, the dominant clay mineral content ranged from 32 to 60%. Clay minerals are generally saponite types within the smectite group based on XRD and SEM analysis. Several scientific publications show that the smectite group has a high absorption to water which allows the material to become unstable and reduce its cohesive strength. This makes the area composed of rocks with a dominant content of this type of clay prone to landslides, especially if it is on a relatively moderate to very steep slope.

8. ACKNOWLEDGMENTS

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