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Tropical Volcanic Residual Soil

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Abstract

In West Lampung, Sumatra, Indonesia, tropical volcanic residual soils are formed from weathering of volcanic breccias in hydrothermal alteration areas with a thickness of up to 20 m. This soil has the characteristics of clayey silt, low to high plasticity, brownish-red color, has the potential to swelling, easily eroded, and slide when it is saturated, and contains the minerals kaolinite, halloysite, illite, dickite, nacrite, montmorillonite, despujolsite, hematite, and magnetite. The results showed that this soil can cause corrosion of steel and is widely used by the community as a medium for growing plants and vegetables and as a foundation for infrastructure (for example, houses). The volcanic residual soil of the research area had Low Rare Earth Element (LREE) potential and specific uses. The soil with characteristic low plasticity has Liquid Limit (LL) brine value <50% will be suitable for agriculture purposes, building foundations, and earth construction. At the same time, the other category is soil with intermediate to high plasticity characteristics, which has an Liquid Limit (LL) brine value >50%, was more ideal for the primary forest.

Keywords: Corrosion, eroded, LREE, soil plasticity, West Lampung

1. Introduction

The soil (Greek: pedon; Latin: solum) is a part of the earth's crust made up of minerals and organic matter. The soil originates from rocks' physical and chemical weathering and has particle sizes ranging from clay to boulders. In general, the soil is divided into two types: residual soil and sedimentary soil [1].

Residual soil is soil formed directly from the rock source due to rock chemical weathering, dominated by the hydrolysis process (reaction between silicate minerals and acids) due to high rainfall and temperature conditions. The soil is above and in contact with the source rock or, in other words, does not undergo a transport process [1–4]. Based on the degree of rock weathering, this soil is within or equal to zone VI [5–8] (**Figure 1**).

Residual soil is mainly formed in tropical climates and has high rainfall and is formed in areas with many quaternary volcanic rock formations, such as Indonesia (tropical volcanic residual soil) [9–12]. In Indonesia, these deposits occupy 53% of the land area and form the basis for constructing various types of infrastructure. [9, 13–15].

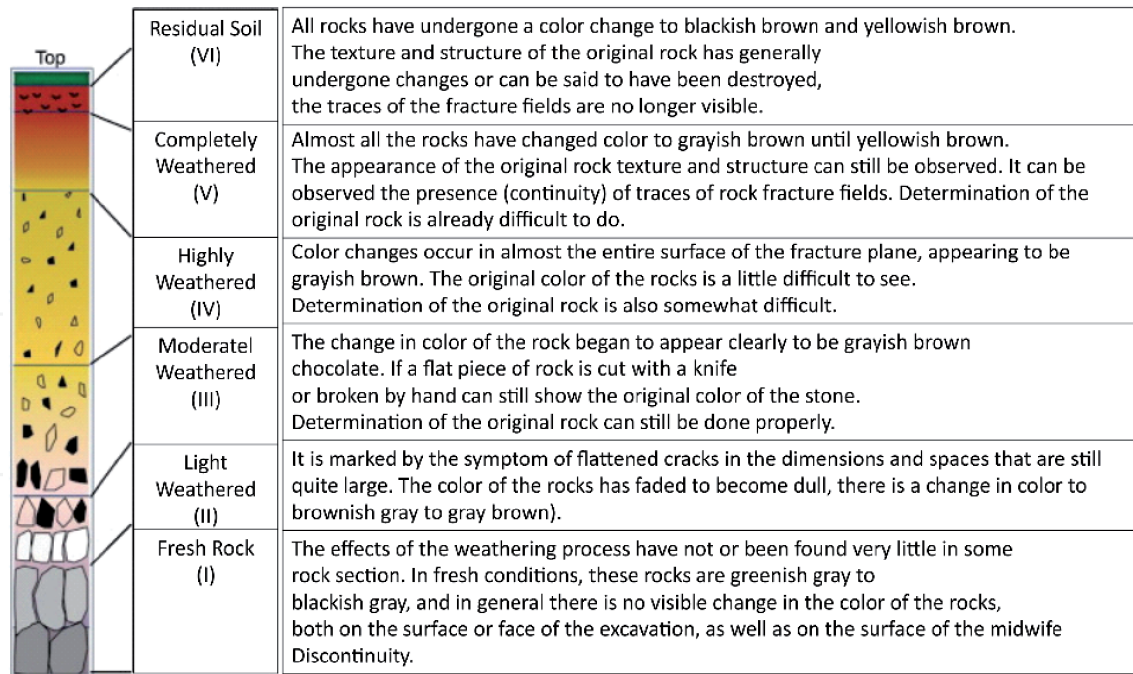


Figure 1. Rock weathering profile and residual soil formation (Modification from [7]).

Geologically, the residual soils have a unique mineral composition of clay. Allophane, halloysite, kaolinite, illite, and montmorillonite are some minerals of clay found in the residual soil [13, 16]. The formation of residual soil will produce its own physical and engineering characteristics [10, 17]. Rahardjo et al. and Huat et al. [10, 18] have revealed that the soil has complex and diverse properties. Depending on the characteristics and history of eruptions, residual soils, in particular volcanic residual soils, may be layered or massive, coarse-grained or fine-grained, bonded or unbound, cracked or not broken. Volcanic residual soil can cover flat or sloping areas, reaching thicknesses of up to tens of meters. This soil covers an essential part of the world's surface, including the formation of slopes, areas occupied by urban settlements, structures, and infrastructure, and can create environmental problems, such as landslides, erosion, and land degradation [19–30].

The remainder of this chapter deals with genetics, characteristics, advantages and disadvantages, land suitability, soil improvement, and comparison with tropical volcanic residual soils. This research was conducted in West Lampung Transect Road, West Lampung, Lampung Province, Sumatra, Indonesia (Figure 2).

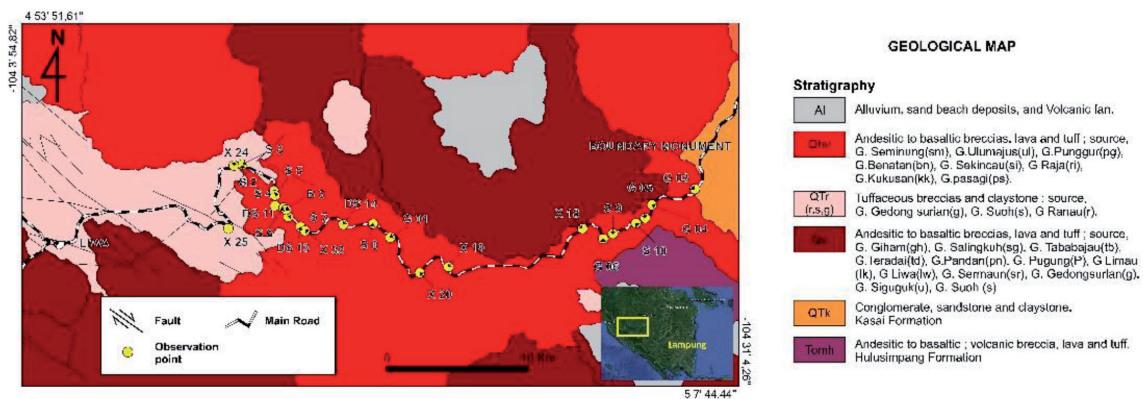


Figure 2. Research area observations and geological map. (Modified from Sohaimi et al. [31]).

2. Genetic

The research area was on tropical wet climate [18]. Annual precipitation in this area was more than 2000 mm per year [32]. The region's geography is characterized by rolling hills with a V valley shape, a medium to a steep slope, and an altitude of 850–1150 meters above sea level (see **Figure 2**). The landscape regulates the flow patterns of regional research into radial, parallel, and sub-dendritic (see **Figure 2**). An important aspect that forms the romance of the research area today is the Sumatra Fault that passes through the area. Geographical conditions of the research area and



Figure 3.
Tropical volcanic residual soil.



Figure 4.
Volcanic breccias.

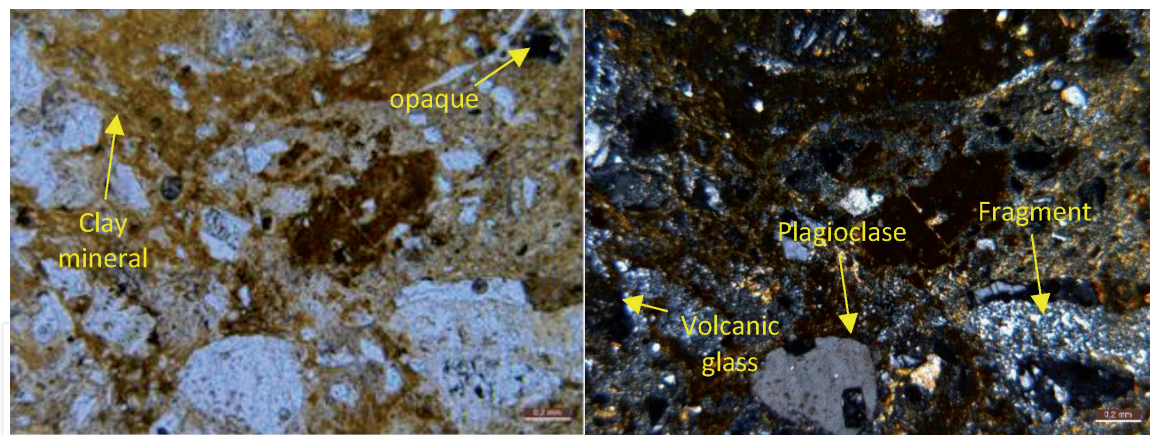


Figure 5.
Rock photomicrograph.

earth dynamics processes formed volcanic soil with a thickness of more than 20 m [28] (**Figure 3**).

Based on field findings and petrographic analysis, the research area consists of volcanic breccias with tuff components embedded in the tuff, sand, and clay matrix. (see **Figures 2** and **4**).

Tuff, the dominant rock, is characterized by crystal tuff and lithic tuff. Those tuff exhibit welded and flow structures, porphyritic and clastic textures, consisting of fragments and cement. The fragments consist of feldspar (partially insulated and alkaline feldspar type), quartz (showing embayment), plagioclase (andesine type), pyroxene, epidote, sericite, iron oxide, opaque minerals, and biotite embedded in the flow-textured volcanic glass base (**Figure 5**).

The rocks that make up the research area are deposited on land. The rock is deposited in a hydrothermal alteration environment. Evidence of hydrothermal alteration in the presence of geothermal manifestations around the research area, namely in the Mt. Seminung to the north and in the Suoh area, Mt. Sekincau, to the south [33].

3. Soil geochemistry

Volcanic glass, mica, and feldspar, as the main components of the rock source, are mainly submerged in clay minerals [34]. Based on XRD analysis, clay minerals are made up of kaolinite, dickite, nacrite, halloysite, illite, montmorillonite, and chlorite. Other minerals, including quartz, hematite, magnetite, and cristobalite, were present (**Figure 6**).

Kaolinite, dickite, nacrite, and halloysite are kaolinite groups $\{Al_2Si_2O_5(OH)_4\}$ [31]. Hunt and Yuan et al. [35, 36] noted that the occurrence of kaolinite and halloysite indicates soil extracted from volcanic rocks with a felsic composition. They described the forming climate at tropical temperatures, neutral to acidic pH conditions, free drainage, and porous rocks. Kaolinite and halloysite are secondary minerals commonly present in Andisols [37]. Both minerals are derived from feldspar and chlorite weathering [38]. Nacrite and dickite are clay minerals from the rarest group of kaolinites. The mineral is a transition from an illite mineral. Chen et al. [39] revealed that the presence of nacrite and dickite was associated with tuff deposition. These minerals are produced in the hydrothermal alteration environment.

The illite mineral $\{(K, H_3O)(Al, Mg, Fe)_2(Si, Al)_4O_{10}[(OH)_2, (H_2O)]\}$ is defined as clay-sized mica contained in clay rocks. Illite is a clay mineral formed in areas with mild climate characteristics or in mountain tropics. This kind of clay is made from weathering rocks rich in K and Al under high pH conditions. Generally,

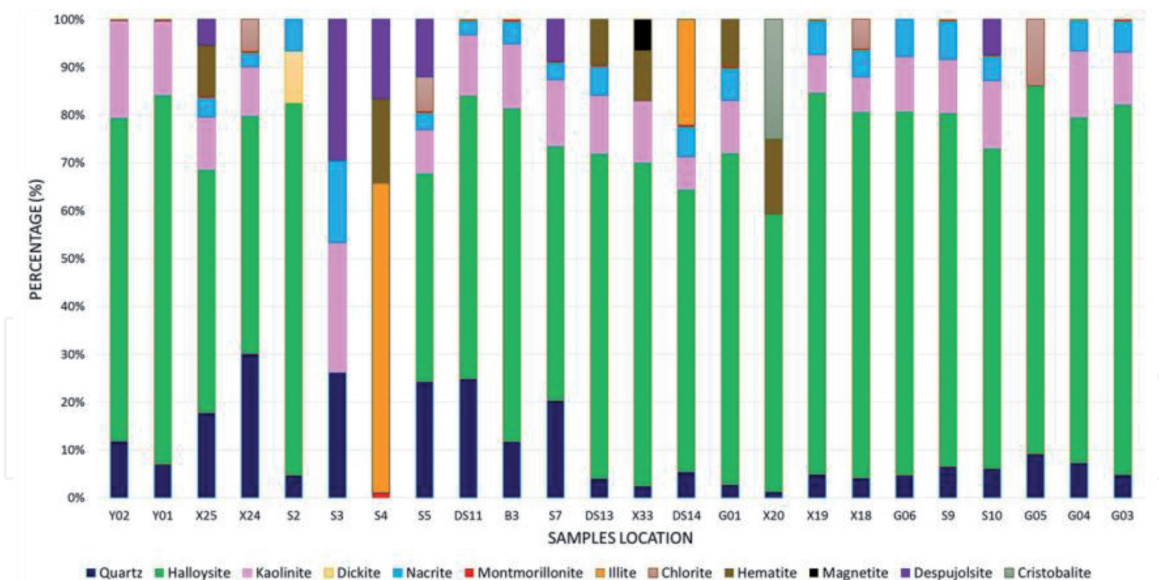


Figure 6.
 Soil composition of mineralogy.

these minerals are formed by weathering mica minerals such as muscovite and feldspar. Chlorite $\{(Mg, Fe)_3 (Si, Al)_4 O_{10} (OH)_2 \cdot (Mg, Fe)_3 (OH)_6\}$ is a secondary mineral, typically found in igneous rock, formed from primary Fe-Mg minerals.

Montmorillonite $\{(Na; Ca)_{0.3} (Al; Mg)_2 Si_4 O_{10} (OH)_2 \cdot nH_2O\}$ is a mineral subclass of the smectite group, formed from the intermediate mica, feldspar, and volcanic ash. The mechanism that acts on the shape of these minerals is the process of neoformation. This phase is typical in source rocks of volcanic glass composition [40, 41]. Ryan and Huertas [42] have proposed that the occurrence of kaolinite-montmorillonite in soil suggests that the soil parent material is andesitic that influenced by hydrothermal alteration.

Hematite (Fe_2O_3) is an iron (III) oxide mineral. Hematite minerals of the clay size can also occur as secondary minerals produced by soil weathering processes and iron oxides or other oxyhydroxides, such as goethite, responsible for the red color of the soil in the tropics [43].

Magnetite (Fe_3O_4) is a mineral and one of the three most common iron oxides in nature. This mineral has magnetic properties. Magnetite, black, a relatively common metallic mineral, is also one of the most important iron ores of modern society, occurring in various igneous, pegmatite, contact metamorphic rocks hydrothermal veins [44].

Cristobalite (SiO_2) is the stable form of silica. This mineral is formed at very high temperatures in medium-acid volcanic rocks [45, 46]. Despujolsite $\{Ca_3Mn_4 + (SO_4)_2 (OH)_6 \cdot 3H_2O\}$ is a mineral formed in hydrothermal manganese deposits [47].

4. Characteristics

Centered on Hardjowigeno [48]; Subardja et al. [49], the West Lampung Semi-Detailed Soil Map on a scale of 1:50,000 in 2016 released by the Agricultural Research and Development Agency, and WRB map (<https://www.isric.org/explore/wrb> accessed on January, 01st, 2021) the research area are made up of Andosol-type soil. The soil is acidic, $PH < 6$, CEC is medium - Low, storage capacity and water absorption are very high; N, P, K, Ca, Mo, Mg content and microbial activity low-very low, and moderate to good drainage conditions/well-drained soils.



Figure 7.
Soil cracking.

Based on observations in the field, generally, the soil in the research area has a brownish-red color, the characteristics of it loose when it is dry and sticky when it is wet, groove erosion can be observed, and it is easy to break off if there is additional water in the rainy season. The soil surface can be seen as the soil severely degraded with very large angular or platy aggregates and restricted pore space (see **Figures 3** and 7).

Based on laboratory analysis (**Table 1**), the soil of the research area is included in the high plasticity silt type (MH) [50]; has characteristics low to medium plasticity characteristics (LL Brine 32.12% - 68.66%) [51, 52]. This soil has a specific gravity of 2.41–3.03. According to Bowles [53], the soil of the research area consists of mica and iron. Next, the soil has a wet unit weight of 1.27 g/cm³–2.15 g/cm³ and porosity 35.25% to 67.00%, based on de Castro et al. [54] these characteristics belonged to the soil which has clayey silt and uniform grain size, and inorganic soil type. The soil has a liquid limit >50%, has a plasticity index >17%. Prakash and Jain [55] categorize this type of soil as soil with high plasticity. The permeability of this soil is 4.63E-11 to 5.54E-05 m/s (soil with small to sufficient permeability) [56]. The engineering characteristics of this soil are cohesion values of 0.008 kg/cm² to 1,675 kg/cm² and internal shear angles 18.36° to 39.26°. These values represent that the soil of the research area is in a very loose to solid state/good and slide hazard [57].

5. Soil microstructure

The soil microstructure investigation was carried out using a scanning electron microscope (SEM), and SEM images at different magnifications are shown in **Figure 8**. SEM photos show that the soil microstructure of the soil of the research area is an aggregation of soil particles with fractures and pores (see **Figure 8**). The percentage of soil aggregation compared to fractures and pores is 70:30. This Figure implies that soil aggregation is dominant against fractures and pores, causing the soil permeability of the volcanic residue in the research area to be small to relatively permeable.

From **Figure 8**, it can be seen that the soil aggregate is kaolinite in the form of platy, illite in the form of curved and spongy sheets, and halloysite in the form of

No	Code	Specific Gravity (GS)	Porosity (%)	Liquid Limit (%)	Plasticity Index (IP) (%)	Permeability (m/s)	Wet Unit Weight γ_s (g/cm ³)	Cohesion (Kg/Cm ²)	Internal Friction Angle (Deg)	LL Brine (%)
1	X25	2,84	54,66	79,70	29,74	7,15E-08	1,78	0,00829	32,4118	53.55
2	S1	2,59	55,60	70,37	36,03	1,65E-09	1,61	0,06626	39,2644	50.00
3	X24	2,72	59,53	94,51	28,85	1,48E-10	1,68	1,67528	24,2048	40.19
4	S2	2,41	53,20	67,65	33,78	2,11E-06	1,69	1,03402	18,6025	101.17
5	S3	2,65	62,70	56,70	22,16	2,05E-10	1,46	1,15602	19,7825	46.64
6	S4	2,78	64,30	54,75	15,59	1,39E-07	1,27	0,71624	34,9597	68.66
7	S5	2,70	51,34	53,35	23,19	3,24E-07	1,80	1,5752	20,8547	48.68
8	DS11	2,80	56,17	71,50	30,75	5,54E-05	1,63	0,23531	20,2978	43.11
9	S6	2,45	45,87	59,22	27,84	3,19E-06	1,67	0,25504	34,5343	52.00
10	S10	2,50	48,57	61,00	26,95	4,63E-11	1,70	0,67808	33,5389	51.93

Table 1.
Some soil samples and their physical properties.

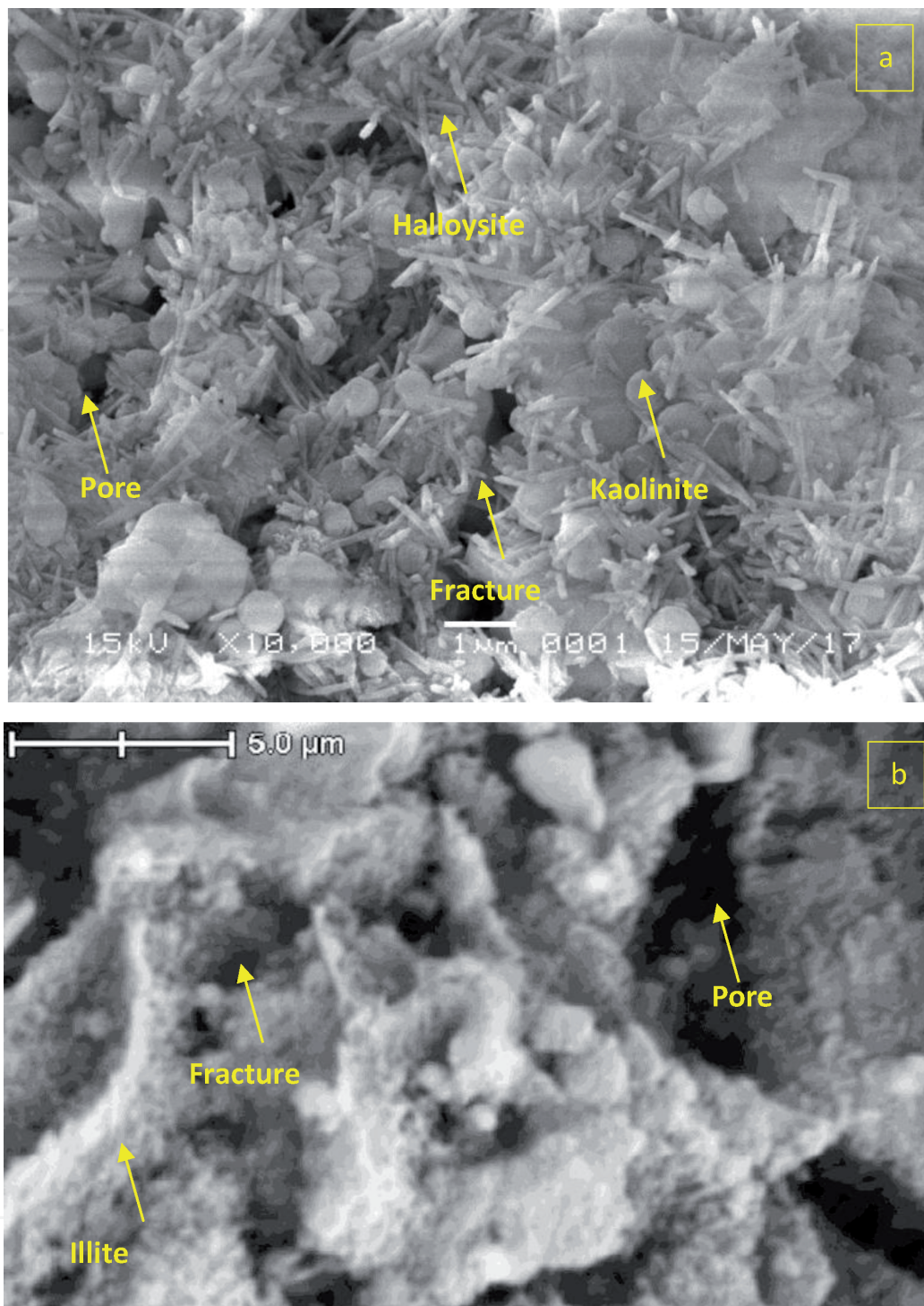


Figure 8.
a-b SEM tropical volcanic residual soil.

tubes. The three minerals are bound/cemented by iron oxide. Plate-shaped particles will be susceptible to degradation due to mechanical efforts and forces acting in nature. The shape of the plate particles causes the shear strength of the volcanic residual soil in the research area to be not so large [58, 59].

6. Advantages and disadvantages

People usually use volcanic residual soil as a growing medium for different kinds of plants [60, 61] because the soil has an organic layer and organic minerals [62]. Priddle et al. [63] argued that volcanic soil, especially red soil, is one of the most

fertile soils in the world as a product of volcanic material. This soil is very suitable for growing root crops such as potatoes and ginger. In some countries, such as Japan and China, volcanic residual soil is a critical resource with significant consequences for sustainable agricultural production and stable economic growth. These countries use this soil as a basis for infrastructure (roads, buildings, etc.) and landfills [64–67].

Because this type of soil is widely used for agriculture, fertilizers for plant fertilization will be intensive. One source said that the use of fertilizers in the West Lampung area was 17,845 tonnes. The subsidized fertilizer consists of urea of 9,365 tons, SP36 1,300 tons, ZA 1,230 tons, NPK (nitrogen, phosphorus and potassium) Fonseka 5,150 tons, and organic 800 tons. (<https://www.liputan6.com/bisnis/read/4464775/alokasi-pupuk-bersubsidi-lampung-barat-tahun-2021-naik> accessed on March 03, 2021). Hu et al. [68] and Ramos et al. [69] state that fertilizers in the soil will increase the likelihood of REE forming. The main areas with an increase of REE in the soil are restricted to regions where agriculture is intense. In agricultural areas, the main REE entrance is caused by the application of phosphate fertilizers. These factors form REE in addition to the parent material that forms the soil and the mineralogical content of the soil. REE will form in all types of rock and soil. Soils originated from igneous rocks, schists, and sandstone tend to contain more REE when compared to those originated from other materials. The adsorption of REE in soils is influenced by clay type and content, especially the concentrations of aluminum silicates and iron and manganese oxides. These last ones have the most remarkable adsorption capacity.

Because the soil type in the research area comes from Quaternary volcanic rock, dominant clayey soils, and contains manganese oxide (Despujolsite), we hypothesize that in the soil of the research area, there is an Low Rare Earth Element (LREE) type. One of the benefits of Rare Earth Element (REE) is in the electronics industry. REE will be used as a chemical catalyst for the manufacture of portable electronic device batteries.

On the other hand, volcanic residual soil still has its disadvantages. Iqbal et al. [28] observed that the liquid limit of volcanic residual soil is >50%, while some researchers [70–73] found that liquid limits >40% would decrease the shear strength of the soil and cause landslides (**Figure 9**). Landslides usually occur during the rainy season. Landslide due to soil lack of strength as rainwater infiltration induces positive pore water pressure and reduces the safety factors (FoS).



Figure 9.
Landslide event.

Many residual soils in the tropics exhibit abnormally high internal shear angles, which can be explained by soil particles randomly arranged by weathering [58]. Another reason the residual soil angle has a large enough internal shear angle is iron oxide in the soil. Zhang et al. [23] revealed that iron oxides in residual soils are present due to local enrichment and exist in the form of layers of clay aggregates binding them to coarser aggregations. Zhang et al. [58] stated that iron oxide in residual soil would cause poor compacting properties, but it is an agent to increase cementation and structural strength of the soil. The presence of iron oxide will make the internal friction angle in the soil quite large. The weakness of the bonds (cementation) formed by iron oxide is that when the soil is saturated with water, the cementation can be damaged or destroyed. The event will reduce soil cohesion. If the soil forms a slope, there will be a possibility of landslides.

Darajaat et al. [74] revealed that one of the factors that influence the stability of the volcanic residual soil slope is rainwater with an intensity condition of 10–43 mm/hour and 120–168 hours. This condition will reduce the slope safety factor by 2–30%. Another, Widisaputra et al. [75] simulated the stability of the volcanic residual soil slopes that were affected by earthquakes. The result is that the safety factor of the volcanic residual soil slopes will decrease by 1/3 to 1/2.

The observations of Iqbal et al. [76] concluded that the volcanic residual soil in the West Lampung area has swelling potential. This potential is due to the volcanic residual soil containing clay minerals such as kaolinite, halloysite, illite, and montmorillonite. The swelling-shrinking features that belong to this type of soil result in cracking, which occurs during the dry season. The fractures that occur would affect the local hydrological conditions. These conditions can impact the stability of slopes, agricultural production, and plantations [77–81]. On the other side, the mechanism of swelling and shrinking of the soil can cause considerable damage to the walls of the buildings [27, 82, 83].

Another thing that is concerned about is the corrosion process of steel. Veleva et al. [84]; Norhazilan et al. [85]; Noor and Al-Moubaraki [86]; Lim et al. [87]; Wasim and Shoaib [88]; Liu et al. [89] revealed that soil composed of silt and clay will have the highest level of corrosion compared to soil composed of rough grains (gravel to sand), this is related to the water content, the corrosion process will be high in soils with high water content. Iqbal et al. [29] stated that the properties of soil engineering (plasticity index, water content, and clay content) impact the corrosion process of steel. Their paper found that the water content had an adequate contribution of 24.79% to the corrosion process. The corrosion process (in this case, the corrosion rate) will increase if 1% of the index plasticity and water content is added.

Since the soil characteristic of the research area is silt and clay, this process should be taken into account when building infrastructure (such as water/gas/oil buried pipelines or building foundations).

7. Land suitability

According to several researchers [90–94], there have been very drastic shifts in land use in West Lampung, Sumatra, Indonesia over the last ten years (2000–2010). Primary forests have declined significantly, while dryland agriculture (coffee-based farming), rice fields, and residential areas have grown. These adjustments cause soil erosion and surface runoff. According to the author's observations in the region, soil depletion resulted in erosion and landslides during the rainy season (see **Figure 9**). Meanwhile, during the dry season, there is drought and soil cracking (**Figure 7**). This phenomenon indicates the occurrence of soil quality issues in the West Lampung

region. As a result of these issues, it is assumed that the volcanic residual soil of the study area has unique characteristics for specific land use.

Based on our research, using a statistical approach (K-Means Clustering) (Tables 2 and 3) and qualitative analysis, the soils of the research area are divided into two clusters (Figure 10). The first cluster soils with low plasticity, LL brine value of 50% or less (low to intermediate salt content). This cluster included soils with the inactive soil category (< 1) and contained minerals: despujolsite, hematite, chlorite, montmorillonite (< 0.4%), and quartz. While the second cluster soils with intermediate to high plasticity have LL brine values greater than 50% (intermediate to high salt content), and soils with the normal to active soil category (> 1). Despujolsite, hematite, magnetite, illite, montmorillonite (> 0.4%), dickite, and quartz are the minerals that can be found in this cluster.

The following is an example of soil suitability. The first cluster includes swell-shrink features ranging from zero to intermediate. This soil type has well-structured soil, strong consistency, low seepage losses, and a limited pore area [67, 95]. The soils would be ideal for agriculture, building foundations, and earth construction due to their characteristics [67].

The second cluster is distinguished by intermediate to high swell-shrink characteristics [96]. These soils are dispersed because of their high Natrium content. The soils had been heavily eroded, and platy aggregates had formed [95]. These traits contribute to slow seedling emergence and germination [97]. These soils have insufficient soil intensity [98]. Infiltration in these soils can be rapid at first, but they later stay wet for long periods, causing erosion, infrastructure destruction, and trafficability problems [99]. Because of their characteristics, soils in this cluster are well suited for primary forest growth.

No	Sample Code	Soil Activity	LL_brine	Montmorillonite	Clusters
1	X25	1.25	53.55	0.6	2
2	X24	0.82	40.19	0.4	1
3	S2	0.92	101.17	0.9	2
4	S3	1.51	46.64	0.4	2
5	S4	1	68.66	0.9	2
6	S5	0.91	48.68	0.4	1
7	DS11	0.92	43.11	0.4	1
8	S10	0.97	51.93	0.4	2
9	G05	1.26	59.17	0.6	2
10	G03	0.99	47.26	0.5	2

Table 2.
Tropical volcanic residual soil cluster.

	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
Soil_Activity	37.354	1	.327	54	114.313	.000
LL_brine	18.026	1	.685	54	26.327	.000
Montmorillonite	20.784	1	.634	54	32.800	.000

Table 3.
 ANOVA.

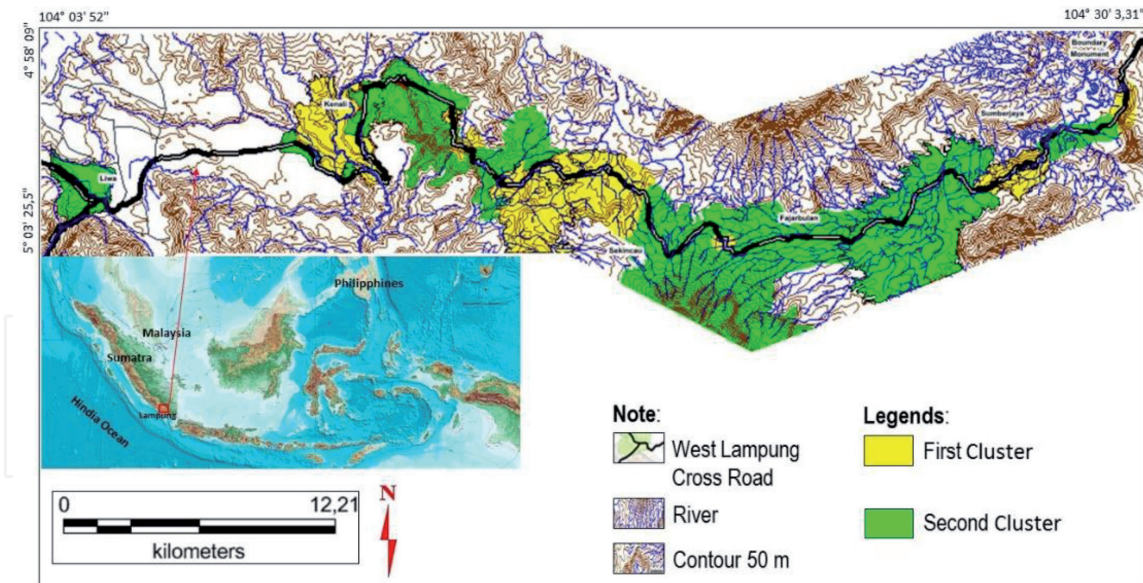


Figure 10.
Soil cluster map.

8. Soil improvements

Volcanic residual soil is unique for engineering purposes. For engineering purposes, much volcanic residual soil is compacted to increase soil strength and/or decrease permeability. This is done to increase density, reduce porosity, and shrink pores. Volcanic residual soil exhibits wretched incompetence, but this property can often be overcome by drying. Significant changes in cohesion and internal friction angles can be induced during drying to make volcanic residual soil suitable for engineering purposes.

One example is that a Road Engineer would dry volcanic residual soil in the sun to irreversibly reduce its moisture content or apply calcined lime (CaO), gypsum, cement, and/or bitumen to create an exothermic dehydration reaction [67, 96, 100].

Another way to improve the physical properties of volcanic soil is by using agro-ecological methods, which is not allowing volcanic residual soil to be bare, the goal is to prevent the soil from being easily eroded [67, 96, 101, 102]. Planting elephant grass is an agro-ecological effort. In addition to helping increase soil cohesion, elephant grass can also be used as animal feed.

9. Comparison

In several years, Buurman, P. [103], Northmore, et al., [104], and Prasetyo and Gilkes [105], research on the characteristics of volcanic residual soils in Indonesia was conducted. Case studies involved soils on andesitic volcanic material between 100 and 1000 m altitude in West and East Java, West Sumatra acid volcanic tuffs, and South-East Sulawesi ultramafic rocks in Indonesia. Discussions are mainly on soil classification, soil genetic, engineering characteristics, and engineering use.

On West Java, Indonesia, Latosols in a toposequence between 40 and 1020 m altitude on andesitic rocks and derived sediments were classified according to Soil Taxonomy. Although soils can be classified according to Soil Taxonomy, several of the boundaries in Soil Taxonomy units are inconvenient for practical use. It is proposed to define Red and Yellowish Red Latosols. The Location of the research took place on the Salak and Gede Volcanoes, West Java. This area consists of intermediary volcanic tuffs (andesite). Soil, which is the result of weathering of the source

rock, contains halloysite as the main mineral that already shows some kaolinite characteristics (metahalloysite). This mineral is accompanied by fair amounts of interstratified illite-vermiculite, some illite-chlorite, goethite, and quartz.

The subsequent research is on the west and north to east slopes of the Lawu Volcano, East Java, Indonesia. The physical chemistry and mineralogy were studied of two sequences of soils: Andosols, Latosols, Mediterranean Soils, and Grumusols on the west slope and Mediterranean Soil on the north-east slope of the Lawu Volcano. Soils are developed from pyroxene andesite parent material on Upper Pleistocene and Holocene surfaces. Weathering gradually increases downslope. Andosols are the least weathered soils, while Mediterranean Soils at the lowest altitude are most strongly weathered. Downslope, free iron in soils, and particularly iron concretions in the sand fraction increase considerably, hence, perhaps the red color of soils at lower altitudes. Weathering with the prevailing high rainfall and constantly high (isohyperthermic) temperature produces deep soils with predominantly halloysitic mineralogy. Gibbsite is formed in medium acid soils. Smectite appears in neutral to mildly alkaline soils with a high supply of bases.

The presence was demonstrated of Oxisols on felsic and ultramafic parent materials on South-East Sulawesi. On ultramafic rocks, there was an association of Inceptisols, Alfisols, Ultisols, and Oxisols governed by topography. The rocks are mainly peridotites with a varying degree of serpentization. They are separated from the main body by a fault zone with schists and phyllites. Montmorillonite minerals predominate in the clay fractions with additional vermiculite-illite, margarite, illite, and quartz following a high supply of bases—mainly magnesium—by weathering of peridotite. Montmorillonites form in contact with the disintegrating rock or in places with magnesium-rich groundwater. As soon as Mg becomes depleted, interstratified minerals form that finally change to kaolinite.

The soils studied in West Sumatra occur on Tertiary or Early Quaternary volcanic tuffs of dacitic and liparitic composition. The landscape is an undulating dissected peneplain, and erosion is only slight. The soil Colors were mainly strong brown and redder. Textures were very clayey. The soils were strongly desaturated. Clay fractions were invariably dominated by kaolinite, showed minor amounts of gibbsite, chlorite, goethite, and quartz.

Based on the literature review above, the soil in the research area has several similarities and differences in characteristics. The equation lies in the color reddish brown-brownish red, iron, and soils with predominantly halloysitic mineralogy. Its distinguishing characteristic is the content of other minerals. This difference is due to differences in geographical location and surrounding geological conditions. It is known that an area with mountainous conditions, tropical climates, bypassed by fault structures, and there is a manifestation of the geothermal/hydrothermal alteration environment, will produce soil with a sufficiently varied and concentrated clay mineral content, as well as minerals that are characteristic of the hydrothermal alteration region (e.g., Despujolsite) as in the research area.

10. Conclusions

Tropical volcanic residual soils of the research area have several similarities and differences in characteristics compared to other volcanic residual soils in the Indonesian area. The equation lies in the color reddish brown-brownish red, iron, and soils with predominantly halloysitic mineralogy. Its distinguishing characteristic is the content of other minerals. This difference is due to differences in geographical location and surrounding geological conditions. It is known that an area with mountainous conditions, tropical climates, bypassed by fault structures, and

there is a manifestation of the geothermal/hydrothermal alteration environment, will produce soil with a sufficiently varied and concentrated clay mineral content, as well as minerals that are characteristic of the hydrothermal alteration region (e.g., Despujolsite) as in the research area.

The soil has a specific use. For the first cluster, the community can use the soil to growing some plants and vegetables because it is very fertile. The soil can be used for building foundations, but the soil can cause steel corrosion, requiring special attention when using it. Another particular concern is for the soil in the second cluster. This soil type has the potential to swelling and landslide during the rainy season. Soil improvements are needed when the community will use them. Finally, the soil in the research area has Rare Earth Element (REE) potential. Low Rare Earth Element (LREE) is the type that is likely to be in the soil.

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Conflict of interest

This statement is to certify that all authors have seen and approved the manuscript being submitted. We warrant that the article is the Authors' original work. We warrant that the article has not received prior publication and is not under consideration for publication elsewhere. On behalf of all Co-Authors, the corresponding Author shall bear full responsibility for the submission.

This research has not been submitted for publication, nor has it been published in whole or in part elsewhere. We attest that all authors listed on the title page have contributed significantly to the work, have read the manuscript, attest to the validity and legitimacy of the data and its interpretation, and agree to its submission to IntechOpen.

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Notes/Thanks/Other declarations

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