

Investigation of Lithologic Discontinuities Phenomenon in Andisols derived from Mt. Patuha

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ABSTRACT

Lithologic discontinuity reflects the distinct change between different types of soil layers that can occur due to various geological process, resulted in variation composition, colour, texture, organic matter, consistency, structure, and others characteristics. Soils derived from volcanic eruption have the possibility to have lithologic discontinuity in the depth of the soil profiles due to the different eruption that formed the soils. Soils developed from the eruption of Mt. Patuha were investigated whether lithologic discontinuity presence the soil layers. The research used descriptive and comparative method of two profiles, analysed the soil macro-morphology and soil laboratory analyses covered colour, organic carbon, texture, consistency and structure. The result showed that the unusual pattern distributed of colour, organic matter, consistency, structure indicated the lithologic discontinuities of the underlying 2Ab (A buried) horizon to the overlying horizon. The darker colour, higher organic matter content, friable consistency in 2Ab in deeper depth, were some indications of lithologic discontinuities, where in soil without lithologic discontinuities the deeper depth or horizon was normally lighter colour, lower organic matter content and firmer consistency. However, detailed analysed with instruments like XRF and VIS DRS are needed to have the precise elemental composition in every horizon which conclude the horizon from the same or different parent materials.

Keywords: colour, organic carbon, consistency, structure, XRF, VIS DRS

1. INTRODUCTION

Lithologic discontinuity in soils marks a boundary between layers with different origins, significantly impacting soil characteristics and behaviors (Lorz et al, 2010). It refers to a distinct change in the soil's parent material within a soil profile. This discontinuity can occur due to various geological processes, such as changes in depositional environments, tectonic activities, or erosion. It often indicates a change in the geological history of an area, for example in volcanic area it can refer to different of volcanic eruption that develop the soil in the surrounding. It also indicates the change that soil horizons above and/or below the discontinuity have originates from different parent materials that may have also distinct physical, chemical and mineralogical properties

The origin of the parent materials above and below the lithologic discontinuity may have been deposited under different conditions, such as different time periods

(Kowalska et al, 2020). It is typically identified by noticeable differences in soil texture, structure, colour, mineral content, and sometimes even in the biological activity or organic matter content between the layers. The discontinuity can affect the soil-forming processes, leading to variations in soil development and horizon differentiation. The upper layer is rich in organic matter, with high porosity and good drainage. The lower layer, affected by previous volcanic activity and weathering, might be more compact, with different mineral content and nutrient availability.

Differences in texture and structure can influence water movement and retention within the soil profile. The understanding of lithologic discontinuities is important for soil management and agricultural practices, as it can impact root growth, nutrient availability, and drainage. Differences in parent materials can influence soil fertility and its suitability for different crops or vegetation types. Lithologic

discontinuities can affect erosion and deposition patterns.

Soils around Mt. Patuha in West Java Province, Indonesia is classified as Andisols according to Bapeda (2008) and referred to parent materials of volcanic eruption that meet the requirements of andic soil properties as mentioned in Soil Survey Staff (2022). Volcanic materials like ash, pumice and other pyroclastic materials as the parent materials, are the main source that developed to Andisols, and the repeated eruptions of volcanic activities can trigger the existence of lithologic discontinuity since every eruption may bring different minerals content and composition (Ahr et al, 2017).

Andisols that formed on a volcanic slope may consists of recent volcanic ash in the upper layer, while the lower layers may contain the weathered of older volcanic deposits and bedrocks. The lithologic discontinuity between the fresh ash and the older material creates distinct soil horizons. Volcanic landscapes like the area of Mt. Patuha are often dynamic, with new ash deposits covering older soil layers, creating complex soil layers. It was therefore interesting to investigate the lithologic discontinuity in Andisols in the area of Mt. Patuha.

2. MATERIAL AND METHOD

The research was done on Andisols in the southern slope of Mt. Patuha in Patengan Village, Bandung District, West Java Indonesia. Several maps were used to determine the proper location for making soil profiles and describing them:

1. Soil map of Bandung District scale 1:125.000 (Badan Perencanaan Daerah, 2008)
2. Geological map of Sindangbarang and Bandarwaru sheet scale 1 : 100.000 (Koesmono et al., 1996).
3. Topographical map of Bandung District scale 1 : 125.000 (Badan Perencanaan Daerah, 2008).

4. Land use map of Bandung District Scale 1:250.000 (Badan Perencanaan Daerah, 2008).

Determining the location of observation location was done by overlying the existing maps to have the combination map of soil ordo, distribution of parent materials and geological formations, the expecting of topography and slope, in a certain natural vegetation. Profiles description and soils sampling were done in Andisols from the eruption of Mt. Patuha, in the slope of 8-15% under natural forest vegetation of Kajuput and Pine. There were two profiles identified for profile description.

Field observations were done for having data of slope, land use, soil morphology like solum depth, boundary and horizon thickness, soil color, texture, structure, consistency, pores, pH, roots, referred to Field Book for Soil Describing and Sampling Soils (NSSC, 2002).

Disturbed soil samples were taken from profiles in every horizon for analysing of physical and chemical characteristics like texture, bulk density, organic carbon, P-retention and $Al + \frac{1}{2} Fe$ with acid ammonium oxalate, which the analyses referred to van Reeuwijk (2002). Undisturbed soil samples were taken for analysing of bulk density certain horizon. Observation of lithologic discontinuities were based on profile observations (colour), physical analyses (texture) and chemical analysis (organic carbon).

3. RESULT AND DISCUSSION

Profile description of both profile is shown in Table 1 and 2. The first profile namely PTH 1 located at Desa Patengan, Rancabali Regency, Bandung, West Java Province. It parent material was lava and lahar from Mt. Patuha. The geographical position was at $107^{\circ} 23' 35''$ East and $07^{\circ} 08'40''$ South at the elevation of 1781 m asl with 8% slope. The drainage was good with high permeability. Cajeput tree (*Melaleuca cajuputi*), and cogon grass (*Imperata cylindria*) were the vegetations found there. Udic and isothermic were the soil moisture regime and soil temperature regime in the area. Profile picture shown in Fig. 1.

The second profile namely PTH 2 also located at Desa Patengan, Rancabali Regency, Bandung, West Java Province. The geographical position was at 107° 23' 47" East and 07° 08'42" South at the elevation of 1896 m asl with 9% slope. The drainage was good

with high permeability. Cajeput tree (*Melaleuca cajuputi*), and shrubs were the vegetations found there. It has the same parent material as PTH 1: lava and lahar from Mt. Patuha, same soil moisture regime and soil temperature regime: udic and isothermic.

Table 1 Profile Description of PTH 1

Depth (cm)	Horizon	Description
0-11	Ap1	Dark brown (10YR 3/3); silt; crumb, medium, week, very loose, abundant of macro. meso and micro pores; abundant of big, medium and fine roots; pH 5; horizon boundary clear and flat.
11-19	Ap2	Dark grayish brown (10YR 3/4); silt; crumb, medium, week, very loose; abundant of macro. meso and micro pores; abundant of big, medium and fine roots; pH 5; horizon boundary clear and flat.
19-39	Ap3	Dark yellowish brown (10YR 3/6); silt; crumb, medium, week, very loose; abundant of macro. meso and micro pores; abundant of big, medium and fine roots; pH 5; horizon boundary clear and flat.
39-67	Bw	Dark yellowish brown (10YR 4/6); silt; crumb, medium, week, loose, abundant of macro. meso and micro pores; abundant of big, medium and fine roots; pH 5; horizon boundary clear and flat.
67-85/95	BC	Yellowish brown (10YR 5/6); silt; angular blocky, medium, firm, abundant of volcan rock fragment; few of big, medium and fine pores; abundant of big, medium and fine roots; pH 5; horizon boundary clear and wavy.
85/95-102	2 Ab1	Yellowish brown (10YR 5/4); silt; angular blocky, fine, medium, firm; abundant of volcan rock fragment; few of big, medium and fine pores; few of big, medium and fine roots; pH 4; horizon boundary clear and wavy
102-125	2 Ab2	Yellowish dark brown (10YR 4/4); silt; angular blocky, friable, medium, firm; few of big, medium and fine pores; no big and medium roots; few fine roots pH 4; horizon boundary clear and flat
125-141	2 CB	Yellowish dark brown (10YR 4/6); silt; angular blocky, firm, medium, loose, abundant of volcan rock fragment; few of big, medium and fine pores; no big and medium roots; few of fine roots pH 4; horizon boundary clear and flat
141-157	2 C	Yellowish dark brown (10YR 3/6); silt; crumb, fine, medium, loose; few of big, medium and fine pores; no big, medium and fine roots; pH 5; horizon boundary clear and flat
157-200	R	No description for R

Table 2 Profile Description of PTH 2

Depth (cm)	Horizon	Description
0-18	Ap1	Dark brown (10YR 3/3); silt; crumb, very fine, week, very loose; abundant of macro, meso and fine pores; abundant of macro, medium, and fine roots; pH 5; horizon boundary clear and flat.
18-29	Bw1	Yellowish dark brown (10YR 3/4); silt loam; crumb, very fine, medium, very loose; few of macro pore, abundant of meso and micro pores; abundant of big roots, few of medium and fine roots sedikit, pH 5; horizon boundary clear and flat.
29-47	Bw2	Yellowish dark brown (10YR 3/6); silt loam; angular blocky, fine, medium, loose; few of macro and meso pores, abundant of micro pores; medium of big roots, few of medium roots, no fine roots, pH 5; horizon boundary difuse and wavy.

Depth (cm)	Horizon	Description
47-57	2 Ab	Yellowish dark brown (10YR 3/4); silt loam, crumb, fine, medium, loose; few of macro and meso pores, no fine pores, dan tidak ada kara kecil, pH 5, horizon boundary clear, flat.
57-69	2 BCR	Yellowish dark brown (10YR 4/4); silt; angular blocky, fine, medium, firm; few rick fragment; few macro and meso pores, abundant of micro pores; moderate of big and medium roots, few of small roots; pH 4; horizon boundary difuse and flat
69-89	2CBR1	Yellowish dark brown (10YR 4/6); silt loam; angular blocky, very fine, week, firm; abundant of volcan rock fragment; few of macro and meso pores, abundant of micro pores; abundant of big roots, few of medium roots, no fine roots; pH 4.5; horizon boundary clear and flat.
89-130	2CBR2	Yellowish brown (10YR 5/8); silt loam; structureless; abundant of volcan rock fragment; few of macro and meso pores, abundant of micro pores; no big, medium and fine roots; pH 5; horizon boundary difuse and flat.
130-200	2 CR	Brownish yellow (10YR 6/8); silt, structureless; abundant of volcan rock fragment; few of macro and meso pores, abundant of micro pores; no big, medium and fine roots, pH 5.

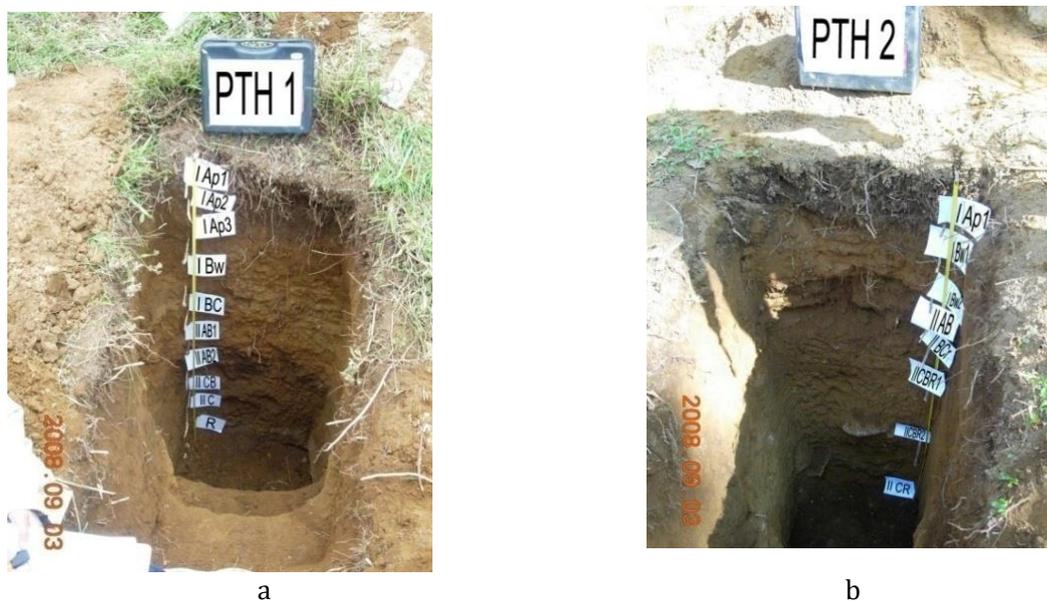


Figure 1 Profile of (a) PTH 1 (b) PTH 2

The data of Andisols referred to the Soil Map from Bapeda (2008). Soil analyses support it by complete the data of andic soil properties as required by Soil Survey Staff (2014) to be classified as Andisols, through bulk density, P-retention, organic carbon and $Al + \frac{1}{2} Fe$ by acid ammonium oxalate. Analyses of soil in every horizon of both profiles shown that the soils has the bulk density of less than 0.9 g cm^{-3} , P-retention of higher than 85%, organic carbon of less than 25%, and $Al + \frac{1}{2} Fe$ of more than 2%. The data complete the need of andic soil

properties to be classified as Andisols. Focus to the lithologic discontinuity, some data investigated like colour, organic carbon, texture, consistency and structure as shown in Table 3 and 4.

Lithologic discontinuity is marked by the presence of A buried horizon (2Ab) underneath the upperlying horizon. In this profile it can be seen in 2Ab 1 and 2Ab 2 horizons. The comparisons and observations were done within these horizons and the overlying horizons.

Table 3 Data of some lithologic investigation of PTH 1 profile

Profile	Horizon	Depth cm	Color	Organic-C	Texture	Consistency	Structure
PTH 1	Ap1	0-11	10YR 3/3	9.48	silt	friable	crumb
	Ap2	11-19	10YR3/4	7.27	silt	Very friable	crumb
	Ap3	19-39	10YR 3/6	7.50	silt	Very friable	crumb
	Bw	39-67	10YR 4/6	3.30	Silt	friable	Crumb
	BC	67-85/95	10YR 5/6	2.62	Silt	Firm	Angular blocky
	2Ab 1	85/95-102	10YR 5/4	3.51	Silt	Firm	Angular blocky
	2Ab 2	102-125	10YR 4/4	4.25	Silt	Friable	Angular blocky
	2 CB	125-141	10YR4/6	2.09	Silt	Friable	Angular blocky
	2 C	141-157	10YR 3/6	4.17	Silt	Friable	Angular blocky
	R	157-200	N/A	1.26	N/A	N/A	N/A

Lithologic discontinuity of PTH 1 profile was detected from the color of BC horizon (10YR 5/6) to 2Ab 1 horizon (10YR 5/4) and 2Ab 2 horizon (10YR 4/4). It was changed from yellowish brown to dark yellowish brown. In profiles without lithologic discontinuity, it is uncommon that the lower underlying horizon darker than the overlying one. The lower horizon normally lighter due to the decreasing of organic matter, since organic activities are optimum in aerobic condition in the upper horizon.

The darker color of the lower horizons 2Ab 1 and 2Ab 2 (85-125 cm) indicated higher organic C (3.51-4.25%) compared to upper BC horizon (67-85 cm) which had lower organic C (2.62%). The darker color in the lower horizon that inline with the higher carbon content which is unusual color distribution pattern in one profile is one of the indication of the existence of lithologic discontinuity.

The higher organic C in the lower horizon in the lithologic discontinuity process can be due to preserving organic matter by the reactive surfaces of non crystalline minerals in Andisols like allophane, Immoigoite and ferrihydrite, that can protect organic carbon from decomposition (Kleber et al, 2005). Organic matter and those minerals create the aggregates in the soils that can encapsulate organic matter itself. These aggregates also less accessible to decomposers and thus preserving it at deeper levels. Another reference mentioned that in soils with lithologic discontinuity, the physical characteristics of the lower layer might

promote better preservation of organic carbon, Increased moisture in the lower horizon can create anaerobic conditions that slow down the decomposition of organic matter.

Other observed on the lithologic discontinuity was focussed on the physical characteristic like soil consistency. It showed that consistency change from firm in the depth 67-102 cm to friable in the lower depth (102-141 cm). It seemed contrary to the provision, where the lower horizon may be more compact than the overlying. In soil without lithologic discontinuity, friable horizon can be formed from a softer, more weathered material. While in a deeper, firmer horizon may originate from more resistant parent material like compacted clay or un weathered rock, with less biological activities (Ande and Senjobi, 2005). It contributed to higher compaction. In deeper horizons, soil structure may be more blocky or massive the upper horizons and lead to a firmer consistency. It is also typical that organic matter content decreases with depth. Organic matter contributes to soil friability by improving aggregate stability. Lower organic matter in deeper horizons leads to less aggregation and increased firmness.

Contrary to the soils without lithologic discontinuity, in soil with lithologic discontinuity, the deeper horizons may consist of less weathered or entirely different parent materials (Ahr, et al, 2012). These materials are often looser and less compacted, contributing to a more friable consistency. In case of this profile, the friable consistency also can be related to the higher organic matter

content in the deeper layer. It changed as discussed previously, the organic C increased from 2.62% in depth of 67-85 cm to 4.25% in the depth of 102-125 cm. Organic C play a role in determining the soil consistency. More organic C content results in more crumbly the soil. In this profile the increasing of organic C contributed to the change of the consistency from firm to friable. The change from firm to friable consistency in soils with lithologic discontinuity can be due to differences in parent material, soil formation processes, organic matter content and compaction levels between the upper and deeper horizons.

The data in Table 3 shows that the structure have no different in the layer with an indication of lithologic discontinuity. The consistencies were different, firm and friable due to the difference of organic C content (Reganold, 1988). However, their structure is the same as angular blocky. The consistency of soil and its structure, such as angular blocky structure, can indeed coexist with different levels of firmness. The physical processes that form angular blocky structures, such as clay mineralogy and shrink-swell cycles, can occur in both firm and friable conditions. The same angular blocky structure can exist in both firm

and friable because the processes that create the structure (clay content, root activity). The key difference is in the level of compaction, organic matter content, and moisture stability, which affects the ease with which the soil aggregates can be deformed or crumbled.

Data of colour, organic C, consistency and structure reflected some presence indications of lithologic discontinuity due to uncommon distribution pattern in the soil profile. However, the texture were precisely same silt from the top to the lowest horizon. According Lorz and Phillips (2006) soil lithologic discontinuity can exhibit the same texture across the boundary. Lithologic discontinuity often resulting in differences in mineral composition, structure, and other properties. However, the texture, relative proportions of sand, silt, and clay particles, to remain similar. If the parent materials on either side of the discontinuity are different but have undergone similar weathering, the resulting soil textures can be quite similar. It does not necessarily result in changes in soil texture. The specific characteristics of the parent materials and the processes they have undergone will determine the extent of any differences.

Table 4 Data of some lithologic investigation of PTH 2 profile

Profile	Horizon	Depth cm	Color	Organic C	Texture	Consistency	Structure
	Ap1	0-18	10YR 3/3	11.20	silt	friable	crumb
	Bw 1	18-29	10YR 3/4	9.95	Silty loam	friable	crumb
	Bw 2	29-47	10YR 3/6	9.05	Silty loam	friable	crumb
	2 Ab	47-57	10YR 3/4	9.09	Silty loam	friable	crumb
	2 BCR	57-69	10YR 4/4	9.63	Silt	firm	Angular blocky
PTH 2	2 CBR 1	69-89	10YR 4/6	8.27	Silty loam	firm	Angular blocky, many rock fragments
	2 CBR 2	89-130	10YR 5/8	6.01	Silty loam	firm	Structureless, many rock fragments
	2 CR	130-200	10YR 6/8	8.00	Silt	firm	Structureless many volcan rock fragment

The observation of lithologic discontinuity was also observed trough out profile PTH 2, where data served in Table 4. The pattern in PTH 2 profile is a bit different with PTH 1

profile. The indication of lithologic discontinuity was subtle refer to color, organic C content, texture, consistency and structure. This profile was also different with PTH 1.

Horizon Ab or A buried horizon was very thin, only 10 cm (depth of 47-57 cm). There was also a lot of volcanic rock fragments starting from the depth of 69 cm to the depth of 200 cm.

Actually, the detailed and accurate analyses are needed to conclude whether the lithologic discontinuity presence in certain location from the observation of soil profile. It is not only from the macromorphological observation, but also supported by the analyses of mineralogical and element in sand, silt and clay fraction. Weindorf et al (2015) mentioned that there are many instruments that can be used to support and prove that certain horizon in the soil were derived from different parent materials with other horizon in the same profile. The instruments like X-Ray Fluorescence Spectrometry and Visible Near-Infrared Diffuse Reflectance Spectroscopy can be explored to investigate the lithologic discontinuity.

X-Ray Fluorescence (XRF) Spectrometry is a valuable tool for analysing soil lithologic discontinuity, different depositional events and weathering processes. The principles of XRF analyses was mentioned by Bouh (2020), where XRF bombarding a soil sample with primary X-rays, causing the atoms in the sample to emit secondary (fluorescent) X-rays. These emitted X-rays have energies characteristic of specific elements present in the sample. The intensities of these characteristic X-rays are measured to determine the concentrations of the elements.

The result then compared with the elemental compositions of soil samples from different depths and locations, that will inform changes in the concentrations of major and trace elements. The major elements like Si, Al, Fe, Ca, Mg, K, and Na. Changes in these elements can indicate different soil types or weathering processes. The trace elements like Sr, Ba, Zn, Cu, and some rare earth elements (REEs). Variations in trace elements can indicate specific geological or anthropogenic influences. The data will conclude whether horizons in soils derived from the same or different parent materials. By using XRF spectrometry to analyse soil samples, we can effectively detect

and interpret lithologic discontinuities, providing valuable insights into the history and processes affecting soil formation and composition.

Another instrument that can be used in Visible Near-Infrared Diffuse Reflectance Spectroscopy (Vis-NIR DRS), a non-destructive analytical technique that measures the reflectance of soil in the visible (400-700 nm) and near-infrared (700-2500 nm) spectral regions (Romero et al., 2017). It can be used to identify and analyze soil lithologic discontinuities by detecting changes in soil properties and composition. Here's how Vis-NIR DRS can be utilized for this purpose: Soil samples are illuminated with light across the visible and near-infrared spectrum, provide information about the soil's physical and chemical properties, as different soil components absorb and reflect light differently. The reflectance for example indicates the organic matter in the visible range of 400-700 nm, clay minerals in the near-infrared regions of 700-2500 nm, iron oxide in several visible range. The reflectance creates the spectral signatures, which identify unique signatures that associated with different soil types or layers. Changing in the signatures may indicate the lithologic discontinuities, that combine with multivariate statistical methods can classify and differentiate soil layers based on their spectral properties. Using Vis-NIR DRS, the soil scientists can effectively detect and analyze soil lithologic discontinuities, gaining insights into soil formation processes, environmental changes, and land use history.

4. CONCLUSION

The unusual pattern distributed of colour, organic matter, consistency, structure indicated the lithologic discontinuities of the underlying 2Ab (A buried) horizon to the overlying horizon. The darker colour, higher organic matter content, friable consistency in 2Ab in deeper depth, were some indications of lithologic discontinuities, where in soil without lithologic discontinuities the deeper depth or horizon was normally lighter colour, lower organic matter content and firmer consistency.

However, detailed analysed with instruments like XRF and VIS DRS are needed to have the precise elemental composition in every horizon which conclude the horizon from the same or different parent materials.

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