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SOIL CHARACTERISTICS AND CLASSIFICATION IN AREAS DEVELOPED FROM THE ERUPTION OF MOUNT PATUHA, WEST JAVA, INDONESIA

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ABSTRACT

Soils derived from volcanic eruption parent materials have distinct and unique characteristics that unalike the other minerals soils. These soils are classified as Andisols, even though not all of soils developed from volcanic origin is Andisols since they have to complete the criteria of andic soil properties. Soils from Mt. Patuha of the Holocene age and andesite basalt parent materials were observed the characteristics and the classification. The research used a descriptive and comparative method, using survey, soil sampling and laboratory analyses, where the data obtained were used for characterizing and classifying the soils. The site was located at Patengan Village, Rancabali District, Bandung Regency, West Java Indonesia. The result showed that soils had quite dark colour, silt to loamy silt texture, well developed structure of crumb to angular blocky, friable to firm consistency, many pore and roots and pH around 5. There was also the indication of lithologic discontinuity. They had non-crystalline minerals like allophane, imogolite and ferrihydrite together with the crystalline minerals of 1:1 and 2:1 mineral like kaolinite, halloysite, mica and smectite. The soils were classified as Andisols as a result of accomplish the whole the requirements of andic soil properties. It strengthens the information of soils from volcanic parent materials will comply with Andisols. They were classified as medium, mixed, isothermic, Hapludands in the subgroup level.

Keywords: Non-Crystalline Minerals, Crystalline Minerals, Udic, Isothermic, Hapludands.

1. INTRODUCTION

1.1 Background

Materials develope from volcanic eruption have several specific characteristics and different element compositions depend on the characteristics of the parent rocks. It can be acidic, if the parent rock was andesitic, and it can be basic if the parent rock was basaltic. These characteristics will reflect in the soils derived from these materials, following the characteristics of their parent rocks and then the parent materials. Some specific characteristics of soils derived from volcanic eruptions figure out in the andic soil properties, that if fulfilled in certain soils, will be classified specifically as Andisols in Soil Taxonomy (Soil Survey Staff, 2016). Andic soil properties covers the bulk density that 0.9 g.cm^{-3} or less, P-retention that 85% or more, organic carbon that 25% or less and aluminium plus ½ iron that 2% or more.

Soils derived from parent material of volcanic eruption therefore are not directly classified as Andisols since they have to accomplish the prerequisite of andic soil properties. Refers to soil developed and soil forming factors, soils derived from volcanic eruption can fulfilled or not fulfilled soil andic properties. Mt. Patuha in West Java, Indonesia has a basaltic-andesitic parent rock/parent materials from Holocene Epoch is therefore interesting to investigate the soil characteristics and soil classification in the surrounding area. This research focused on the soil characteristics and classification in this site.

2. METHODOLOGY

The research used a descriptive and comparative method, using survey, soil sampling and laboratory analyses, where the data obtained were used for characterizing and classifying the soils. The site was located at Patengan Village, Rancabali District, Bandung Regency, West Java, Indonesia (Fig.1a). This area was situated around Mt. Patuha, to ascertain that the soils were derived from the material erupted from Mt. Patuha. Several maps were used like Geological Map of Sindabarang and Bandarwaru (Koesmono et al, 1996), presented in Fig.1b. The climatic data obtained from climate station of Ciwidey within the last 10 years (Table 1). The geological map, topographical map and landuse map were overlayed to have the point of sampling location. Data in Table 1 informed the soil moisture regime was udic where the soil is not dry in any part as long as 90 cumulative day (Soil Survey Staff, 2016). It also informed that soil temperature regime is isothermic referred to Soil Survey Staff (2016) where the temperature is between 15-22°C and the different between the coldest and hottest temperature is not more than 6°C.

Field Surveys are intended to determine the study area. Soil observation and sampling were carried out at landform Volcan (V), natural forest and soil types based on geological maps, land-use maps and soil maps. The soil field characteristics were observed from three soil profiles, descripted in every horizon. Soil samples were also be taken from those horizon to be analyzed in the laboratory.

The study area was a Holocene age (10,000 years ago-present) with andesite-basalt parent material according to the geological map of Sindangbarang Sheet (Koesmono, 1976) Soil observation and sampling were carried out on profiles located on a slope of 8-15% in natural forest areas, resulted in three represented observation profiles. Field observations covered slope, land use and soil morphology include solum depth, horizon boundaries and thickness, color, texture, structure, consistency, pores, pH and plat roots. The field observation referred to the Field Book for Soil Describing and Sampling Soils (NSSC, 2002). Disturbed soil samples were taken from each horizon on each profile for physical, chemical and mineral analyses. Samples of undisturbed soil were taken for analyzing of bulk density and porosity. Disturbed soil samples were taken for analyzing of texture, P-retention, organic C and Al + ½ Fe with acid ammonium oxalate.

The analyses methods of soils assign to some references. Bulk density, P-retention available P, Al and Fe with acid ammonium oxalate referred to Van Reeuwijk (1992), organic carbon referred to Walkley and Black (1934).

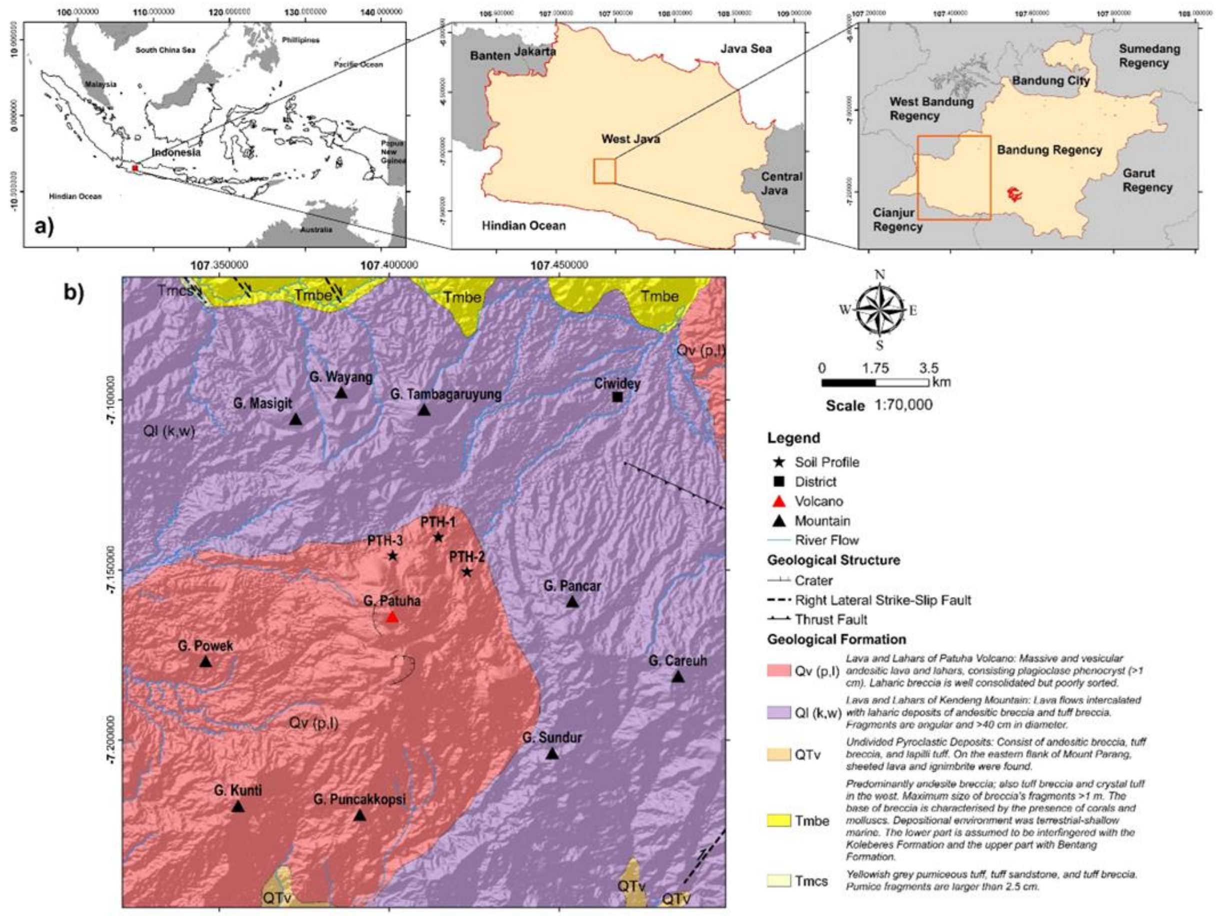

Fig 1. Site locations in Patengan Village, Bandung Regency, Indonesia (a) and geological map of area around Mt. Patuha from Sindangbarang sheet according to Koesmono,1976 (b)

Tabel 1. The average of rainfall, air temperaure and soil temperature within 10 years

Months	**Rainy day (day)**	**Rainfall (mm)**	**Air Temperature (^{0} C)**	**Soil Temperature (^{0} C)**
January	21	303	15.9	18.4
February	24	318	15.9	18.4
March	26	405	16.1	18.6
April	11	146	16.1	18.6
May	11	146	16.2	18.7
June	4	56	16.2	18.7
July	6	64	16.4	18.9
August	1	5	16.4	18.9

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September	5	76	16.3	18.8
October	3	28	16.1	18.6
November	17	464	16.1	18.6
December	21	477	16.1	18.6
Sum	150	2488	193.8	223.8
Average	12.5	207.3	16.2	18.7

3. RESULTS AND DISCUSSIONS

3.1 Profile Description

The study sites were abbreviated as PTH (Patuha), and three profiles were named as PTH 1, PTH 2 and PTH 3. The area has udic soil moisture regime and isothermic soil temperature regime (Table 1). The vegetations were *Melaleuca leucadendron, Imperata cylindrica* and Coffea sp. The whole area had good drainage and high permeability. The geographical position of the study area can be seen in Table 2. The result of profile description can be seen in Table 3.

Table 2. The geographical position of the study area

Profile	Coordinates	Elevation (m asl)	Slope (%)
PTH 1	107°23’35” - 07°08’40”	1791	8
PTH 2	107°23’47” - 07°08’42”	1806	9
PTH 3	107°23’37” - 07°08’44”	1797	9

Data in Table 2 informed the coordinate position of the profiles which located quite closer to each other, situated at the relatively similar slope (8-9%) and at the alike positioned altitude above 1700 meter above-sea-level (m asl) (1791-1806 m asl). This information was important for showing that those three profiles reflected the represented soils derived from Mt. Patuha. The data gained from these three profiles can be used to draw conclusions on the described soils.

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Table 3. Profile description and morphological caharacteristics of the study site

Profile	**Horizon**	**Depth Cm**	**Color**	**Texture**	**Consistency**	**Structure**	**Roots**	**Pores**	**pH**	**Horizon Boundary**
PT H 1	Ap1	0-11	10YR 3/3	Silt	Friable	Crumb	Many	Many	5	Clear, Flat
	Ap2	11-19	10YR 3/4	Silt	Very Friable	Crumb	Many	Many	5	Clear, Flat
	Ap3	19-39	10YR 3/6	Silt	Very Friable	Crumb	Many	Many	5	Clear, Flat
	Bw	39-67	10YR 4/6	Silt	Friable	Crumb, Many Rock Fragments	Many	Many	5	Clear, Flat
	BC	67-85/95	10YR 5/6	Silt	Firm	Angular Blocky	Medium	Medium	5	Clear, Wavy
	2 Ab 1	85/95-102	10YR 5/4	Silt	Firm	Angular Blocky	Medium	Medium	4	Clear, Flat
	2 Ab 2	102-125	10YR 4/4	Silt	Firm	Angular Blocky	Few	Few	4	Clear, Flat
	2 CB	125-141	10YR 4/6	Silt	Friable	Angular Blocky	Few	Few	4	Clear, Flat
	2 C	141-157	10YR 3/6	Silt	Friable	Angular Blocky	Few	Few	4	Clear, Flat
	R	157-200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PT H 2	Ap1	0-18	10YR 3/3	Silt	Friable	Crumb	Many	Many	5	Clear, Flat
	Bw 1	18-29	10YR 3/4	Silty Loam	Friable	Crumb	Many	Many	5	Clear, Flat
	Bw 2	29-47	10YR 3/6	Silty Loam	Friable	Crumb	Many	Many	5	Difuse, Wavi
	2 Ab	47-57	10YR 3/4	Silty Loam	Friable	Crumb	Many	Many	5	Clear, Flat
	2 Bcr	57-69	10YR 4/4	Silt	Firm	Angular Blocky	Few	Medium	4	Difuse, Flat
	2 CBR 1	69-89	10YR 4/6	Silty Loam	Firm	Angular Blocky, Many Rock Fragments	Many	Few	4.5	Clear, Flat

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	2 CBR 2	89-130	10YR 5/8	Silty Loam	Firm	Structureless, Many Rock Fragments	Few	Few	5	Wavy Flat
	2 CR	130-200								
PTH 3	Ap 1	0-17	10YR 3/3	Silt	Friable	Crumb	Many	Many	5	Difuse, Flat
	Ap 2	17-23	10YR 3/4	Silt	Friable	Crumb	Many	Many	5	Difuse, Wavi
	BA	23-29	10YR 3/6	Silt	Friable	Angular Blocky	Few	Few	4	Clear, Flat
	Bw 1	29-50	10YR 4/6	Loam	Friable	Angular Blocky	Few	Few	4	Clear, Flat
	Bw 2	50-76	10YR 5/8	Loam	Friable	Angular Blocky	Few	Few	5	Clear, Flat
	C	76-96	10YR 5/6	Silt	N/A	Structureless, Many Regolith	N/A	Few	5	Clear, Flat
	R	96-111	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	CR 1	111-127	10YR 5/6	Silt	N/A	Structureless, Many Regolith	N/A	Few	5	Clear, Flat
	Cr 2	127-144	10YR 5/8	Silt	N/A	Structureless, Many Regolith	N/A	Few	5	Clear, Flat
	CR	144-200	10Yr 4/6	Silt	N/A	Structureless, Many Regolith	N/A	Few	5	-

Data in Table 3 informed that those three profiles were observed till the depth of 200 cm, as the requirements of a profile description. Profile PTH 1 and PTH 2 had the similarities indicated by the founding the buried horizons (2 Ab1 and forward). It was the indication of lithologic discontinuity, where the soils above the depth of 85 cm (PTH 1) and 47 cm (PTH 2) had different parent materials with the soils below that depth. Morphologically it was indicated by changing colour to darker in the lower depth. It can be seen at PTH 1 that changed from 10YR 5/6 at depth of 67-85/95 cm (BC) to 10 YR 5/4 at depth of 85/95 cm (Ab1). It also can be seen at PTH 2 where it changed from 10YR 3/6 at depth of 29-47 cm (Bw2) to 10 YR 3/4 at depth of 85/95 cm (2 Ab). It is uncommon where the lower depth has darker colour than above (Owen, 2005). It is one of the indications of lithologic discontinuity among other several lithologic discontinuity characteristics. Profile PTH 3 did not show lithologic discontinuity till depth of 200 cm, however it still had possibility at lower depth (Rowe, 2005).

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Data of soil texture informed that the textures were relatively alike ranged from silt to silty loam and loam. PTH 1 had even silt texture in the whole depth. PTH 2 had vary of silt and silty loam meanwhile PTH 3 had silt, silty loam and loam. The description of texture of soil derived from material of volcanic eruption in the field, can be different with the result of soil texture in the laboratory, since it had difficult clay dispersion. It then typically displays large difference comparing to laboratory analysis (Nanzyo et al, 1993).

Structures of crumb to angular blocky with very friable, friable and firm consistency were related to high organic carbon content and also related to high non-crystalline minerals like allophane in the clay fraction. One characteristic that contributed as Andisols is crumb structure with friable consistency (Anda, 2021) as can be seen in Table 3, which made them easy to work with agricultural purposes. Soils with high allophane have has high surface area which enhance soil's ability to retain organic carbon (Harsh, 2005). The presence of many pores and roots also related to structure and high organic carbon. A well structure with good porosity soils encourage root activities and vice versa (Lucas et al, 2023). It also offered good fertility by have high organic carbon, high CEC, that hold nutrient with water retention with pH ranged in slightly acid, and mineral of allophane which are aluminium silicate minerals that contribute to their unique properties. Those characteristics make Andisols important for agriculture due to their fertility, water holding capacity, and favourable physical properties. Andisols also played a role in various ecosystems and can influence water and nutrient cycling.

The soils pH was identical to 4 and 5, referred to the andesite basalt parent materials. The weathering process of andesite basalt parent materials contributed to release certain minerals and elements, which the weathering can affect the soil pH. Breakdown of minerals in andesite basalt will result in soil acidity (Arifin et al, 2022).

3.2 Soil Classification

Soils derived from material of volcanic eruption can be classified as Andisols as far it covered andic soil properties. Data in Table 4 informed some soil characteristics related with andic soil properties such as bulk density, organic C, P-retention and Al plus ½ Fe with acid ammonium oxalate. In accomplish andic soil properties, the bulk density must be 0.9 g cm^{-3} or lower, organic C must be 25% or less, P-retention must be 85% or more and Al + ½ Fe with acid ammonium oxalate must be 2% or more which have to be achieved within 60 cm depth (Soil Survey Staff, 2016). The result analyses of andic soil properties are presented in Table 4.

Table 4. Soil Physical and Chemical Properties supporting Andic Soil Properties

Profile	Horizon	Depth	Bulk Density	Organic C	P-retention	Alo + ½ Feo*
		cm	g cm^{-1}	%	%	%
PTH 1	Ap1	0-11	0.85	9.48	91.40	2.3
	Ap2	11-19	0.84	7.27	97.20	2.6
	Ap3	19-39	0.71	7.50	99.50	4.5
	Bw	39-67	0.75	3.30	98.50	3.9
	BC	67-85	0.85	2.62	98.80	4.0
	2 Ab1	85-102	0.85	3.51	99.40	4.7
	2 Ab2	102-125	0.69	4.25	99.20	5.3
	2CB	125-141	0.77	2.09	98.70	4.5
	2C	141-157	0.71	4.17	98.60	4.2
	R	157-200	0.97	1.26	92.20	-
PTH 2	Ap1	0-18	0.82	11.20	96.39	2.1
	Bw 1	18-29	0.74	9.95	96.06	2.2
	Bw 2	29-47	0.72	9.05	95.90	2.2
	2 Ab	47-57	0.77	9.09	96.12	4.9
	2BCr	57-69	0.74	9.63	96.24	3.9
	2CBR1	69-89	0.80	8.27	96.30	4.5
	2CBR2	89-130	1.08	6.01	96.49	4.3
	2CR	130-200	0.73	8.00	96.33	4.7
PTH 3	Ap1	0-17	0.90	11.04	96.15	2.7
	Ap2	17-23	0.70	10.98	96.25	2.7
	BA	23-29	0.90	10.73	96.26	4.5
	Bw1	29-50	0.73	9.75	96.36	4.6
	Bw2	50-76	0.90	9.48	96.26	4.5
	C	76-96	0.92	6.79	96.39	4.5
	R	96-111	0.98	6.12	96.68	4.1
	CR1	111-127	0.82	7.22	96.47	3.2
	Cr2	127-144	0.78	5.77	96.28	3.2
	CR	144-200	0.83	5.89	92.73	3.1

Monitoring on the data in Table 4 within the depth of 60 cm, PTH 1, PTH 2 and PTH 3 completed all of the qualification of andic soil properties. Fulfilments of these requirements indicated that soils in PTH 1, PTH 2 and PTH 3 can be classified as Andisols referred to Soil Survey Staff (2016). Those qualification were even fulfilled in the whole profile till depth 200 cm in PTH 1 and PTH 2. In PTH 3 it was completed till the depth of 76 cm, and it was enough.

These results strengthened the concept of Andisols derived from the volcanic origin like ash, pumice and other volcanic ejecta parent materials, soils that commonly found in volcanic region. One of the main characteristics is the bulk density that 0.9 g cm^{-3}, that noted as the lightest mineral soils, where others are ranked in 1.1-1.6 g cm^{-3}. This low bulk density related to some unique composition of Andisols, including volcanic ash particles, high organic matter content, a favourable soil structure that promote pore space between aggregates resulted in low bulk density (Anda and Dahlgren, 2020).

Other distinguish characteristics of Andisols is the high P retention, that 85% or more. There are several caused of high phosphate (PO_4^{3-}) retention related to the parent materials of volcanic eruption that in the weathering release aluminium and iron oxide which have affinity for phosphorus adsorption. The minerals form during the weathering of ash, pumice, and other volcanic ejecta are indicated as allophane, imogolite and ferrihydrite. These minerals can be seen in Table 5. The surface area of these minerals contains various reactive sites, including hydroxyl (OH^-) groups and aluminium and silicon atoms with unshared electron pairs, which that sites can form bonds with phosphate ions through adsorption processes. Phosphate ions are negatively charged (PO_4^{3-}) and allophane surface have positive charged sites due to isomorphic substitution (for example aluminium substitutes silicon in the mineral structure. This results in electrostatic attraction between phosphate ions and the positively charged sites on allophane surfaces, leading to phosphate retention (Auxtero, 2004).

Table 5. Extracted with acid ammonium oxalate and pyrophosphate to predict non-crystalline minerals (allophane, imogolite and ferrihydrite)

Profile	Hor	Sio %	Alo %	Feo %	Fep %	Alp %	al %	im %	fer %
PTH I	Ap1	0.49	2.01	0.65	0.7	1.1	3	3	1
	Ap2	0.56	2.26	0.7	0.93	1.21	4	3	1
	Ap3	1.36	3.89	1.21	0.74	1.12	10	3	2
	Bw	1.1	3.57	0.74	0.22	0.54	8	5	1
	BC	1.22	3.49	1.07	0.1	0.41	9	4	2
	2 Ab1	1.38	3.99	1.43	0.12	0.44	10	4	2
	2 Ab2	1.49	4.58	1.38	0.21	0.52	11	5	2
	2 CB	1.41	4.03	0.95	0.02	0.32	10	4	2
	2 C	1.4	3.57	1.18	0.29	0.57	10	4	2
	R	1.91	4.12	0.42	0.01	0.22	14	3	1

Notes:
Sio = Si extracted with acid ammonium oxalate
Alo = Al extracted with acid ammonium oxalate
Feo = Fe extracted with acid ammonium oxalate
Fep = Fe extracted with pyrophosphate
Alp = Al extracted with pyrophosphate
al = Allophane
im = Imogolite
fer = Ferrihydrite

Organic carbon in Andisols is 25% or lower, which most of mineral soils have the organic carbon less than 25%. However, Andisols characterized by high organic matter content compared to other mineral soils. This condition also related to the presence of allophane, where organic compound can act as a ligand facilitating the bonding of phosphate ions to allophane surface to complexation reaction (Yuan, 2008).

The value of aluminium and iron extracted with acid ammonium oxalate indicate the weathering and development of Andisols as mentioned by Dahlgren et al, 2016. This extraction is commonly used to determine the presence of non-crystalline minerals. This extraction method is based on the ability of oxalate ions to dissolve amorphous or poorly crystalline aluminium and iron compound like allophane, imogolite and ferrihydrite which are common constituents of Andisols (Rennert et al, 2021).

Fulfilling the whole requirements of andic soil properties, constructed the soils of those three profiles can be classified as Andisols in the order level. Referred to Key to Soil Taxonomy (Soil Survey Staff, 2016), this area had Udic Soil Moisture Regime as mention in the Profile Description, and therefore can be classified as Udands or Udic Andisols in Sub Order level.

In the Great Group level, it cannot be classified as Placudands due to did not have placic horizon within the depth of 100 cm. It also cannot be classified as Durudands by reason of no cementation horizon within 100 cm depth. Further, it cannot be classified as Melanudands and Fulvudands on account of no melanic and fulvic horizon. It cannot be classified as Hydrudand because of did not have 100% water retention at 1.500 kPa. It therefore be classified as Halpudands.

Classification in the sub group level requires the data of textures and mineral. The texture ranged from silt to silty loam informed medium texture. Meanwhile the existence of non-crystalline minerals presented in Table 5 and some crystalline of 1:1 and 2:1 mineral presented in Fig. 2. The presence of non-crystalline minerals like allophane, imogolite and ferrihydrite together with the crystalline minerals of 1:1 and 2:1 mineral like kaolinite, halloysite, mica and smectite informed that these Andisols contained mixed minerals in their clay fraction. The classification therefore was medium, mixed, isothermic, Hapludands.

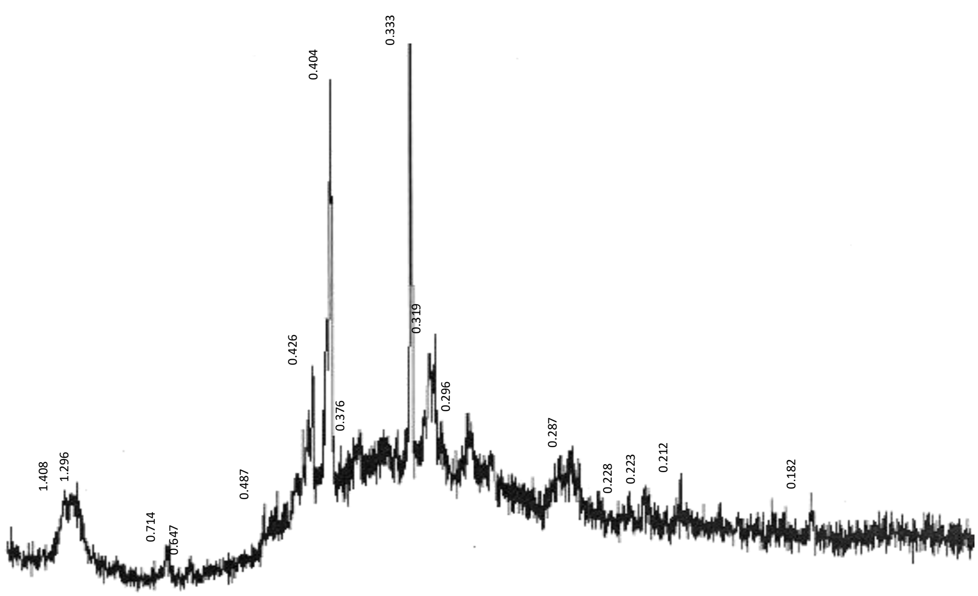

Fig 2. The 1:1 and 2:1 mineral in B horizon of PTH 1

4. CONCLUSION

1. Soils derived from Mt. Patuha of the Holocene age and andesite basalt parent materials were characterized as soils with morphological characteristics of quite dark color, silt to loamy silt texture, well developed structure of crumb to angular blocky, friable to firm consistency, many pore and roots and pH around 5. There was also the indication of lithologic discontinuity. They had non-crystalline minerals
2. The soils were classified as Andisols as a result of accomplish the whole the requirements of andic soil properties. It strengthens the information of soils from volcanic parent materials will comply with Andisols
3. The soils were classified as medium, mixed, isothermic, Hapludands in the subgroup level.

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