MICROMORPHOLOGICAL CHARACTERISTICS OF ANDISOLS IN WEST JAVA, INDONESIA

Mahfud Arifin*, Rina Devnita

Dept. of Soil Science, Faculty of Agriculture, Padjadjaran University, Bandung, Indonesia

mahfud_arifins@yahoo.com
Tel. ++62-22/779.63.16 Fax. ++62-22/779.63.16; ++62-22/779.72.00

Abstract

Micromorphological characteristics have been studied for six pedons of Andisols developed in volcanic materials in West java, Indonesia. The pedons represent deposits of different volcanoes (Mt.Tangkuban Perahu A and C, Mt. Patuha, Mt. Kendeng, Mt. Papandayan, Mt. Guntur), with different ages (Pleistocene, Holocene) and different types of volcanism (andesitic, basaltic), in three agroclimatic zones (A, B1, B2). Undisturbed soil samples for thin section preparation were taken from every identifiable horizon (49 samples in total). Observations were made with a magnifying lens, binocular stereomicroscope, polarization microscope, and scanning electron microscope. The results demonstrate that the study of micromorphological characteristics is very useful to identify pedogenetic processes in Andisols.

INTRODUCTION

Soil micromorphology is a method to study undisturbed soil samples using microscopic and submicroscopic techniques to identify soil components and establish their spatial, temporal, genetic and functional relationships [3, 13].

Historically, micromorphological investigations have mainly been used for soil genesis studies, but they also have wider applications, e.g. in soil physics, biology and chemistry [3]. Two basic principles of micropedology are the use of undisturbed (oriented) samples and the concept of functional research whereby all observations are directed towards reaching as an understanding of the function of soil components and the relationship between one another.

Micropedology covers all microscopic analyses of undisturbed soil samples [14], including the study of soil thin sections, microchemical and microphysical methods, and submicroscopic techniques. The most advanced analysis is the study of the entire soil fabric (soil micromorphology) and its quantitative aspects (soil micromorphometry).

Many soil micromorphology studies have been conducted and published, especially on Ultisols, Oxisols, Spodosols and Paleosols [3]. However, research on Andisols is still rare, especially in Indonesia. Therefore, there is a few information concerning micromorphological features of Andisols in Indonesia, particularly the Andisols developing on different parent materials and in different agroclimatic zones.

For this study, research has been done on the micromorphological characteristics of Andisols in six pedons in the tea plantation area of West Java, Indonesia. The studied soils represent six different volcanic eruptions, ages, and parent materials, in three agroclimatic zones [11].

MATERIALS AND METHODS

Pedon CTR-A2 (Acrudoxic Durudan) represents eruption C (middle Holocene) of Mt. Tangkuban Perahu (Ciater District, andesitic, agroclimatic zone A), and pedon CTR-B4 (Acrudoxic Thaptic Hydrudand) represents eruption A (early Holocene) of Mt. Tangkuban Perahu (Ciater District, andesitic, agroclimatic zone A), both located in Subang Regency. Pedon SNR-A2 (Acrudoxic Hydrudand) at Mt. Kendeng (Sinumbra

District, Pleistocene, andesitic, agroclimatic zone B1), pedon SNR-B5 (Lithic Hapludand) at Mt. Patuha (Sinumbra District, Holocene, basaltic, **B1**), pedon SDP-A3 (Typic Hapludand) at Mt. Guntur Cs (Sedep District, Pleistocene, basaltic, agroclimatic zone B2), and pedon SDP-B5 (Hydric Thaptic Hapludand) at Mt. Papandayan (Sedep District, Holocene, basaltic, agroclimatic zone B2) are all located in Bandung Regency.

Undisturbed soil samples for the preparation of soil thin sections were obtained for every identifiable horizon in all profiles. The total number of samples was 49.

Preparation of the soil thin sections involved hardening of the samples by impregnation. Observations of the undisturbed samples were made with the naked eye, a magnifier lens, binocular stereomicroscope, polarization microscope and scanning electron microscope. The terminology and concepts of the Handbook for Soil Thin Section Description [3] were used, with a few modifications.

RESULTS AND DISCUSSION

Micromass Colour

The colour of the micromass as observed in thin sections partly depends on thickness, light source properties and magnification.

In this study, only small variations in colour were observed. Horizon A/Bw has a brown to dark brown colour. Horizon BC generally has a lighter colour compared to the other genetic horizons. Surface horizons and buried A horizons have the darkest colour. In general, the horizons of pedons CTR-A2, SNR-A2, SNR-B5 and SDP-A3 have a brown colour, except pedon SDP-A3, which was lighter. Pedon CTR-B4 and SDP-B5 have a dark brown colour.

The micromass colour in the thin sections was generally more brownish than the field soil capacity colour. Rainfall, age and parent material appear to have no significant effect on micromass colour. However, in Ciater District pedon CTR-A2 generally has a lighter colour than CTR-B4, in Sinumbra District pedon SNR-A2 has a lighter colour than SNR-B5, and in Sedep District SDP-A3 is lighter than SDP-B5. **This indicates that the older parent materials have a lighter colour than the younger parent materials.**

Microstructure

Microstructure refers to the shape, size and arrangement of soil aggregates and pores, generally observed at rather low magnification.

Pedality

The complete results of observation of the microstructure are presented in Table 1. Some examples of soil microstructure features are presented in Figure 1. The microstructure of the Andisols ranges from granular to massive. The surface horizon generally has crumb and granular microstructures (Fig. 1.a and 1.b), whereas the subsurface horizon has a blocky to subangular blocky microstructure.

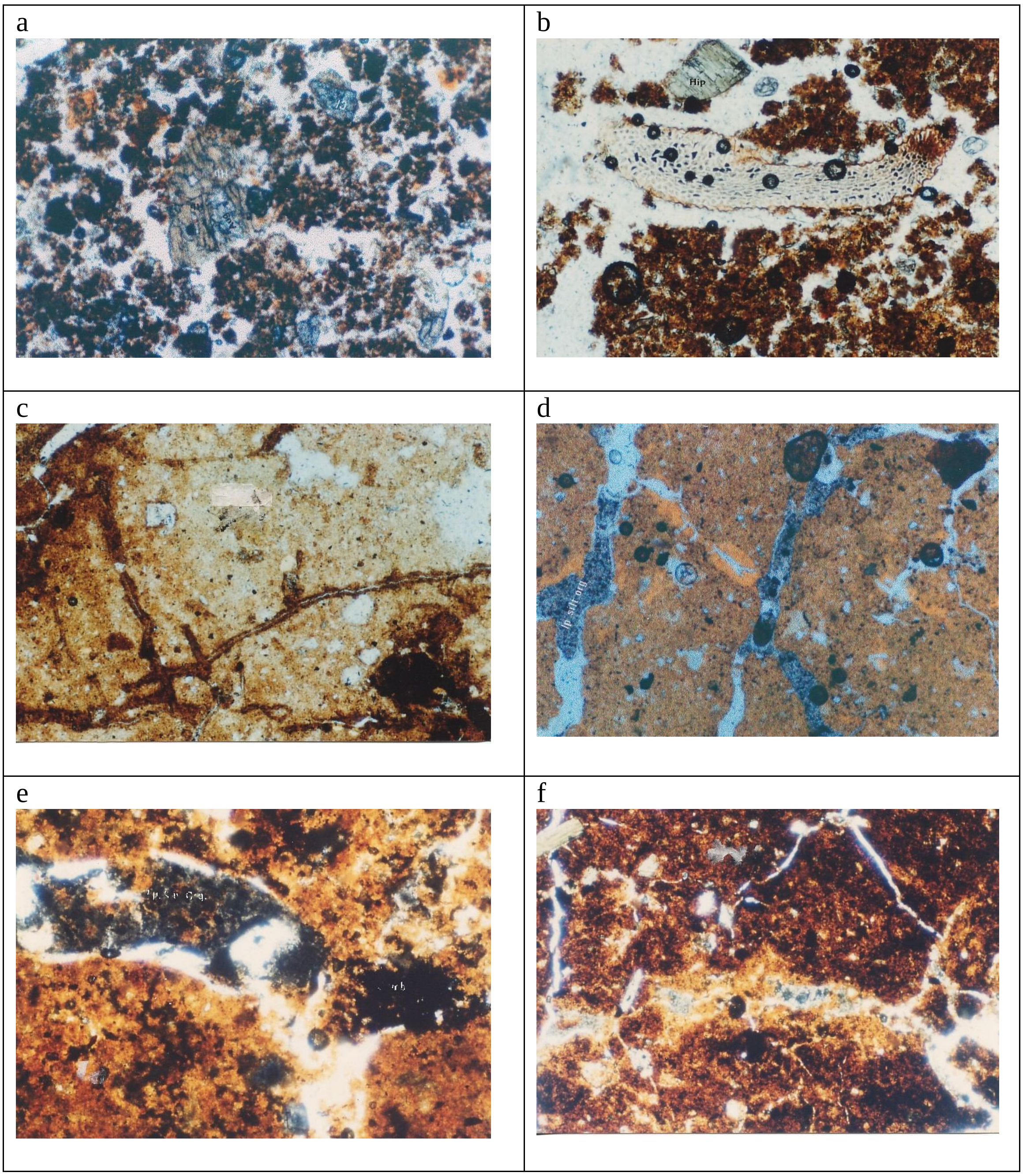
The surface horizons (Ap) of soils developed in areas with high rainfall (e.g. Ciater) have a more strongly developed pedality (and darker colour) than those developed in relatively drier areas (Sinumbra and Sedep), which generally also have a lighter colour and tend to show rounded and subangular peds. This suggests a relationship between organic matter content and pedality. Besides, the granular peds in the Ap horizon of soils developing on older parent materials are generally larger and have a denser groundmass than the younger soils. Chemical analysis indicates that the Ap horizon has a high organic carbon content and also contain Al- and Fe-bearing organic complexes. Those materials are predicted to play a role in forming a stable granular microstructure.

In all horizons, the size of the peds shows a rather wide range (0.02-11.00 mm). The degree of accommodation ranges from well accommodated to unaccommodated, and is generally partly accommodated (Fig. 1.f).

Types of voids

In surface horizons, compound packing voids are observed (Fig. 1.a and 1.b). The voids are equant to elongate, interconnected, occurring between granular, crumb and angular blocky peds, which are unaccommodated. Other void types that are recognized are planar voids, chambers and vughs (Fig. 1.a, 1.b, 1.f)

Subsurface horizons, which show crumb, granular or angular blocky microstructures, with or without pores, generally have planar voids, or planar voids with compound packing voids (Fig. 1.f). In a subsurface horizon **(**A'', Bw**)** developed on old parent material (e.g. pedon SNR-A2 and SDP-A3), planar voids, vughs, channels, chambers and vesicles are recognized.



g	h

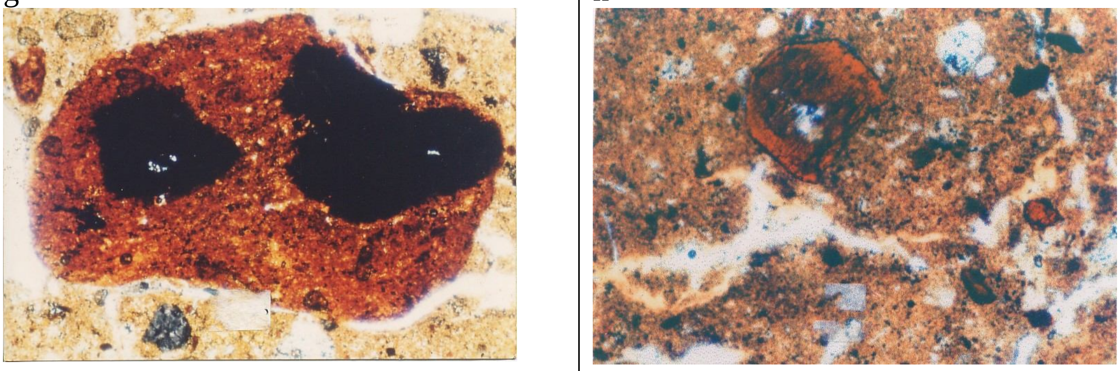


Figure 1. Photomicrograph of thin section with plane polarized light. Hor. Ap, CTR-A2 (a); Hor. Ap, SNR-B5 (b); Hor B'wb, SDP-A3 (c); Hor. 2Ab SNR-A2 (d); Hor. 3Ab, CTR-A2 (e); Hor. Ap, SNR-A2 (f); Hor. A'b2, SDP-A3 (g); Hor. Bw SDP-A3 (h)

Planar voids in the surface horizon (Ap) generally **developed along roots residues or microfauna remain.** In the subsurface horizon, planar void mainly formed by development of cracks in dense groundmass material.

Abundance of voids

The abundance of voids in the thin sections was determined, expressed as percentage of the total area of the thin section [5]. The results show that surface horizons have a higher porosity than the subsurface horizons. Hence, the percentage of voids decreases with depth. This can be clearly seen in old pedons such as SNR-A2 and SDP-A3. This was predicted referring to processes of infilling of voids by illuvial material derived from the groundmass by percolation of water, gravity, and biological activity, taking place during a long period. Therefore several pores have been closed by material derived from **upper** horizons.

Related Distribution Patterns

Horizons in Andisols have porphyric and enaulic c/f related distribution patterns, i.e. they are composed of coarse material embedded in finer material (porphyric) or they have a skeleton of larger fabric units with aggregates of fine material in the interstitial spaces (enaulic) [1,8]. In the latter, the aggregates do not completely fill the interstitial spaces, and the larger units support each other.

Surface horizon generally have enaulic c/f related distribution patterns (Fig. 1.a and 1.b), especially in Andisols developed on young parent materials. Andisols developed from old parent material have porphyric c/f related distribution patterns in their surface horizon. The granular or crumb structure in the surface horizon could be related to high biological activity (e.g. termites, ants), and the intensive growth of roots. The allophane content in the surface horizon is generally lower than in subsurface horizons due to the strong accumulation of organic matter in the surface horizon, preventing the formation of allophanes because of the formation of Al-humus complexes [9].

The subsurface horizons have porphyric c/f related distribution patterns. These horizons have a high total density, with porous and non porous parts. Pores in the porous parts can **be** filled with material derived from upper horizons. With time, they can develop into non-porous materials in this way.

Pedons SNR-A2 and SDP-A3 have porphyric c/f related distribution patterns (Fig. 1.c and 1.d). Both pedons represents the **older** parent materials. The partly short range-order minerals have been weathered to crystalline minerals like halloysite, metahalloysite and gibbsite. The change in mineral composition was predicted to be accompanied by a change in c/f related distribution pattern from enaulic to porphyric.

The subsurface horizons of pedon CTR-B4 still have enaulic c/f related distribution patterns, although the age of this pedon is **older** than that of CTR-A2, which shows porphyric c/f related distribution patterns. This indicates that the accumulation process in the subsurface horizons (pedon CTR-A2) was intensive due to the presence of impervious layers that prevent transportation of material to the lower horizons.

Table 1. Shape and size of aggregates, degree of pedality and accommodation of the studied profiles. ab; angular blocky;sab subangular blocky; gr granular; cr crumb; ***mv massive****; w weak; m medium; s strong; pr part; gd good; no non*

Pedon/ Hor.	**Depth (cm)**	**Shape**	**Size (mm)**	**Pedality**	**Acc.**	**Proportion (%)**
Pedon CTR-A2						
Ap	0-17	gr	0.042-0.2	s	no	80
		ab	0.4-4.0	w	pr	20
Bw	17-31	gr	0.04-0.4	m-w	no	45
		sab	0.4-1.6	w	pr	55
BC	31-43	ab-sab	1.6-2,8	w	pr	30
		gr	0.4-0.8	w	no	30
		gr	0.04-0.12	w	no	40
2Ab	43-60	gr	< 0.08	w-m	pr	20
		gr	0.4-0.8	w-m	pr	40
		gr	1.6-2.4	w	no	40
2Bw	60-70	cr-gr	0.04-0.2	m-s	pr	40
		ab	0.08-4.4	m-s	pr	60
2BC	70-94	mf	-	-	-	90
		ab	-	m	no	10
3Ab	94-110	sab	0.4-0.8	m	pr	40
		cr	0.04-1.2	w	no	60
3Bw	110-128	ab	4.8	s-m	pr	80
		gr	0.08-0.4	s-m	no	20
Pedon CTR-B4						
Ap	0-15	gr	0.04-0.2	m	no	60
		gr	0.2-0.4	m	no	20
		gr	0.4-3.2	m	no	20
Bw	15-30	cr	0.04-11.0	m	no	70
		ab	2.0-5.0	m	no	30
BC	30-38	mf	-	-	-	100
2Ab	38-52	cr	0.02-0.04	m	no	80
		ab	0.4-1.0	m	pr	20
2BCb1	52-65	gr	0.02-0.2	m	no	60
		ab	0.7-2.0	m	pr	40
2BCb2	65-90	ab	5.0	m	pr	100
2A’b1	90-105	ab	0.04-0.4	m	pr	50
		ab	1.0-7.0	m	pr	50
2A’b2	105-120	ab	1.0-8.0	m	pr	85
		gr	0.04-0.8	m	no	15
Pedon SNR-A2						
Ap	0-10	gr	2.0-3.0	m	no	100

Bw1	10-23	ab	2.0-5.0	s	no	50
		sab	5.0-5.9	s	no	50
Bw2	23-40	ab	3.0-5.0	s	gd	100
Bw3	40-54	sab	1.0-10.0	s	pr	70
BC	54-73	sab	5.0-10.0	m	pr	70
2Ab	73-84	ab,sab	5.0-7.0	m	pr	80
2BCb	84-98	ab	2.0-7.0	m	pr	100
2A’b	-120/130	ab	2.0-3.0	m	pr	80
2BC’b	-142/148	sab,ab	1.0-2.5	m	pr	100
Pedon SNR-B5						
Ap	0-10	ab,sab	0.04-4.0	m	pr	70;30
Bw	10-19	ab,gr	0.04-3.6	m	pr	70;30
A’b	19-44	ab,gr	0.2-1.2	m	pr	70;30
Bcb	44-60	ab,sab	0.5-5.0	m	pr	
Pedon SDP-A3						
Ap	0-14	ab	1.0-5.0	m	pr	100
A2	14-24	ab,gr	1.0-4.0	m	no	50:50
Bw	24-35	ab	0.05-5.0	m	pr	60
		gr	0.12-0.24	m	pr	40
A’b1	35-46	ab	1.0-10.0	m	gd	100
A’b2	46-65	ab	0.1-5.0	m	pr	100
B’wb	65-81	ab	0.4-10.0	m	gd	100
A”b	81-95	ab	1.0-5.0	m	pr	100
B”wb	95-105	ab	0.4-2.8	m	pr	100
BCb	105-130	ab,mf	-	w	pr	
Pedon SDP-B5						
Ap	0-11	asb	1.0-8.0	m	pr	100
Bw	11-30	gr,sab	-	m	pr	25:75
A’b	30-45	sab,gr	-	m	pr	70:30
B’wb	45-54	asb	0.2-2.4	m	pr	70
		gr	0.08-2.4	m	pr	30
A”b1	54-72	sab	-	s	pr	100
A”b2	72-94	sab	0.2-1.0	m	pr	70
		gr	0.02-0.04	m	pr	30
B”wb	94-115	sab	7.0-8.0	m	pr	100
BCb	115-135	sab	0.4-4.00	m	pr	100
A”’b	135-152	sab	0.4-2.4	s	pr	100

Pedofeatures and weathering features

The types of pedofeatures that have been recognized are textural, amorphous and cryptocrystalline, fabric and excrement pedofeatures [3,4]. Weathering of primary mineral grains is also considered in this chapter. Table 2 gives a detailed overview of the pedofeatures observed in every studied horizon.

The features most commonly found in Andisols are the weathering of primary minerals and the illuviation and accumulation of material derived from **upper** horizons, as found by Goenadi and Tan [6, 7]. Illuvial material can be material derived from the groundmass, or fine organic material mixed with silt to very fine sand (Fig. 1.c and 1.d). In addition, humic substances quite often penetrate the groundmass. These pedofeatures are generally found in the site with young parent material and high rainfall (Ciater), or in the horizon directly underlying the buried A horizon (thaptic) (Fig. 1.e).

The other features generally found were the strong alteration of primary mineral, e.g. minerals susceptible to physical and chemical weathering in A, B, and BC horizons. Physical weathering can be in the form of fragmentation. Chemical weathering can be recognized by the change of form or colour of the mineral grains.

Mineral grains in pedons originated from old parent material generally have anhedral shapes (and low $c/f_{2\mu}$ ratios), whereas grains in younger pedons usually have subhedral to euhedral shape (and higher $c/f_{2\mu}$ ratios). Iron nodules are found in old **pedon** like SDP-A3 in Sedep (Fig. 1.g). The nodules were formed by residual accumulation of iron compounds, related to weathering of primary minerals. Gibbsite coatings (Fig. 2.a) are found in Acrudoxic **Hapludand**.

Weak indications for clay illuviation are only recognized for the B'wb horizon in pedon SDP-A3, originated from old parent material, and in horizon 2BCb of pedon SNR-A2 (Fig. 2.b). These horizons do not fulfill the prerequisite of an argillic horizon **in Soil Taxonomy [12]** due to the small total volume of illuvial clay (< 1 %) and the low degree of orientation within the clay coatings. Maeda et al [10] also reported a few coatings in Andisols. Mohr et al [11] proposed that Andisols often include a horizon with clay accumulation.

Table 2. Pedofeatures of every identifiable horizon in the studied soils.

Pedon/horizon	**Pedofeatures and weathering features (*and plant remains*)**
CTR-A2	
Ap	Partly weathered primary minerals
Bw	Voids of root residue filled by granular groundmass material
	Fragment of altered root, coloured brown-black at the edge
BC	Planar voids filled by isotropic clay mixed with very fine sand
2 Ab	Fragment of yellowish weathered rock
2Bw	-
2BC	Plagioclase covered by opaque material
3Ab	Planar void filled by a mixture of clay and very fine sand
3Bw	Planar voids filled by clay
	Root residue, with black soil material at the edge
CTR-B4	
Ap	Voids of root residue, brownish, 20 %
Bw	Voids of root residue, 15 %
BC	Planar voids filled by a mixture of clay and very fine sand
	Brownish red organic fragments, 10 %
2Ab	-
2BCb1	Voids of root residue and organic fragments, 10 %
2BCb2	Planar void filled by granular clay aggregates and very fine sand
	Fragment of reddish weathered rocks with volcanic glass
2A'b1	Tuff with volcanic glass and yellowish brown clay minerals
2A'b2	Voids filled by very fine sand
2B'wb	Voids filled by very fine sand and groundmass material
SNR-A2	
Ap	Voids of tea plant's root residue, reddish brown wall
Bw1	Voids filled by gibbsite
Bw2	Partly altered root fragments
Bw3	-
BC	Voids of rounded root residue filled by granular groundmass material
2Ab	Planar void filled by clay and gibbsite

2BCb	Planar void filled by clay
	Root fragments, 7 %
2A"B	Void of weathered mineral residue
	Planar void filled by clay and gibbsite
2BC'b	Planar voids and vughs filled by granular groundmass material
SNR-B5	
Ap	Opaque root fragments
Bw	Opaque root fragments
A'b	Opaque root fragments
BC'b	Voids of root residue, partly filled with groundmass material
	Typic nodules
SDP-A3	
Ap	Opaque and reddish brown root fragments
	Voids of root residue, partly filled with granular groundmass material
A2	Typic and nucleic nodules
	Root fragments
Bw	Typic and nucleic nodules
BC	Planar voids filled by groundmass material and very fine sand
A'b1	Hypocoating in the planar voids
	Typic nodules
	Planar voids filled by groundmass material and very fine sand
A'b2	**Typic nodules**
	Voids of root residue, reddish brown wall, partly coated by groundmass material
B'wb	Typic nodules
	Voids of root residue , filled with groundmass material
	Typic clay coatings in planar voids
	Planar voids filled by groundmass material and very fine sand
A"b	Planar voids coated by groundmass material and very fine sand
B"wb	Typic oating in planar voids
	Planar voids filled by groundmass material
BC"b	Typic coating in planar voids
	Planar voids filled by groundmass material and very fine sand
	Typic nodules
SDP-B5	
Ap	Planar voids filled by groundmass material and very fine sand
Bw	-
A'b	Planar voids filled by groundmass material and very fine sand
	Voids of weathered root residue, rounded, reddish brown wall
B'wb	Planar voids and compound packing voids filled by groundmass material and very fine sand
A"b1	Planar voids filled by groundmass material and very fine sand
A"b2	-
B"wb	Chamber filled by micropeds
BCb	-
A"'b	Planar voids and vesicles filled by groundmass material and very fine sand

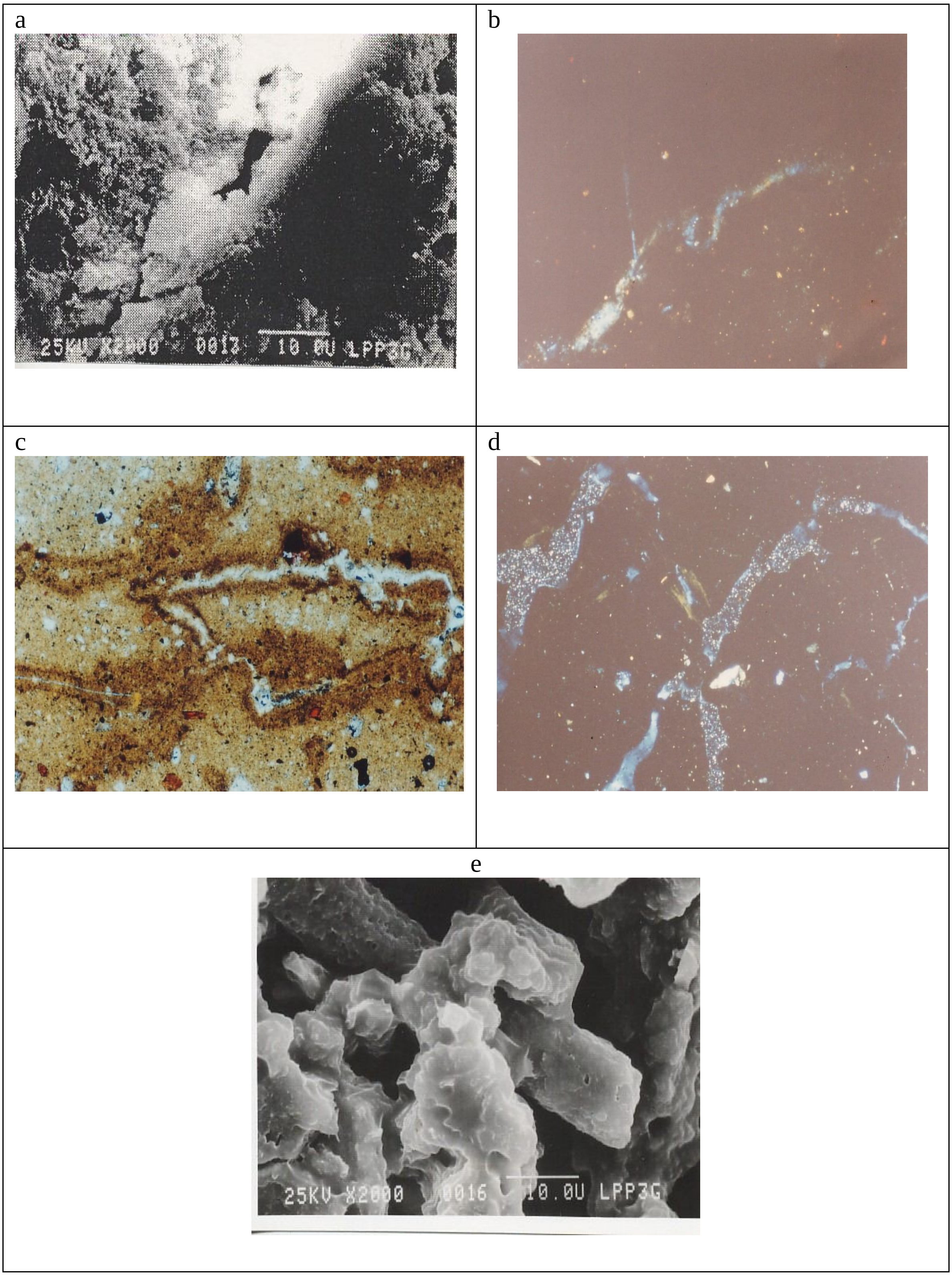


Fig.2 . Scanning electron microscope images (a and e) and thin section photographs. Gibbsite coating in hor. 2BCb, SNR-A2 (a); clay coating in hor. B'wb-SDP-A3, XPL (b); coatings of organic material in hor. B'wb, SDP-A3, PPL (c); pores with infilling in hor. 2BCb, SNR-A2, XPL (d); clay coating on sand grains, hor. Bw, SNR-B5 (e)

CONCLUSION

(1) Pedofeatures observed in thin sections are very useful to reveal pedogenetic processes. The pedon developed after the eruption of Mt. Guntur has clay

coatings and nodules. The pedon developed at Mt. Kendeng has gibbsite coatings, and pedons developed at Mt. Papandayan and Mt. Tangkuban Perahu (eruption A and C) had coatings of organic material.

(2) Micromorphological characteristics of Andisols developed from old parent material were different from those of soils developed from young parent material. The former have porphyric c/f related distribution patterns, low $c/f_{2\mu}$ ratios, poor sorting, common infillings and coatings of voids, a few clay and gibbsite coatings, anhedral primary mineral grains, planar voids, a blocky to angular blocky microstructure, well-developed pedality and good accommodation. The soils on young parent materials have enaulic c/f related distribution patterns, high $c/f_{2\mu}$ ratios, poor sorting, infillings composed of groundmass material, silt and organic material, subhedral to euhedral primary mineral grains, a granular microstructure, a crumb to blocky microstructure with medium pedality, partly accommodated peds and compound packing voids.

REFERENCES

[1] Brewer, R. "Fabric and Mineral Analysis Soils", *John Wiley & Sons, Inc., New York*, (1964).

[2] Brewer, R. "Fabric and Mineral Analysis Soils", *Robert E. Krieger Publ. Co., New York*, (1976).

[3] Bullock, P. L., Federoff, N., Jongerius, A., Stoops, G. and T. Tursina, "Handbook for Soil Thin Section Description", *Waine Research Publ*, 152 p (1985).

[4] Bullock, P. L. "The Role of Micromorphology in the Study of Quaternary Soil Process. Soil and Quaternary Landscape Evolution", J. Boardman (ed), *John Wiley & Sons Lt*, (1985).

[5] FitzPatrick, E. A. "Micromorphology of Soils", *Chapman and Hall, London*, (1984).

[6] Goenadi, D. H. and Tan, K. H. "Mineralogy and micromorphology of soils from volcanic tuffs in the humid tropics", *SSSAJR*, 53(6):1907-1911 (1989).

[7] Goenadi, D. H. and Tan, K. H. "Relationship of soil fabric and particle-size distribution in Davidson soil", *Soil Sci.* 147:264-269 (1989).

[8] Goenadi, D.H and Tan, K. H. "Micromorphology and x-ray microanalysis of an Ultisols in the tropic", *Indon. J. Trop. Agric*, 1:12-16 (1989).

[9] Maeda, T., H. Takenaka and B.P Warkentin. "Physical properties of allophane soils", *Advances Agronomy*, 29:229-264 (1977).

[10] Mohr, E.J.C., F.A van Baren and I. van Schuylenborg. "Tropical Soils, A Comprehensive Study of Their Genesis", The Hague-Paris-Djakarta, (1972).

[11] Oldeman, L. R. "An Agroclimatic Map of Java Central Research", *Institute of Agricultur, Bogor*, (1975).

[12] Soil Survey Staff. "Keys to Soil Taxonomy, SMSS, Technical Monograph No.19, Fifth Edition", *Pocahontas Press. Inc, Blacksburg. Virginia*, (1992).

[13] Stoops, G and A. Jongerius. "Proposal for micromorphological classification in soil materials, I. A classification of the related distribution of coarse and fine particles", *Geoderma*, 13: 189-200 (1975).

[14] Stoops, G and H. Eswaran. "Soil Micromorphology", *Van Nostrand Reinhold, New York* (1986).