Mem. Fac. Agr. Kagoshima Univ., 22, 169-176, 1986

The Soils on the Krakatau Islands

IV. Accumulation and Composition of Humus

Akio SHINAGAWA, Nobufumi MIYAUCHI, Teruo HIGASHI,
Muhamad Rahman DJUWANSAH* and Achmad SULE*
(*Laboratory of Soil Science*)
Received for Publication September 10, 1985

Introduction

Humus content of tropical soils is generally low[2,5]. In the case of the volcanic ash soils, however, a large amounts of black-colored humus are accumulated[9]. For example, average carbon content of the surface soils on Rakata Besar on the Krakatau Islands derived from 1883 pyroclastic flow was more than 9%, as described in Part II in this series. On the other hand, from 1927 to present, fresh ejecta from Anak Krakatau were continuously deposited on the surface soils on Sertung, Rakata Kecil, and Anak Krakatau, accordingly, carbon contents of respective layer on three islands were less than 1.5%.

The objectives of this paper are to study the humus accumulation in the Krakatau soils and also to elucidate the humufication degree of their humus. Furthermore, the comparison was made for the characteriscics of humus in the Krakatau soils and those in young Japanese volcanic ash soils.

Hereafter, Rakata Besar, Sertung, Rakata Kecil, Anak Krakatau and the soils derived from ejecta after 1927 are designated as Be, St, An, and the soils after 1927, respectively, likewise on the case of Part I. and II. And the amount of humus is expressed as carbon content.

Experimental Methods

1. Pollen analysis

Pollen analysis of St-3-2 (A_1 or A_1-like layer), St-3-5 (brown volcanic ash) and St-3-8 (buried A and B horizon derived from pyroclastic flow) were done by Parinosurvey Company (Tokyo, Japan).

2. Total carbon, carbon-nitrogen ratio (C/N), clay content, N CH_3COONH_4 extractable bases and water soluble bases

The methods and results of above-mentioned items were shown in Part II in this series.

3. 0.1 M $Na_4P_2O_7$ extractable carbon, aluminium, iron, calcium and magnesium

Wada and Higashi's method[10].

This study was supported by a grant from the Japanese Ministry of Education [Grant-in-Aid for Scientific Research B (No. 57470085) in 1982, 1983 and 1984]

* National Institute of Geology and Mining (LGPN-LIPI), Bandung, Indonesia

4. Humus composition

Kumada et al's method[3] was applied. After successive extractions with NaOH (pH: 12.5) and with 0.1 M $Na_4P_2O_7$, humic acids were precipitated from each extract adjusting to pH: 1.5 by HCl. PQ (percent of humic acid) of each extract, $\Delta\log K$ ($\log K_{400nm} - \log K_{600nm}$) (where K is absorbance) and RF [(K_{600nm}/ml of 0.1 N $KMnO_4$ consumed by 30 ml of solution used for measurement of K_{600nm}) × 1000] of humic acids were calculated.

Results and discussions

1. Pollen analysis

Numbers of pollen of respective plant and of spore were shown in Table 1.

According to the analysis by Parinosurvey Company, large numbers of decomposing pollens and spores were present in St–3–5 and St–3–8 under microscopic observation, and the identification of exact species of decomposing specimens was impossible. Among the confirmed pollens, *Casuarina* was dominant in the two sub-soils (St–3–5: 32/63, St–3–8: 104/143) as shown in Table 1. Tagawa et al[7,8], stated that the first dominant higher plant grown on the Krakatau Islands was *Casuarina* by observation of present succession. Obtained results of pollen analysis for the past

Table 1. Pollen analysis of selected soil samples

(number/20 g air dry soil)

Pollen, Spore	St–3–2 (A_1 or A_1 like)	St–3–5 (Brown volcanic ash)	St–3–8 (Buried pyroclastic flow)
Pinus		1	
cf. *Dacrydium*	1		
cf. *Keteleeria*	2		
cf. *Acanthaceae*		1	
cf. *Casuarina*	2		
Casuarina		32	104
cf. *Palmae*	1		
cf. *Cuoarbitaceae*		2	2
cf. *Leguminosae*			1
cf. *Myrica*			1
Ulmus-Zelkova			1
cf. *Euphorbiaceae*			10
cf. *Galium-Rubia*			1
cf. *Polygonum sect. Persicaria*			1
cf. *Sabia*			2
Gramineae		1	7
Trizonoporate		1	
Trizonocolpate		8	2
Trizonocolporate	3	17	11
Pollen	9	63	143
Polypodiaceae		4	8
Monolate spore	1	3	27
Trilete spore	3	3	1
Spore	4	10	36
Total	13	73	179

surface soil (St–3–8 was the surface soil at least from 1883 to 1927) showed that Tagawa et al's conclusion for the succession would be valid for the early stage of soil formation after 1883. But as may be described later, the influence of dominant plant species to the amount and the quality of the humus is questionable.

2. Humus and clay content

As shown in Fig. 1., carbon content of the surface soils on the four islands was nearly proportional to the clay content though the mineralogical composition of the soil samples was not the same (Part. III), whereas, for the sub-soils, the proportional relationship between carbon content and clay content was not exhibited.

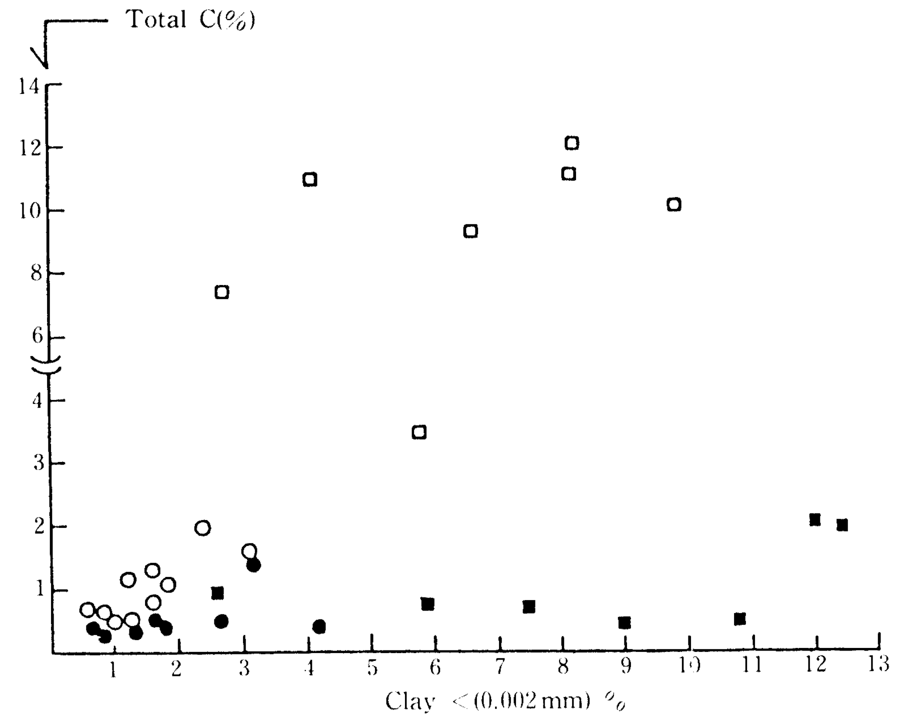

Fig. 1. Relationship between carbon content and clay content of the soil samples.

□: Surface soil derived from 1883 pyroclastic flow
■: Sub soil derived from 1883 pyroclastic flow
○: Surface soil derived from ejecta after 1883
●: Sub soil derived from ejecta after 1883

3. Humus and CH_3COONH_4 extractable (Ca+Mg)

Fig. 2 showed that carbon contents of the soils were nearly proportional to the sum of N CH_3COONH_4 extractable (Ca+Mg), where water soluble (Ca+Mg) was substracted from N CH_3COONH_4 extractable ones.

4. 0.1 M $Na_4P_2O_7$ extractable carbon, calcium, magnesium, aluminium and iron

According to Wada and Higashi[10], $Na_4P_2O_7$ is effective extractant for humus complexed with aluminium and iron in volcanic ash soils from Japan, and probably this reagent dissolves Ca(Mg)-humates. The obtained data by this method and their discussions on the Krakatau Islands is now submitted to "Soil Sci., Plant Nutr." entitled as "Contribution of calcium and magnesium to

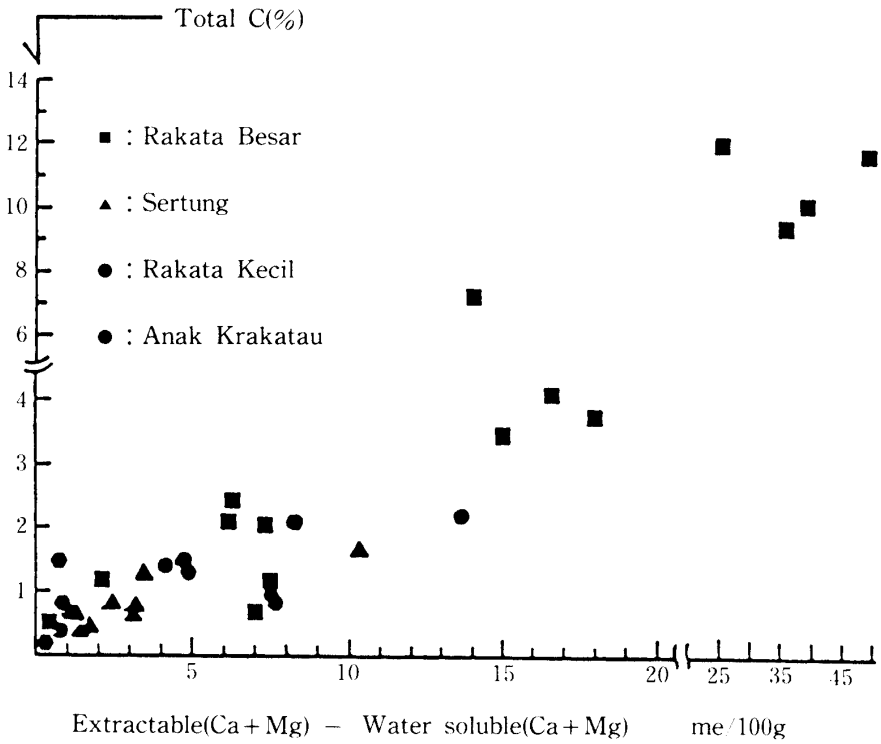

Fig. 2. Relationship between carbon content and [extractable (Ca+Mg) – water soluble (Ca+Mg)] of the surface soils.

the accumulation of humus in Troporthents, Krakatau Islands, Indonesia"[1]. Therefore, in this report, the authors refer to summarized results in following: In $Na_4P_2O_7$ extract of surface soils, the carbon content and (Al+Fe) content was proportional and (Al+Fe)/C molar ratio was about 0.07. And the carbon content was more proportionally increased with the increase of the sum of (Ca+Mg+Al+Fe), where correlation coefficient was 0.97 and (Ca+Mg+Al+Fe)/C molar ratio was about 0.22.

Foregoing results in **3.** and **4.** suggests that the humus of the surface soils on the Krakatau Islands have a tendency to combine with calcium and magnesium as well as with aluminium and iron.

5. Carbon-nitrogen ratio

C/N ratios of the soils of which the carbon contents were less than 2% were varied widely from 7 to 26. But C/N ratios of eight soils whose carbon contents were more than 3% became proportionally larger with the increase in carbon content excepting Be-5-4 (total carbon: 4.16%, C/N: 9.2). As shown in Appendix 2 (Part II) and Fig. 3, these soils were the surface soils of 10 cm thickness from the surface on Be.

The increase in C/N ratio relative to the increase in total carbon content of the surface soils on Be was low, compared with those of the soils derived from Sakurajima's ashes[6].

C/N ratios of the surface soils on St, Ke and An, and sub-soils on Be, especially their carbon contents were less than 1%, were being exceedingly varied. This deviation was presumed to be depended on the presence of decomposing plant residues of high C/N and of half decomposed microorganisms of low C/N.

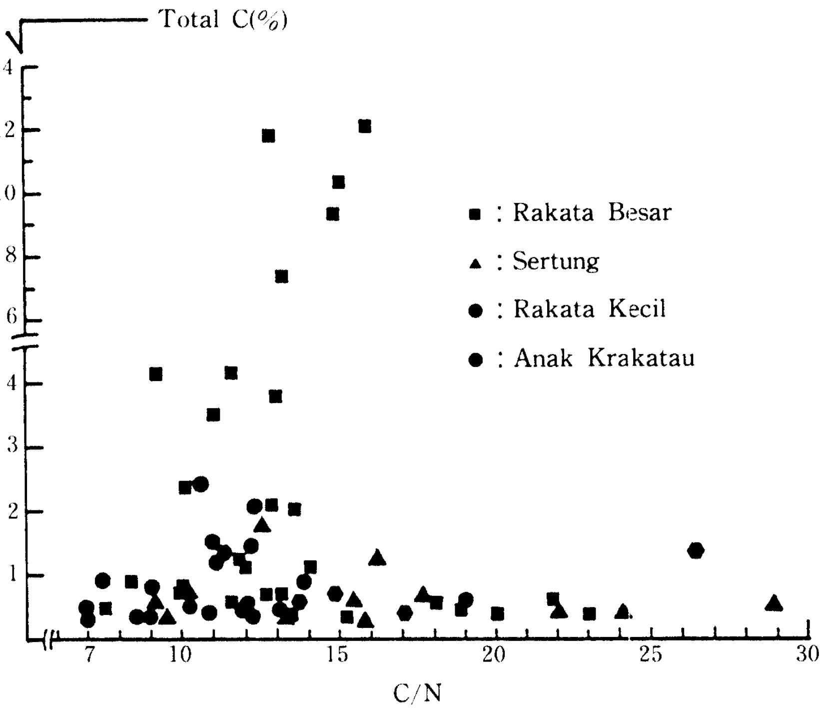

Fig. 3. Relationship between carbon content and carbon-nitrogen ratio (C/N) of the soils.

6. Humus composition

Table 2. showed the chemical properties related with humus and the humus composition of selected soil samples.

(1) C_{OH}/C_P ratio

In the used method, it is assumed that NaOH dissolves the humus combined with aluminium and iron but not dissolve the specimens combined with calcium and magnesium, and the latter was dissolved with successive extraction with $Na_4P_2O_7$, therefore, approximate ratio of Al(Fe)-humate/Ca(Mg)-humate could be evaluated by C_{OH}/C_P ratio, where C_{OH} is NaOH extractable carbon and C_P is carbon dissolve by successive $Na_4P_2O_7$ extraction.

As seen in Table 2., (C_{OH}/C_P) ratio was not in functional relationship with the carbon content and also C/N ratio of the soils. For the soils with (C_{OH}/C_P) ratios of more than 1.0 (3.1–9.3), their chemical properties were as follows; pH(H_2O): less than 6.5, pH(NaF): more than 8.0, base saturation degree: less than 99%, whereas, these values for the soils with (C_{OH}/C_P) ratios were less than 1.0 (0.2–0.7) were as follows; pH(H_2O): more than 6.5, pH(NaF): less than 8.0, and base saturation degree: near 100%. Accordingly, Al(Fe)-humates were presumed to have been accumulated under the eluviation conditions. And in illuviation and/or small scaled eluviation surroundings, Ca(Mg)-humates were presumed to be formed.

(2) PQ and type of humic acid

As ahown in Table 2., PQ of $Na_4P_2O_7$ extractable humus was larger than that of NaOH, for the soils of which C_{OH}/C_P ratios were less than 1.0. Humification degree of humic acids were low judging from the values of $\Delta \log K$ and RF, and the type of humic acid was R_P or P. (Fig. 4.). The type of humic acid obtained from the Krakatau soils was presumed to be changed in the following order: $R_P \rightarrow P \rightarrow A(?)$. This tendency was nearly the same as young volcanic ash soils derived from Sakurajima's ashes[4].

Values of $\Delta \log K$ of $Na_4P_2O_7$ extractable humic acids were smaller than those of NaOH

Table 2. Chemical properties related

Sample No.	Depth (cm)	Horizon	T–C (%)	C/N	pH H_2O	pH NaF	P–absorption coef. P_2O_5 mg/100 g	Base saturation degree (%)
Be–7–1	0– 5	A	12.05	15.9	6.10	8.28	411	86.8
Be–2–3	15–27	IIAB	2.05	12.8	6.10	8.32	333	
An–4	10–15	IIA	1.40	26.4	5.30	8.55	140	62.1
Ke–5–2	2– 9	IIAC	1.36	11.3	6.49	8.00	127	89.5
St–3–5	50–60	VB	0.50	9.1	6.84	8.00	253	98.9
Be–3–1	0– 6	A_1	11.06	12.9	6.50	7.87	217	138
St–3–2	10–20	IIA	1.64	12.6	6.69	7.79	58	101
Ke–1–4	29–55	VB	0.42	7.0	6.40	9.30	343	67
Be–3–4	23–35	IIC_1	0.36	13.3	6.84	7.54		102
St–3–8	71–80	VIIAB	0.20	12.2	6.84	7.00	196	101

* Carbon extracted with NaOH (pH: 12.5)
** Carbon extracted with 0.1 M $Na_4P_2O_7$

extractable humic acids, and the former's RFs were larger than those of the latter's.

As seen in Table 2., with the increase of total carbon content, humification degree of humic acid was not advanced, e.g. Be–7–1 and Be–3–1. This tendency was quite different from Sakurajima's volcanic ash soils[6].

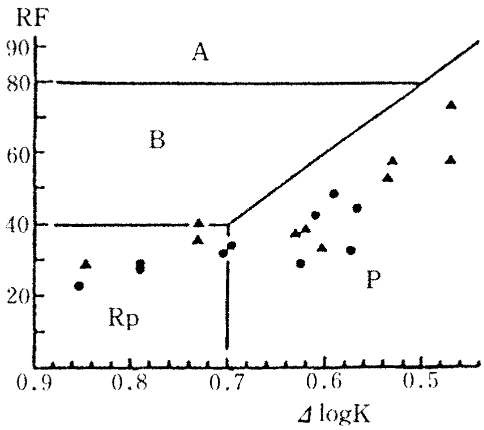

Fig. 4. Types of humic acids of selected soil samples.
●: NaOH extractable
▲: $Na_4P_2O_7$ extractable

7. Vegetation and quality of humus

In Japan, the grass vegetation, especially, *Miscanthus* sp. are presumed to be responsible for the accumulation of highly humified black-colored humus in the volcanic ash soils. As stated in **1.**, dominant vegetation of St–3–5 and St–3–8 was *Casuarina* sp. By authors' own observation, present dominant vegetation on the St–3 site was *Dysoxylum caulostachyum*, though the pollen of this plant could not found in St–3–2 sample by Parinosurvey Company.

Table 1 and 2 showed that the carbon content, C/N, (C_{OH}/C_P), PQ, $\Delta \log K$ and RF of humic with humus and humus composition

C_{OH}* + C_P** / T-C (%)	C_{OH} / C_P	NaOH (PH: 12.5) extract PQ	Humic acid $\Delta \log K$	RF	Type	0.1 M $N_4P_2O_7$ extract PQ	Humic acid $\Delta \log K$	RF	Type
65.8	3.1	58.7	0.791	27.3	R_P	27.1	0.726	35.9	R_P
57.1	4.2	54.6	0.606	44.0	P	49.2	0.465	57.5	P
42.5	9.3	59.6	0.625	29.0	P	45.8	0.603	32.9	P
57.2	5.0	60.2	0.791	29.0	R_P	60.3	0.651	36.7	P
63.1	1.5	47.8	0.699	34.5	P	42.7	0.625	37.0	P
45.2	0.6	53.0	0.702	32.5	R_P	72.7	0.737	40.0	R_P
93.9	0.5	52.9	0.853	22.7	R_P	72.1	0.847	29.3	R_P
91.3	0.2	24.5	0.591	47.6	P	45.8	0.526	56.8	P
28.5	0.7	23.1	0.573	32.3	P	41.8	0.470	74.5	P
90.5	0.5	45.1	0.565	44.8	P	48.4	0.537	52.3	P

acid of St-3-2, St-3-5 and St-3-8 were independent of the present and past dominant vegetation.

Summary

1) Pollen analysis and humus

According to the pollen analysis, it is assumed that the dominant vegetation of buried pyroclastic flow and brown volcanic ash (after 1927) on Sertung was *Casuarina* sp. The amount of humus and humification degree of humic acids were not presumed to be influenced either by present or past dominant vegetation.

2) The factors related with humus accumulation

The carbon content of the soils and the value of N CH_3COONH_4 extractable (Ca + Mg) stood in a proportional relationship.

3) 0.1 M $Na_4P_2O_7$ extractable humus

The carbon content extractable with $Na_4P_2O_7$ was directly proportional to the sum of (Al + Fe + Ca + Mg) extracted by same solution.

4) Carbon-nitrogen ratio

C/N ratios of the soils of which carbon contents were less than 2% were varied widely. But these values increased proportionally larger with the increase in the carbon contents for the soils of which the carbon contents were more than 3%. The increase in C/N relative to the increase of the carbon content was clearly low compared with that of the young Japanese volcanic ash soils derived from Volcano Sakurajima's ashes.

5) Humus composition

According to Kumada's method, humic acids were R_P or P type. There was not proportional relationship between the carbon content, C/N ratio of the soils and humification degree of humic

acids.

The amount of NaOH extractable humus from the soils of which $pH(H_2O)$ of more than 6.5, pH(NaF) of less than 8.0, base saturation degree of about 100% or more, was very small than that of $Na_4P_2O_7$ extractable humus. While, for the rest of the soils mentioned above, the amount of NaOH extractable humus was generally larger than that of $Na_4P_2O_7$ extractable humus.
6) In comparison with the soils with young Japanese volcanic ash soils, the humification degree of humic acids of the formers was lower than that of the latters.

Acknowledgements

The authors wish to express their thanks to Mr. A. Muramoto, Miss K. Kuroki and Miss E. Uto for their technical assistances.

References

1) Higashi, T., Anraku, R. S., Miyauchi, N., Shinagawa, A., Djuwansah, M. R. and Sule, A.: Contribution of calcium and magnesium to the accumulation of humus in Troporthents, Krakatau Islands, Indonesia. *Soil Sci., Plant Nutr.* (submitted)
2) Jenny, H.: *Factors of soil formation.* p. 170–175, Interscience Publisher, Inc., New York (1959)
3) Kumada, K., Sato, O., Ohsumi, Y. and Ohta, S.: Humus composition of mountain soils in central Japan with special reference to the distribution of P type humic acid. *Soil Sci., Plant Mutr.*, **13**, 151–158 (1967)
4) Otsuka, H.: Studies on a volcanic soil at Ohnobaru, Tarumizu City, Kagoshima Prefecture. Part 3. The fractional precipitation of humic acids by alcohol. *J. Science of Soil and Manure, Japan.* **45**, 411–415 (1974) (in Japanese) [English summary: *Soil Sci. Plant Nutr.*, **21**, 195 (1975)]
5) Mohr, E. C. J. and Baren, Van, F. A.: Tropical Soils. p. 270–286, McGraw-Hill Book Company, Inc., New York (1941)
6) Shinagawa, A.: Further accumulation of humus on the volcanic ash soils originated from Volcano Sakurajima's ashes. *Bull. Fac. Agr. Kagoshima Univ.*, **11**, 155–205 (1962) (in Japanese with English summary)
7) Tagawa, H., Suzuki, E., Partomihardjo. T. and Suriaderma, A.: Vegetation and succession on the Krakatau Islands. *Researches on the ecological succession and the formation process of volcanic ash soils on the Krakatau Islands* (edited by Tagawa, H.). p. 48–68. Kagoshima Univ. (1984) (Interim Report of Grant-In-Aid for Overseas Research in 1982 and 1983)
8) Tagawa, H., Suzuki, E. and Suriaderma, A.: Vegetation and succession on the Krakatau Islands, Indonesia. *VEGETATIO,* **80**, 131–146 (1985)
9) Thorp, J. and Smith, G. D.: Higher categories of soil classification: order, suborder, and great soil groups. *Soil Sci.*, **67**, 117–126 (1949)
10) Wada, K. and Higashi, T.: The categories of aluminium- and iron-humus complexes in Ando Soils determined by selective dissolution. *J. Soil Sci.*, **27**, 357–368 (1976)