Natural Science Report, Ochanomizu University, Vol. 33, No. 1~2, 1982 77
お茶の水女子大学 自然科学報告 第33巻 第1~2号

Environmental Factors Influencing the Development of the Humic Horizon in the Eastern Foot Area of Nantai Volcano

Makiko Watanabe

The Doctoral Research Course in Human Culture
Ochanomizu University, Tokyo

(Received September 10, 1982)

1. Introduction

Volcanic ash soils remarkably thick and black in appearance, often called "*Kuroboku*", can be seen throughout the northeastern Kanto district. The parent material of this soil is thought to be related to activities of plural volcanoes. As such, soils are contaminated heavily by humus. In order to contribute to both pedological and geological research, it is significant to study such soils from a broad perspective, including the soil environment. The purpose of this study is to clarify the relationship between the properties of the humic horizon of the volcanic ash soils and the regional soil-forming factors.

2. Sampling Sites and Methods

The area under investigation and the sampling sites are shown in Figure 1. In order to control for the age of the parent material, samples were obtained within the humic horizon covering the Shichihonzakura pumice bed, a kind of tephra derived from the Nantai Volcano about 12,000–13,000 year B.P.. Besides the field survey, soil samples were analyzed chemically and mineralogically. The following items were analyzed:

(1) C% (1): percent of organic carbon (variated Tiurin method)

(2) C% (2): percent of organic carbon (machine used: Yanagimoto MT 500)

(3) N%: percent of nitrogen (machine used: Yanagimoto MT 500)

(4) pH value: exchange acidity (colour method)

(5) humus composition: the method of successive extraction of NaOH and $Na_4P_2O_7$, as reported by Kumada, *et al.* (see reference number 5)

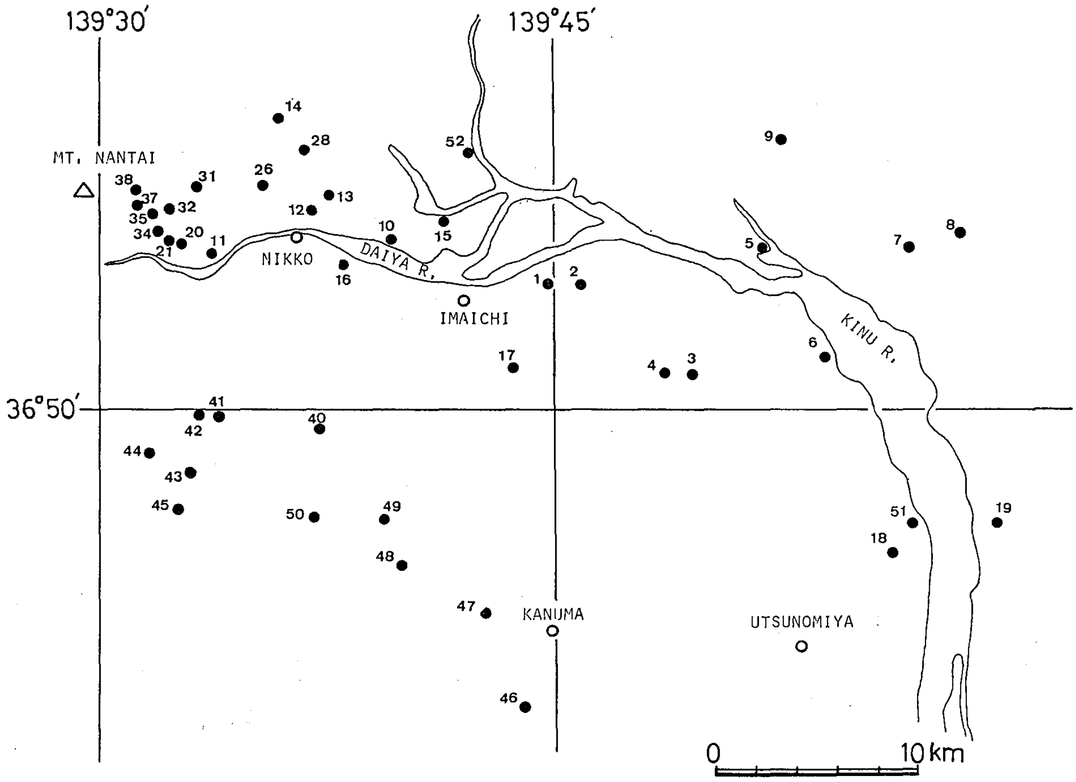

Fig. 1. Investigated area and the sampling sites.

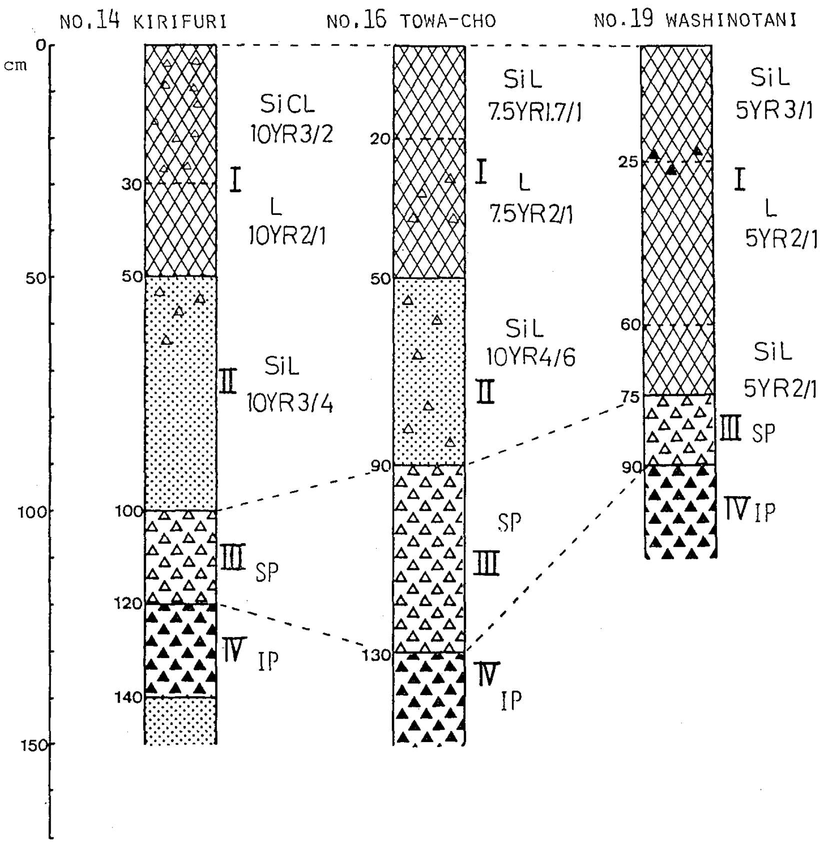

Fig. 2. Representative soil profiles.

(6) heavy mineral composition.
Furthermore, an analysis of principal components was attempted to synthesize the humus properties and also to identify the regional characteristics of the humic horizon.

Table 1. Soil properties (C%, N%, C/N ratio, pH value) of each soil

NO.	C%(1)	C%(2)	N%	C/N	pH
1	11.08	8.56	0.38	22.5	5.1
2	8.17	7.61	0.31	24.6	5.0
3	5.99	7.23	0.46	15.7	5.2
4	10.15	9.83	0.57	17.2	
5	6.90	5.77	0.42	13.7	
6	4.96	4.96	0.19	26.0	5.2
7	10.85	8.09	0.43	18.8	
8	14.65	9.29	0.48	19.4	
9	17.40	10.27	0.38	27.0	
10	15.62	13.40	0.77	17.4	4.7
11	22.81	10.12	0.44	23.0	4.6
12	9.29	8.44	0.39	22.7	4.9
13	14.37	8.78	0.32	27.4	
14	4.90	6.66	0.47	14.2	4.8
15	9.76	7.31	0.36	20.3	4.8
16	18.49	12.76	0.49	26.0	4.5
17	18.04	13.37	0.58	23.1	4.7
18	14.81	10.18	0.42	24.2	4.9
19	10.39	9.28	0.45	20.6	5.1
20	10.82	14.46	0.91	15.9	4.8
21	16.85	14.79	0.98	15.1	4.4
22	9.62	7.63	0.60	12.7	4.5
23	5.75	4.42	0.26	17.0	4.8
24	10.97	8.24	0.62	13.3	4.7
25	6.50	6.04	0.25	24.2	
26	10.42	8.64	0.33	26.2	
27	2.94	2.96	0.19	15.6	
28	10.40	13.42	0.76	17.7	4.9
29	7.48	6.67	0.33	20.2	
30	1.86	8.97	0.51	17.6	
31	12.28	10.13	0.37	27.4	5.0
32	14.96	12.35	0.87	14.2	4.5
33	6.78	3.95	0.26	13.6	
34	14.56	12.81	0.98	13.1	4.9
35	15.89	11.47	0.84	13.7	4.7
36	6.64	6.67	0.45	14.8	4.8
37	11.66	11.73	0.90	13.0	4.6
38	10.08	8.79	0.39	22.5	5.3
39	8.24	8.56	0.52	16.5	5.2
40	7.53	5.60	0.36	15.6	5.0
41	15.12	9.99	0.58	16.9	
42	9.93	8.84	0.78	11.3	4.5
43	6.44	6.55	0.51	12.8	
44	12.81	10.43	0.45	23.2	
45	10.51	8.62	0.65	13.3	
46	3.29	4.33	0.27	16.0	4.7
47	2.50	3.36	0.21	16.0	
48	9.69	10.99	0.67	16.4	4.4
49	10.81	7.18	0.51	14.1	
50	2.67	4.21	0.33	12.8	
51	8.11	6.20	0.33	18.8	
52	7.79	8.33	0.46	18.1	

Table 2-1. Results of humus component analysis (1)

SITE NUMBER	HT	HE	HE/HT	NaOH EXTRACTED						$Na_4P_2O_7$ EXTRACTED								
				a_1	b_1	PQ_1	$\Delta\log K_1$	RF_1	$Type_1$	a_2	b_2	PQ_2	$\Delta\log K_2$	RF_2	$Type_2$	PQ_{1+2}	fHa	fFa
1	277.0			92.59	41.25	69.18	0.5035	134.00	A									
2	204.3	104.2	51.0	63.90	34.24	65.11	0.5028	114.59	A	3.53	2.52	58.35	0.5317	152.08	A	64.7	94.8	93.1
3	149.8			31.41	30.17	51.01	0.5367	108.04	A									
4	253.8			62.53	51.02	55.07	0.4993	114.24	A									
5	148.0			37.19	26.81	58.11	0.5748	111.76	A									
6	171.0			21.95	19.14	53.42	0.5208	140.53	A									
7	271.3			56.84	46.55	54.98	0.5214	112.82	A									
8	366.3			79.30	68.12	53.79	0.5000	140.95	A									
9	435.0			144.48	58.05	71.34	0.4990	182.95	A									
10	390.5	203.7	52.2	103.11	84.87	54.85	0.5265	127.29	A	6.15	9.52	39.25	0.5171	141.73	A	53.7	94.4	89.9
11	570.3			195.16	77.29	71.63	0.5189	135.05	A±									
12	232.3			81.16	48.22	62.73	0.5132	102.76	A									
13	395.3			117.07	57.69	66.99	0.5400	125.45	A									
14	126.5	62.1	49.1	16.24	33.07	32.93	0.5188	94.83	A+	5.40	7.34	42.39	0.5454	87.18	A	34.9	75.0	81.8
15	244.0			53.34	44.26	54.65	0.5038	148.25	A									
16	462.3			179.13	67.64	72.59	0.5235	128.64	A									
17	451.0			172.24	83.08	67.46	0.4910	122.45	A									
18	370.3			53.34	55.51	49.00	0.4895	253.62	A									
19	259.8			58.26	47.52	55.08	0.5225	113.30	A									
20	270.5	151.0	55.8	80.20	64.64	55.37	0.5238	87.64	A+	2.85	3.30	46.34	0.5484	90.28	A±	55.0	96.6	95.1
21	421.2	214.5	50.9	138.23	73.23	65.37	0.5497	89.92	A	2.14	0.89	70.63	0.5854	96.40	A	65.4	98.5	98.8
22	240.5			55.38	62.78	46.87	0.6191	61.34	B									
23	143.8			29.86	32.40	47 96	0.5677	81.15	A±									
24	274.3			64.64	65.18	49.79	0.5332	96.62	A±									
25	162.5			21.80	29.70	42 33	0.4845	135.01	A±									
26	260.5			75.57	35.64	67.95	0.5374	145.87	A±									
27	73.5			14.06	16.80	45.56	0.5699	86.76	A±									
28	260.0	127.8	49.2	68.60	54.37	55.79	0.5246	90.60	A+	2.79	2.03	57.88	0.5345	114.30	A+	55.9	96.1	96.4
29	187.0			47.56	42.54	52.79	0.5027	140.84	A									
30	46.5			28.25	18.18	60.84	0.7515	42.34	B									

Table 2-2. Results of humus component analysis (2)

SITE NUMBER	HT	HE	HE/HT	NaOH EXTRACTED						$Na_4P_2O_7$ EXTRACTED								
				a_1	b_1	PQ_1	$\Delta \log K_1$	RF_1	Type 1	a_2	b_2	PQ_2	$\Delta \log K_2$	RF_2	Type 2	PQ_{1+2}	fHa	fFa
31	307.0	160.6	52.3	98.04	50.79	65.87	0.5179	144.18	A	7.38	4.39	62.70	0.5316	144.18	A	65.6	93.0	92.0
32	374.0	185.4	49.6	106.09	75.36	58.47	0.5720	85.92	A±	1.32	2.63	33.42	0.5828	39.75	P	57.9	98.8	96.6
33	169.5			40.70	39.72	50.61	0.5730	65.74	P/B±									
34	364.0	180.7	49.6	99.36	77.31	56.24	0.5416	79.98	B/A+	1.46	2.57	36.23	0.5586	104.44	A	55.8	98.6	96.8
35	397.3	185.5	46.7	93.05	87.44	51.55	0.5690	68.80	B±	2.25	2.74	45.09	0.5740	70.56	B	50.2	97.6	97.0
36	166.0	83.3	50.2	33.11	40.05	45.26	0.5789	67.79	B	2.69	7.49	26.42	0.5774	89.58	A	43.0	92.5	84.2
37	291.5	156.6	53.7	80.84	71.38	53.11	0.5547	67.84	P/B±	1.55	2.85	35.23	0.5205	111.31	A±	52.6	98.1	96.2
38	252.0	133.4	52.9	76.83	45.12	63.00	0.5205	111.31	A±	5.92	5.55	51.61	0.5416	130.21	A	62.0	92.8	89.0
39	206.0	100.8	48.9	43.44	49.53	46.72	0.4907	90.04	A+	3.04	4.80	38.78	0.5075	108.18	A±	46.1	93.5	91.2
40	188.2			47.55	43.01	52.51	0.5208	134.21	A									
41	378.0			126.75	104.31	54.86	0.5927	70.13	B									
42	248.3			72.67	68.99	51.30	0.6013	62.38	B									
43	161.0			58.35	43.45	57.32	0.5842	73.35	B									
44	320.3			110.56	59.82	64.89	0.5165	122.14	A									
45	262.8			64.94	62.88	50.81	0.5575	88.61	A									
46	82.3			15.14	23.30	39.39	0.6845	40.92	P/B									
47	67.5			10.66	16.46	39.31	0.6689	45.54	P/B±									
48	242.3			83.10	73.47	53.08	0.5990	54.91	P									
49	270.3			68.51	55.33	55.32	0.6158	63.04	B									
50	66.8			20.80	18.29	53.21	0.6534	54.06	B									
51	202.75			71.21	35.64	66.64	0.5013	126.35	A									
52	194.75			46.24	44.29	51.08	0.5334	94.89	A±									
53	73.75			19.57	19.26	50.40	0.5819	60.80	P±									
54	15.25			2.89	3.07	48.48	0.7103	30.64	Rp±									

HT: Total humus, ml of 0.1 N $KMnO_4$ consumed by 1 g of oven-dried soil sample.

HE: Extracted humus, the sum of 0.1 N $KMnO_4$ in ml consumed by humic and fulvic acid fractions of the two extracts per 1 g of oven-dried soil.

HE/HT: Percent of extracted humus in total humus.

fH: Percent of the humus extracted with NaOH in extracted humus of the two extracts.

fHa: Percent of the humic acid extracted with NaOH in humic acid of the two extracts.

fFa: Percent of the fulvic acid extracted with NaOH in fulvic acid of the two extracts.

a, b: The amount of humic acid and fulvic acid, respectively, calculated as ml of 0.1 N $KMnO_4$ consumed by the fractions of each extract corresponding to 1 g of oven-dried soil.

PQ: $a/(a+b)\times 100\%$, percent of humic acid in extracted humus (humic acid+fulvic acid).

$\Delta \log K$: $\log K_{400} - \log K_{600}$, where K_{400} and K_{600} are absorption coefficient at 400 nm and 600 nm, respectively.

RF: K_{600}/(ml of 0.1 N $KMnO_4$ consumed by 30 ml of the humic acid solution used for determining absorption spectrum)$\times$1,000.

Subscripts 1 and 2: The fraction extracted with NaOH and $Na_4P_2O_7$, respectively.

(see reference number 12)

3. Results and Discussion

i) Soil Profiles and Environment

Three representative soil profiles are shown in Figure 2. A fine volcanic ash bed (horizon II) can be found in the eastern foot area of Nantai Volcano within a radius of 12–13 km. This horizon contains pumice-types which resemble Shichihomzakura pumice (SP) and Imaichi pumice (IP), here reffered to as horizons III and IV. In this area, small white pumice is intermixed with the deep black humic horizon (horizon I). Because of the microscopic character of the heavy minerals, the source of this pumice is thought to be the western volcano, that is, Haruna Volcano.

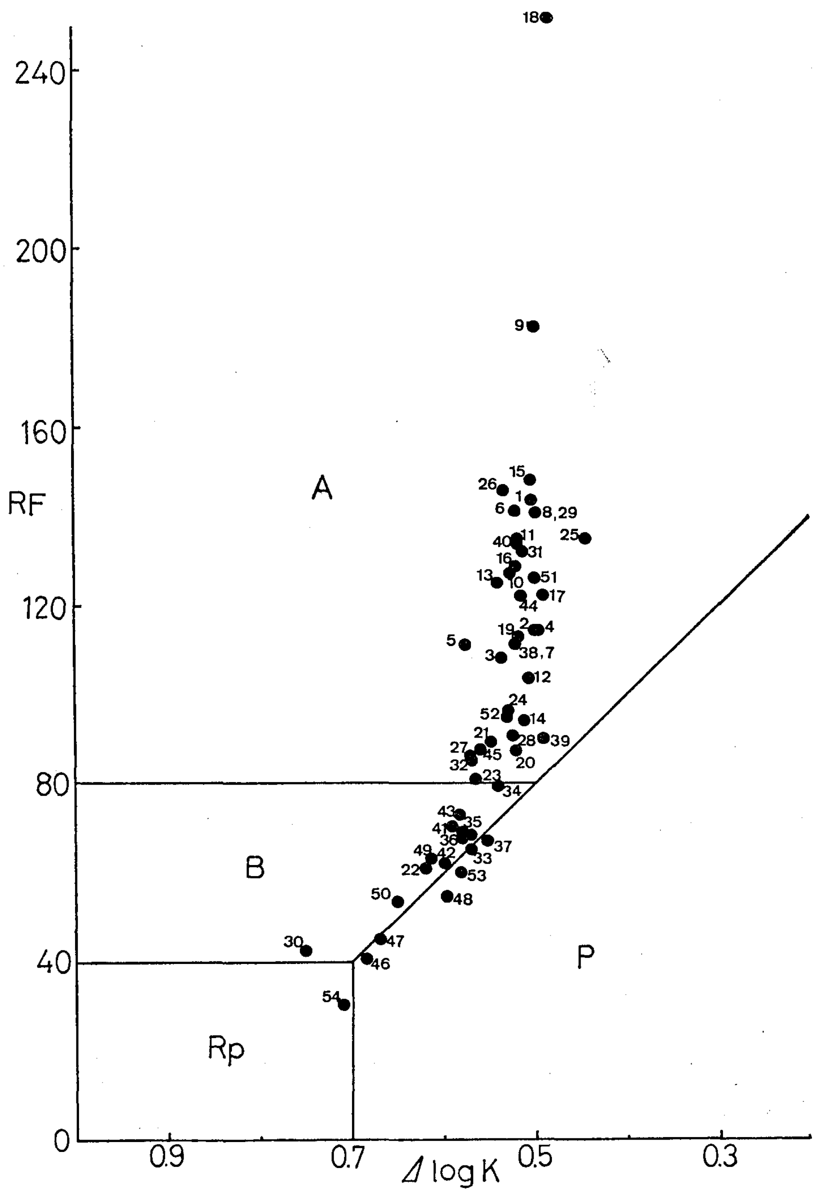

Fig. 3. Classification diagram of humic acid extracted with NaOH.

A variety of environmental factors influencing soil development were also studied. In terms of climate, for example, the mean temperature decreases but the total amount of precipitation increases at higher elevations. Though the range of the annual snow depth is large, the boundary line of continuous snow cover through winter is defined as being 1,500 m above sea level (see reference number 8). The humic horizons located more than 1,000 m above sea level are also under the influence of snow cover.

As for vegetation, the boundary between deciduous and coniferous trees is clearly evident. The evergreen conifer forest is distributed at elevations higher than 900 m above see level in the study area.

ii) Soil Properties

The results of an investigation on soil properties (C%, N%, C/N, pH) are presented on Table 1. In the Kuroboku area, the percent of organic carbon, humus, and nitrogen range from 5 to 20 percent, 8 to 35 percent, and 0.1 to 1 percent, respectively. The C/N ratio

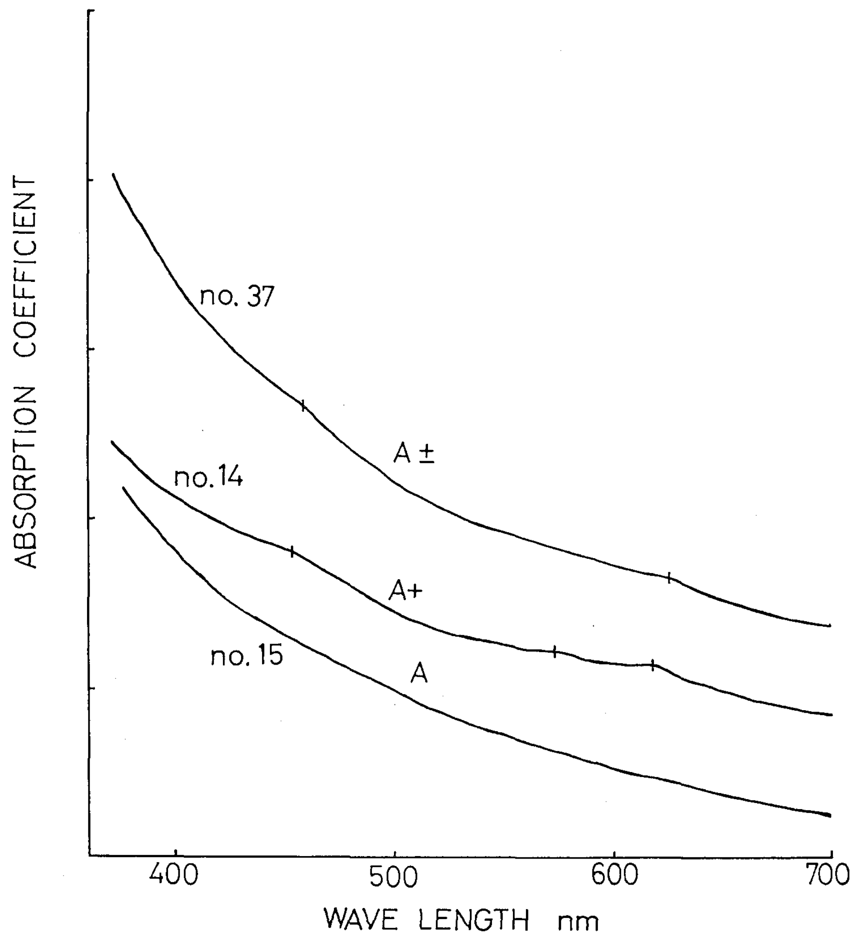

Fig. 4. Absorption spectra of humic acid extracted with NaOH. (concentrations are arbitrary chosen)

is in excess of 20, which is rather high compared with the average value found in volcanic ash soils distributed in north-eastern Japan, as researched by Kobo and Oba (1974).

Table 2 shows the results of an investigation of the humic composition. Except sample No. 14 (Kirifuri), the ratios of free humic acid (humic acid extracted with NaOH) were higher than those of combined humic acid (humic acid extracted with $Na_4P_2O_7$), that is, the humic acid and fulvic acid are in "free form" extracted with NaOH.

Table 3. Results of principal component analysis

	Eigenvector		
	first component	second component	third component
1. C% (1)	-0.0765	0.4347	0.2228
2. C% (2)	-0.1526	0.3791	0.4056
3. N%	-0.2844	0.1499	0.5277
4. C/N	0.2282	0.3205	-0.3294
5. ΔlogK	-0.0364	-0.3714	0.3294
6. RF	0.2265	0.3475	-0.2826
7. PQ	0.0911	0.3765	0.1109
8. distance from Nantai Volcano	0.4047	-0.0648	0.1716
9. thickness of the humic horizon	0.0998	0.3345	0.0608
10. slope gradient	-0.1655	-0.1061	0.0732
11. mean yearly temperature	0.4390	-0.0696	0.2293
12. mean maximum temperature	0.4394	-0.0704	0.2260
13. rain factor	-0.4360	0.0671	-0.2425
Eigenvalue	4.5003	3.7039	1.6555
contributory rate	34.6180	28.4922	12.7345
accumulated contributory rate	43.6180	63.1102	75.8447

The average values of PQ range from 50 to 70, standard values for volcanic ash soils. However, samples No. 14, 22–25, 27, 36, 39 were below 50. As these samples are high and located more than 1,000 meters above sea level, factors such as low temperature and snow cover appear to have restrained "humification".

The type of humic acid was obtained on the basis of the classification diagram shown in Figure 3. Moreover, the symbols + and ± were used as subdivisions according to the absorption spectra (700–370 nm) of humic acid. The representative absorption curves are shown in Figure 4. As for volcanic ash soils, RF values increase and $\Delta \log K$ values decrease with the advance of soil humification following such routes as Rp→P_0→B→A or Rp→B→A (see reference number 6). In the present case, the evolution route of each soil, as shown in Figure 3 is Rp→P/B→A. Type A appears relatively far from Nantai Volcano, where Shichihonzakura pumice bed is visible just beneath the humic horizon. Soils which have fine ash under the humic horizon belong to types A+, A± and P/B. Types such as Rp, B and P are found in soil samples located on new terraces, which are not Kuroboku. It could be said that humification advances according to the distance from Nantai Volcano.

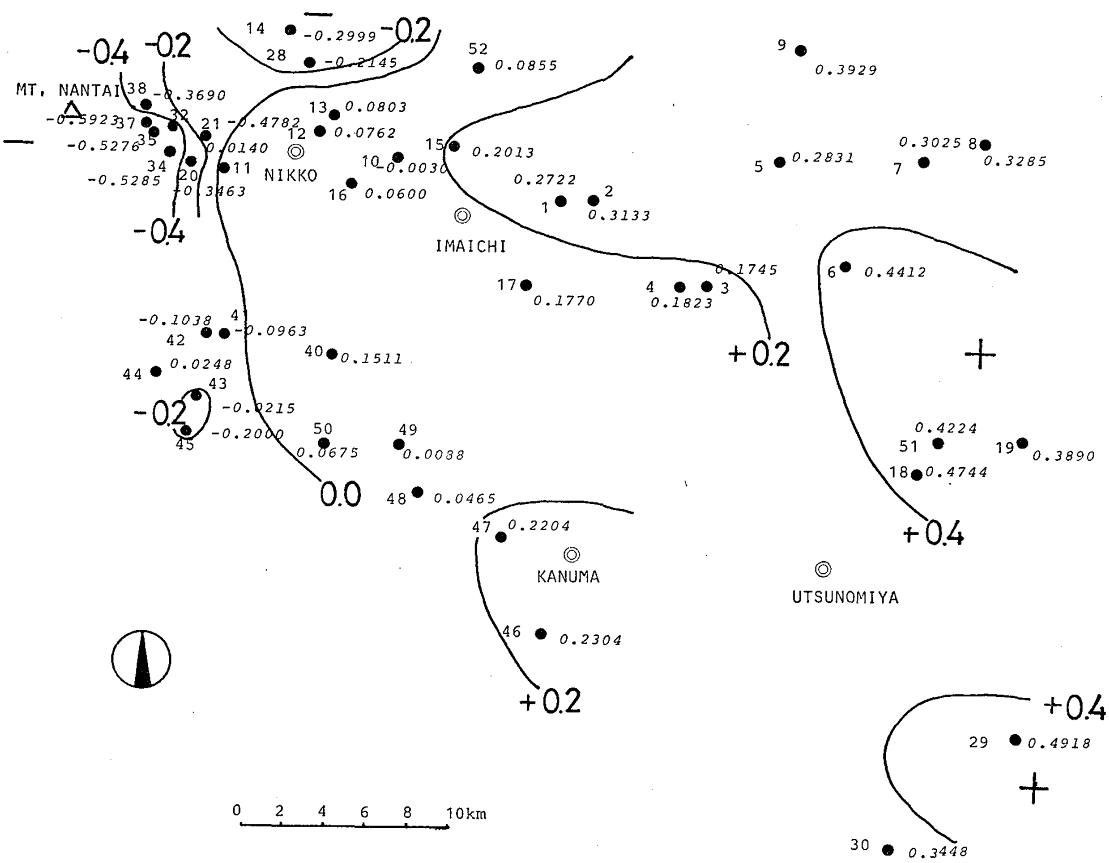

Fig. 5. Geographical disribution of the first principal component scores.

iii) Principal Component Analysis

Regional properties of the humic horizons were obtained by principal component analysis at 52 places using 8 soil humus characteristics and 5 environmental characteristics as follows:

(1) C%-1, (2) C%-2, (3) N%, (4) C/N ratio, (5) $\Delta \log K$, (6) RF, (7) PQ, (8) distance from Nantai Volcano, (9) thickness of the humic horizon, (10) slope gradient, (11) mean yearly temperature, (12) mean maximum temperature, (13) rain factor.

Three principal components are identified, as shown in Table 3, and the accumulated contributory rate of these three components is approximately 76 percent. The first principal component (column one) mainly explains the spatial climatic change. The second column explains the degree of humus accumulation, that is, the change in humus quantity, and the third column, the degree of humus decomposition, that is, the change in humus quality.

The geographical distribution of these principal component scores are shown in Figures 5 through 7. The spatial variation in climate in this region is visualized in terms of Figure 5. Figure 6 is characterized as the maximum area around Nikko and Imaichi where humus accumulation is dominant. The major axis across the area is identical

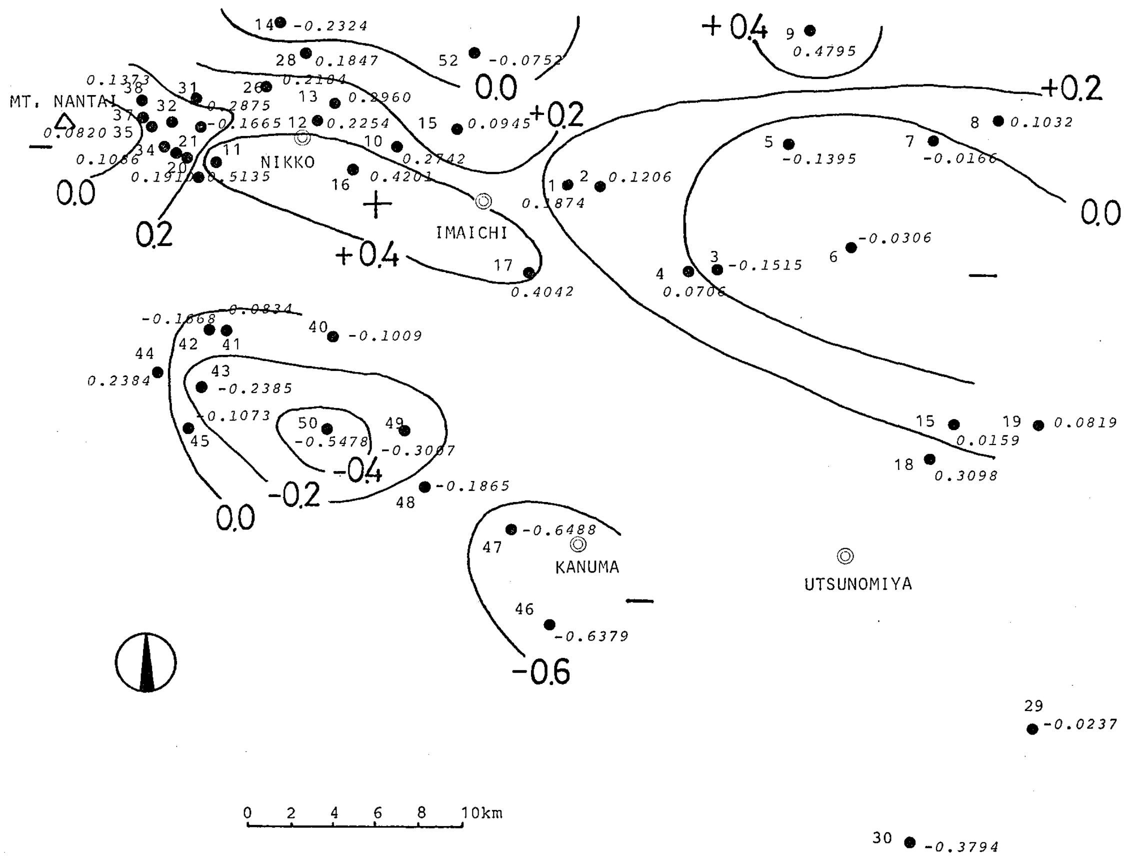

Fig. 6. Geographical distribution of the second principal component scores.

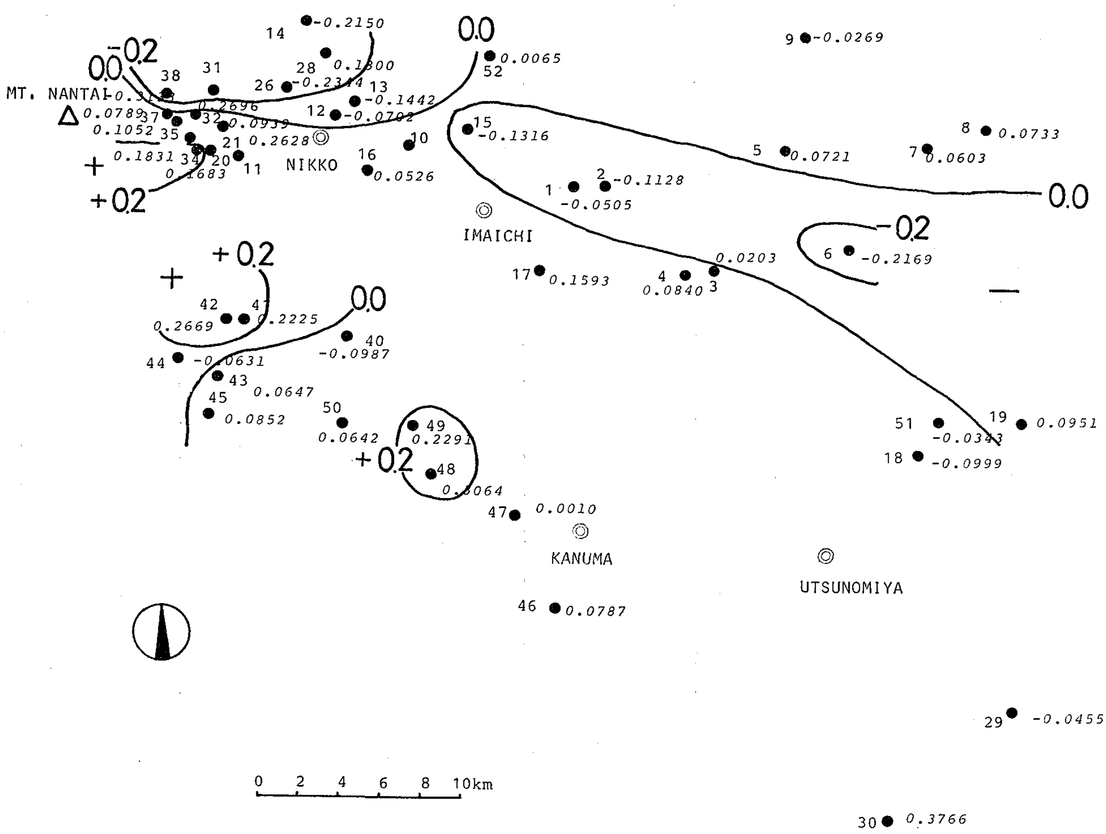

Fig. 7. Geographical distribution of the third principal component scores.

with the main axis of the distribution of the Shichihonzakura pumice bed in the direction of East Southeast (ESE). Compared with the characteristics of the soil profiles examined in the field survey, the parent material of the humic soil is inferred to have originated primarily from the Nantai Volcano. Figure 7 inditcates the decrease of the first principal component score according to the distance from Nantai Volcano, which means, on the whole, the degree of "humification" is proportional to the distance from Nantai Volcano.

The spatial variation of humus properties as mentioned above can be analyzed in terms of linear variation according to the distance from Nantai Volcano. Figure 8 summarizes this point of view. The region showing a maximum principal component score, where humus accumulation is active, is regulated by the following factors: warm humid climate, undulating relief, vegetation dominated by deciduous trees, the existances of the volcanic ash bed below the humic horizon, and new ash deposits mingled with the humic horizon. Climate is the major factor which controls soil properties on the eastern side adjacent to the maximum score area. On the other hand, on the western side (Mt. Nantai, Kirifuri), humus formation as well as the humification process is restrained, due to steep slopes which cause

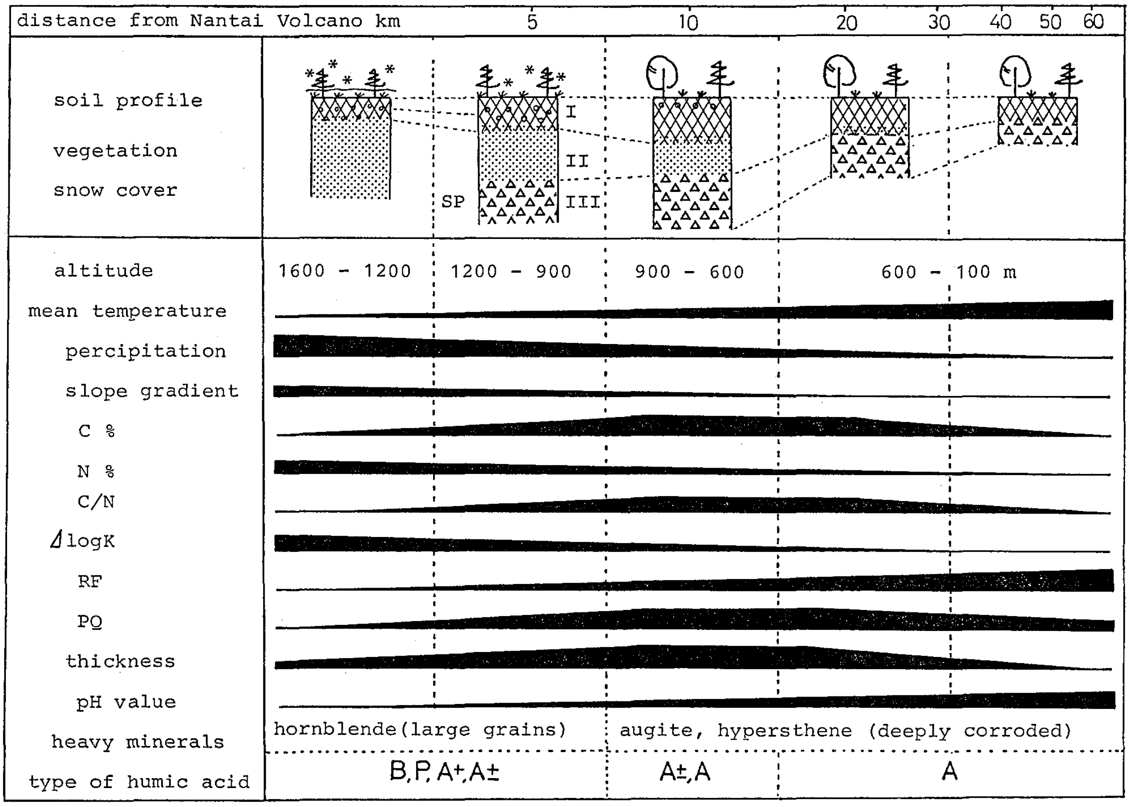

Fig. 8. Summary.

soil erosion, poorly decomposed plants such as coniferous trees and some species of grass, low temperature with snow cover in winter which restrains the activity of soil fauna, and relatively large amounts of new ash deposits. It is to be noted in particular that the region of maximum humus content is located in the area from 600 to 900 m above sea level, which is regarded to be the most suitable climatic condition for the development of humic horizon.

Acknowledgement

The author is grateful to Professor S. Asami and Associated Professor T. Mikami, Dept. of Geography, Ochanomizu University for many helpful suggestions during the course of this work. Appreciation is also expressed to Professor R. Hamada and Dr. K. Sakagami, Faculty of Agriculture, Tokyo University of Agriculture and Technology for their valuable advice.

References

[1] Arai F., Marker-tephras deposited after Jomon age in northwestern Kanto distict. Kokogaku Journal, **157** (1979), 41–52.

[2] Kobo, K. and Ohba, Y., Genesis and characteristics of volcanic ash soil in Japan. Part 7. J. Sci. Soil Manure, Japan, **45** (1974), 227–233.

[3] Kobo, K. and Ohba, Y., Genesis and characteristics of volcanic ash soil in Japan. Part 8. J. Sci. Soil Manure, Japan, **45** (1974), 293–297.

[4] Kondo, H., Black soil under coniferous forest in montane belt. Shinrin Ritchi, **5** (2), (1964), 21–24.

[5] Kumada, K. and Ota, N., The process of humification of soils derived from limestone near Toyohashi. Part 2. J. Sci. Soil Manure, Japan, **36** (3) (1965), 57–62.

[6] Kumada, K., Chemistry of soil organic matter. Gakkai-shuppan Center, (1979), 113.

[7] Machida, H., Stratigraphy and chronology of late quaternary Marker-Tephras in Japan. Geographical Reports of Tokyo Metropolitan Univ., **11** (1976).

[8] Maruyama, N., A study of the seasonal movements and aggregation patterns of Shika Deer. Bulletin of the Faculty of Agriculture, Tokyo University of Agriculture and Technology, **23** (1981).

[9] Shoji, S., Yamada, I., and Masui J., The carbon-14 ages of humic horizon of volcanic ash soil in Mamiana Utsunomiya-shi and Shimokuzawa Sagamihara-shi. Chikyu Kagaku, **28** (4) (1974).

[10] The Group of Japanese Pedologists, Volcanic ash soils around Imaichi and Kanuma area. (1977).

[11] Yamasaki, M., The volcanic activity in the later stages of the development of Nantai. Nikko. Volcano, **2** (2) (1957).

[12] Yoshida, M., Takagami, K., Hamada, R., and Kurobe, T., Studies on the properties of organic matter in buried humic horizon derived from volcanic ash. Soil Sci. Plant Nutr., **24** (2) (1978).