Clay Minerals Of Alluvial Soils In Kyushu Part1 : Alluvial soils of the Shira River

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CLAY MINERALS OF ALLUVIAL SOILS IN KYUSHU
PART 1
Alluvial soils of the Shira River[1]

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In Kyushu, casual floods are frequent owing to heavy rainfall. These floods cause landslides, debris avalanches, slumping, or washing away of surface soils in upper reaches, and depositing of mud in lower reaches. Therefore, clay minerals in the alluvial soil would be largely dependent upon those in soils of upper basins.

Late in June, 1953, heavy rainfall, ranging from 300 mm. to 1,000 mm. visited the northern and middle parts of Kyushu after a long spell of wet weather. Soil erosion happened at various places of the Aso district and others, and vast mud deposited from the flood water on alluvial soils, especially of the midstream of the Chikugo River and of the lower reaches of the Shira River (1), (2).

The purpose of this research is to study clay minerals in newly-deposited mud comparing them with those in alluvial soils covered with the mud and in eroded soils.

MATERIALS AND METHODS

Soil samples used herein were collected from localities which were subjected to large scale erosion of soil or depositing of mud, as seen in Table 1. Their mechanical composition and cation-exchange capacity are given in Table 2, and mineralogical composition of their fine sands is shown in Table 3.

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Table 1. Soil samples used.

Laboratory number	Horizon	Depth (cm.)	Locality and explanation
Locality:			Koji, Yamada-mura, Aso County, Kumamoto Pref.
984	D*	0–20	Dark brown loam being deposited from the flood water on a rice field on the left shore of the Kuro River, a tributary of the Shira River.
985	A	20–35	Dark brown clay loam. This horizon was covered with the mud of 984 by the flood, namely was a former A horizon.
Locality:			Sanbonmatsu, Hakusui-mura, Aso County.
995	A_1	0–20	Dark brown loamy sand, very porous and friable.
996	A_2	20–80	Dark brown sandy loam, porous and friable.
997	B	80–90	Yellowish brown loamy sand, considerably compact and structureless. This horizon played as a slip surface in the time of the landslide. Above three samples were taken from a profile formed by the landslide.
Locality:			Nakamatsu, Hakusui-mura, Aso County.
1006	D	0–20	Dark brown sandy loam being deposited on a rice field on the left shore of the Shira River.
Locality:			Nakashima, Jinnai-mura, Kikuchi County, Kumamoto Pref.
1008	B	0–10	Grey sandy loam with numerous iron stains and concretions. Compact and hard. The horizon appeared on a surface, because a former A horizon, a plowed surface of a rice field, was washed away by the flood.
Locality:			Watarishika, Kumamoto City.
1010	D	0–15	Grey brown loam being deposited on a field from the flood water.

* D refers to a layer newly deposited by the flood.

Table 2. Mechanical composition of soil samples.

		984	985	995	996	997	1006	1008	1010
Coarse sand (2–0.2 mm.)	(%)	0.39	2.62	13.61	16.92	19.23	2.98	22.73	0.23
Fine sand (0.2–0.02 mm.)	(%)	40.88	31.42	63.19	58.74	57.02	51.50	36.34	33.15
Silt (0.02–0.002 mm.)	(%)	43.99	32.24	17.01	14.12	18.85	31.88	25.15	47.11
Clay (below 0.002 mm.)	(%)	14.74	33.72	6.19	10.23	5.00	13.64	15.78	19.51
Humus	(%)	4.48	8.93	3.62	3.95	0.90	5.46	2.21	6.20
C.E.C. (m.e./100 gm.)		18.5	41.8	14.1	23.7	31.7	17.9	17.9	24.7

Oven dry basis.

Table 3. Mineralogical composition of fine sands.

		995	997	1,006	1,008
Heavy minerals*	(%)	16	14	21	18
Light minerals*	(%)	84	86	79	82
Magnetite		II §	I	I	I
Common hornblende		II	II	II	II
Basaltic hornblende		II	II	II	II
Augite		II	II	II	II
Hyperthene		III	III	IV	III
Glass (n=1.50)		II	{IV	V	IV
Glass (n<1.50)		IV		V	VI
Plagioclase		V	III	V	IV

* Heavy minerals are of specific gravity more than 2.70, and light minerals less than 2.70.

§ I: less than 1%, II: 1-5%, III: 5-10%, IV: 10-20%, V: 20-30%, VI: more than 30%.

Methods for preparing clay separates from the soil samples and for indentifying clay minerals were similar with those ordinarily adopted in our laboratory (3).

X-Ray Diffraction Analysis

X-ray diffraction data obtained from air-dried clays are given in Table 4. The patterns show several very weak or barely visible lines with the exception of about 10.2 Å line in some

Table 4. X-ray diffraction data of air-dried Ca-clays ($<2\mu$).

984		985		995		996		997		1,006		1,008		1,010	
d(Å)	i*	d(Å)	i*	d(Å)	i*	d(Å)	i*	d(Å)	i*	d(Å)	i*	d(Å)	i*	d(Å)	i*
10.1	V	10.0	V	10.3	VI	10.1	IV	10.0	IV	10.1	IV	10.2	IV	10.1	IV
										5.58	VI				
4.87	VI	4.97	VI	5.02	VI					4.94	VI	4.99	V	4.95	V
4.50	V	4.51	V	4.52	VI	4.52	VI	4.47	IV	4.47	V	4.52	V	4.50	V
4.12	V	(4.17	IV	4.15	VI	4.09	VI	4.13	VI	4.09	V	4.14	V	4.14	V
3.78	VI	3.69	VI	(3.64	VI	3.76	VI	3.75	VI	3.78	VI				
3.50	VI					(3.53	VI			3.53	VI				
								3.41	VI						
3.23	V	3.21	V	3.24	V			3.22	IV	3.21	V	3.24	V	3.22	V

3.00 V	3.00 VI		2.99 VI	2.96 VI	2.99 V	3.00 V	2.99 V
				2.80 VI			
2.56 V	(2.54 VI		2.53 VI	2.53 V	2.53 V	2.58 V	2.54 VI
2.31 VI	(2.28 VI		2.31 VI				
			2.24 VI		2.26 VI	2.27 VI	
					2.03 VI		2.06 VI
						1.91 VI	1.91 VI
						1.80 VI	
1.50 VI				(1.49 IV		(1.50 VI	(1.50 VI

* i: Intensity, IV: Weak, V: Very weak, VI: Barely visible,
(: Reflection broadened.

samples. The line at approximately 10.2 Å is that of basal spacing of hydrated halloysite, for the 10.2 Å line is replaced by a line at about 7.2 Å by heating at 110°C. According to the intensity of the line, the content of the mineral in the clay separates is considerable in the subsoil of the volcanic ash soil and the alluvial soils from the lower reaches, appreciable in the alluvial soils from the upper reaches, and a trace in the surface soils of the volcanic ash soil.

In all clay separates examined, hydrated halloysite was only recognized as a crystalline mineral, and amorphous material, presumably allophane, is suggested to be predominant in all samples, particularly in the surface horizons of the volcanic ash soils and the alluvial soils from the upper reaches.

Differential Thermal Analysis

Differential thermograms of the clay separates from selected soil samples are reproduced in Figure 1. Since these curves were obtained by the same method and a fixed amount of the separates prepared in the same way was put to analysis, one would be able to know an approximately relative quantity of a reactive component by comparing the area or height of a peak for one clay with that of the same peak for another clay.

The curves have two marked endothermic peaks at about 170°C. and 530°C. and in most samples two exothermic peaks at about 360°C. and 900°C. are noticed. Compared with the peak at 530°C., the endothermic peak, depending on hygroscopic water, is fairly high in every clay for usual crystalline clay minerals. This indicates the presence of predominant allophane in every clay and agrees with the results of the X-ray diffraction analysis. The second endothermic peak, being attributed to expelling of OH ions from the layer lattice, shows the presence of some kaolin, presumably hydrated halloysite, from the characteristic shape. It was confirmed by the x-ray analyses as already mentioned.

The thermogram of mud deposited from the flood water looks a good deal like the shape of the clay from soils covered with that mud, as seen in no. 984 and no. 985. It also seems that the clays of the soils from the upper reaches have less hydrated halloysite than those from the lower reaches. Meanwhile, the clays of the upper horizons on the central cone, where the landslides took place in 1953, mainly consist of allophane, but the underlying horizon, which remained on its site against the slide, has much kaolin in its clay fraction.

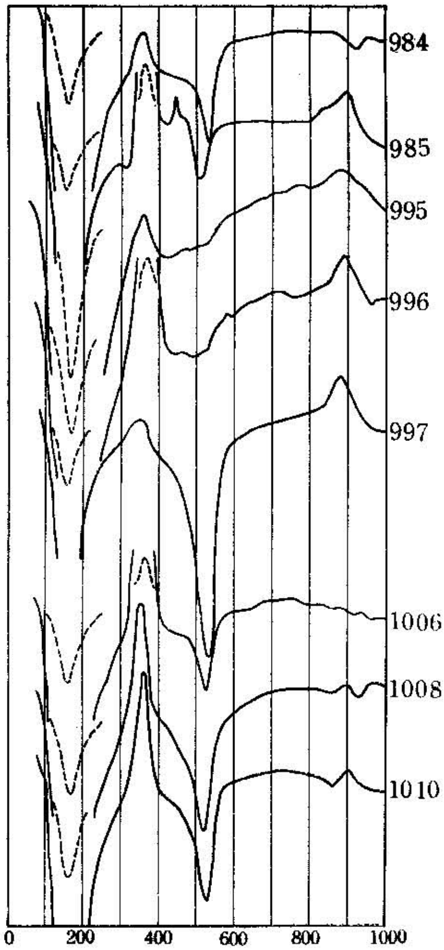

Fig. 1. Differential thermal curves of Ca-clays ($<2\mu$).
The portions in dotted lines are on one fifth of the intensity scale.

Most clay samples showed a noticeable exothermic reaction between 300°C. and 400°C. It would be probably attributed to some unoxidizable organic matter by the H_2O_2 treatment.

CHEMICAL ANALYSIS

Chemical analysis was carried out on four selected Ca-clays from the samples. The results obtained are shown in Table 5. Hygroscopic water on the clays was regulated by 50 per cent H_2SO_4 before analysis.

Table 5. Chemical composition of Ca-clays ($<2\mu$).

		984	995	997	1,010
SiO_2	(%)	31.54	24.02	33.40	33.14
Al_2O_3	(%)	22.49	23.50	20.15	20.59
Fe_2O_3	(%)	14.96	15.96	18.27	15.05
MnO	(%)	0.07	0.28	0.14	0.11
MgO	(%)	0.66	0.24	0.48	0.12
CaO	(%)	3.00	2.42	2.90	2.76
Na_2O	(%)	0.43	0.17	0.52	0.47
K_2O	(%)	0.36	0.14	0.24	0.39
TiO_2	(%)	0.32	0.36	0.48	0.29
P_2O_5	(%)	0.47	0.98	0.82	1.55
$H_2O(+)$	(%)	11.86	13.98	10.34	13.34
$H_2O(-)$	(%)	11.98	18.06	11.18	11.40
Total	(%)	98.14	100.11	98.92	99.21
Molecular ratio	SiO_2/Al_2O_3	2.38	1.73	2.81	2.73
	SiO_2/R_2O_3	1.67	1.25	1.78	1.86
C.E.C. (m.e./100 gm.)		51.8	66.4	53.1	57.0

The clays chiefly consist of water, silica, alumina, and iron, and strong bases are contained rather in small quantities. Ratio of silica to alumina ranges from 1.73 to 2.83, and the ratio of the clay separates from the lower reaches or the subsoil is higher than that of the separates from the upper reaches or the surface soil, respectively. This is in accordance with the content of hydrated halloysite in the clay separates, as seen in the results of x-ray diffraction and differential thermal analyses.

The content of iron in the clays is generally high and amounts to about 15 per cent or more, and the ratio of the component to alumina resembles the ratio in fresh volcanic ash from Mt. Aso (5).

Comparing the chemical composition of the clay separates to that of fresh ash, the former is markedly more in water, appreciably more in phosphor, less in silica and strong bases, and considerably less in alumina than the latter.

Notwithstanding that the clay separates all largely consist of allophane and hydrated halloysite as already discussed, some samples show a considerably high ratio of silica to alumina in comparison with that of allophane (3), (4), (7) or hydrated halloysite. This is probably attributable to the presence of some primary minerals having a high ratio of silica to alumina.

ELECTRON MICROSCOPY

Electron micrographs of some clay separates below 2 microns are shown in Figures 2, 3, and 4. The clay fractions are largely consisted of irregularly outlined particles in which the majority seem to be aggregates of several single particles having various shapes. Tubular particles are also recognized in some samples. It would be plain that the tubular particles are hydrated halloysite, from their characteristic feature. These hydrated halloysite particles are observed a great deal in the clays from the lower reaches and the subsoil, indicating the similar result with the x-ray and thermal analyses.

In addition to these particles, a few hair-like particles (3), (6) were found in some samples.

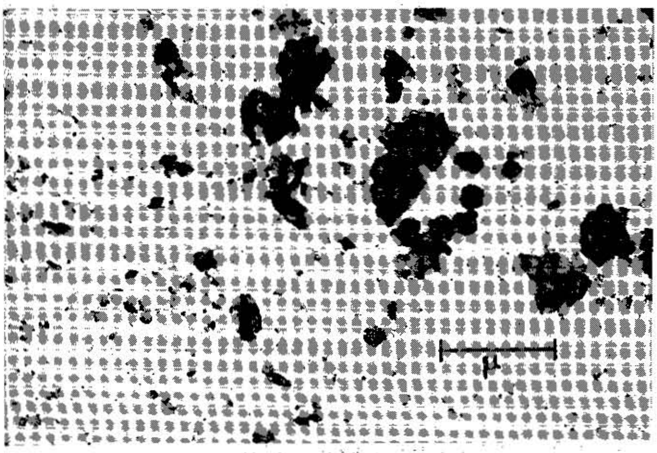

Fig. 2. Electron micrograph of Ca-clays ($<2\mu$). 984.

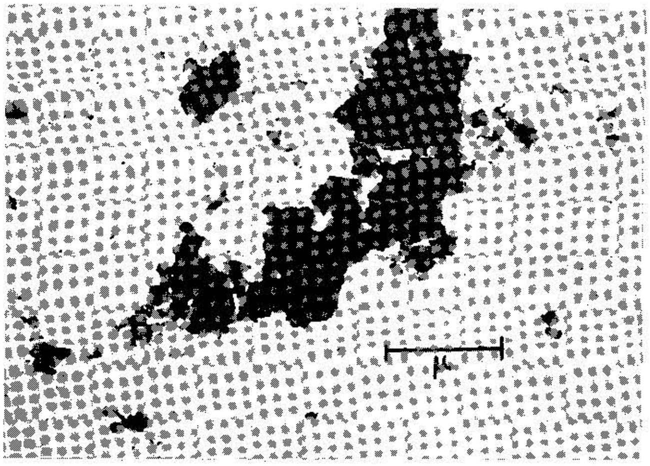

Fig. 3. Electron micrograph of Ca-clays ($<2\mu$). 997.

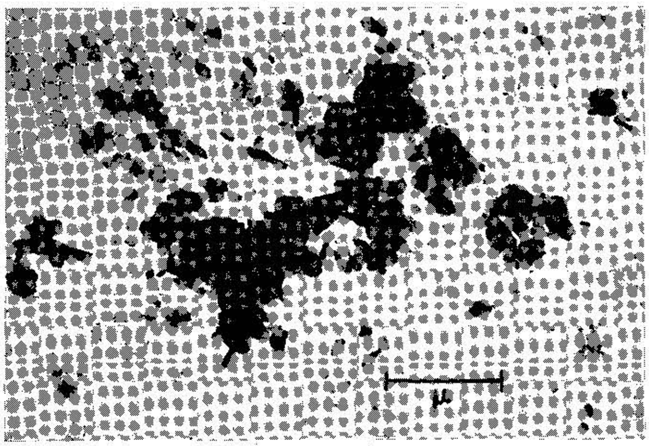

Fig. 4. Electron micrograph of Ca-clays ($<2\mu$). 1010.

SUMMARY AND CONCLUSIONS

Late in June, 1953, the Aso area in Kyushu was visited by a great flood which caused numerous landslides in various scales at the upper section of the central cone, washed surface soils down from many fields on the shores at the upper and middle reaches of the Shira River, and deposited a great deal of mud on the fields at the lower reaches of the river.

Minerals of the clay fractions of soil samples taken from the soil profiles which were shaved from erosion, and mud samples deposited from the flood water have been investigated by the chemical and differential thermal analyses, and the x-ray diffraction and electron micrographic methods.

The volcanic ash soil from which the alluvial soils were derived, contains allophane and hydrated halloysite as main clay minerals. In fact, its surface horizon, derived from comparatively fresh ash, contains allophane in general, whereas the lower one, derived from old ash, has some hydrated halloysite in addition to allophane. The former horizon is very porous and permeable, but the latter one shows somewhat poor internal drainage and compactness. As one would expect from these characteristics of the horizons, the erosion was carried out in the surface layers containing chiefly allophane in the clay fraction.

The alluvial soils of the river contain allophane with hydrated halloysite, which is seen in more quantities in the soils of the lower reaches than in the upper reaches. The mineralogical composition of the clay separates from horizons of the alluvial profile, is closely similar regardless of their depth. It would be suggested that soil materials of the alluvial soil at a certain site have come from the same location by the similar means in comparatively recent years. It means that the soil erosion, such as that which happened in 1953, has been repeated over and over again in the basin of the Shira River.

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