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CLAY MINERALS OF ALLUVIAL SOILS IN KYUSHU
PART 2
Alluvial soils of the Chikugo River[1]

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An account of the clay minerals in the alluvial soils of the Shira River has been given in a previous communication (1). This paper presents a similar study of clay minerals in the alluvial soils of the Chikugo River having a basin which is different in geological formation from that of the former river.

SOIL SAMPLES AND METHODS

From a total of 31 soil samples collected from the mid-stream (Hida City) to the downstream (Yasutake-mura) following the flood in 1953, several representative specimens were selected for this investigation as shown in Table 1.

Table 1. Soil samples used.

Labora-tory number	Horizon	Depth (cm.)	Characteristics
Locality: Hinokuma, Hida City, Oita Pref.			
A soil profile in a rice field having developed on an old river bed of the Mikuma River, an upper stream of the Chikugo River. Being covered with sand to depth of 10 cm.			
912	A	10-20	Grey loamy sand. A buried former A horizon.
913	B	20-30	Grey loamy sand with some iron concretions.
Locality: Iriji, Daifuku-mura, Asakura County, Fukuoka Pref.			
The right bank of the Chikugo River was broken at upstream Tanaka of the village, situating at distance of 2 km. from Iriji. Mud was deposited a great deal from the flood water coming through Tanaka at the hamlet.			
933	D*	0-40	Light brownish grey sandy loam.

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Locality: Hayashita, Hinashiro-mura, Asakura County.
This place is located at 4 km. further down the flood flow from Iriji above mentioned.

940 D 0–5 Light brownish grey loam.
941 A 10–20 Grey loam.

Locality: Tanaka, Daifuku-mura, Asakura County.
To this place the broken bank was only 0.5 km. distant, but soil erosion was got off excepting the top 2 to 5 cm. of the surface. The partly eroded surface was covered with sand layer of about 1 cm. in thickness.

951 A 1–7 Grey sandy loam.
952 B_1 7–13 Grey sandy loam with a few iron concretions.
953 B_2 13–25 Grey sandy clay being largely stained with yellowish brown iron deposits.

Locality: Zendoji, Zendoji-machi, Mii County, Fukuoka Pref.
Samples were taken from a rice field on the left shore of the Chikugo River, covering with mud.

961 D 0–4 Grey loam.
963 A 4–20 Grey sandy loam.

Locality: Minamikoga, Yasutake-mura, Mizuma County, Fukuoka Pref.

967 D 0–0.3 Light grey silty clay loam.

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

The deposited materials generally consist of comparatively uniform particles which were sorted by the flood water. Moreover, they have some organic matter which seems largely to come from cultivated surface layers of arable lands. Mechanical composition and humus content of the soil samples are given in Table 2. In general, the samples from the upper reaches have coarse texture, those from lower reaches fine texture, and texture of horizons of a profile resembles each other. Minerals of fine sand

Table 2. Mechanical composition of soil samples.

		912	913	933	940	941	951
Coarse sand (2–0.2 mm.)	(%)	48.21	41.63	0.66	0.14	6.48	14.20
Fine sand (0.2–0.02 mm.)	(%)	28.89	36.92	56.25	37.90	40.36	44.78
Silt (0.02–0.002 mm.)	(%)	16.38	16.01	31.12	44.81	37.49	25.10
Clay (below 0.002 mm.)	(%)	6.52	5.44	11.97	17.15	15.67	15.92
humus	(%)	2.17	0.88	3.22	4.55	2.17	2.22
C.E.C. (m.e./100 gm.)		9.9	7.5	19.3	23.8	13.7	12.4

		952	953	961	963	967
Coarse sand (2–0.2 mm.)	(%)	13.43	12.36	0.38	9.84	0.04
Fine sand (0.2–0.02 mm.)	(%)	45.68	37.23	33.17	48.52	2.70
Silt (0.02–0.002 mm.)	(%)	32.98	27.88	47.68	27.39	63.86
Clay (below 0.002 mm.)	(%)	7.91	22.53	18.77	14.25	33.40
humus	(%)	1.96	1.12	2.13	2.64	n.d.
C.E.C. (m.e./100 gm.)		13.1	12.2	23.3	16.5	26.4

Oven dry basis.

fractions consist largely of plagioclase, glass, amphibole and pyroxene, and newly deposited mud contains some coloured glass particles which have a refraction index of about 1.55 as seen in Table 3.

Experimental methods used for identification of clay minerals were the same ones in a previous paper (3).

Table 3. Mineralogical composition of fine sands.

		912	933	951	953
Heavy minerals*	(%)	22	3	9	13
Light minerals*	(%)	78	97	91	87
Magnetite		II§	I	I	I
Common hornblende		III	II	II	II
Basaltic hornblende		II	I	II	II
Augite		III	I	I	I
Hyperthene		III	II	II	II
Biotite		I	I	I	II
Zircon			I	I	I
Glass (n=1.50)		IV	IV	III	III
Glass (n>1.50)			II		
Orthoclase		II	II	II	II
Plagioclase		VI	VI	VI	VI
Quartz		II	II	II	II

* Heavy minerals are of specific gravity more than 2.70, 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%.

X-Ray Diffraction Analysis

The x-ray diffraction patterns of the clay fractions from the samples all were almost identical to each other. Table 4 shows a representative data of a Ca-clay (< 2μ) saturated with ethylene glycol. The data show the presence of montmorin, hydrated halloysite or illite, halloysite, and gibbsite.

Table 4. X-ray diffraction data of a Ca-clay saturated with ethylene glycol.

d(Å)	i*	d(Å)	i*
16.9	III	2.37	VI
10.6	IV	2.23	VI
7.3	IV	2.02	VI
4.83	VI	(1.69	VI
4.46	II	1.54	VI
4.03	III	1.50	VI
3.62	V	1.37	VI
3.34	V	1.29	VI
3.18	V	1.24	VI
2.57	V		

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

By heating the air-dried clay to 100°C. for 3 hours, the line at 10.6° Å turned into a very weak one, the line at 7.3 Å became stronger, and the 16.9 Å line was replaced by a 15 Å line. These facts reveal that the clays have montmorin, hydrated halloysite, halloysite, and a little illite. Since the 16.9 Å line is more or less broad and slightly less than that of typical montmorin treated with ethylene glycol (17.5 Å), the montmorin in the samples may be some mixed-layer minerals of montmorin and vermiculite or others.

From darkness of the background and intensity of the lines it is suggested that the clays contain amorphous material in addition to the crystalline clay minerals above-mentioned.

DIFFERENTIAL THERMAL ANALYSIS

Differential thermograms of the separated Ca-clays are shown in Figures 1 and 2. The curves, as seen in the figures, bear a consiberable resemblance to each other. They have three endothermic peaks; namely, a noticeable initial peak due to loss of adsorbed water; the second small peak at about 280°C. to 330°C.; a marked reaction beginning at about 400–450°C. and with a peak at about 550°C. They also indicate a striking exothermic peak at about 910°C., and most of them show a small endothermic reaction between about 900°C. and 860°C. followed immediately by the final exothermic reaction.

The resemblance of the thermograms suggests that the mineralogical composition of the clay fractions are generally similar

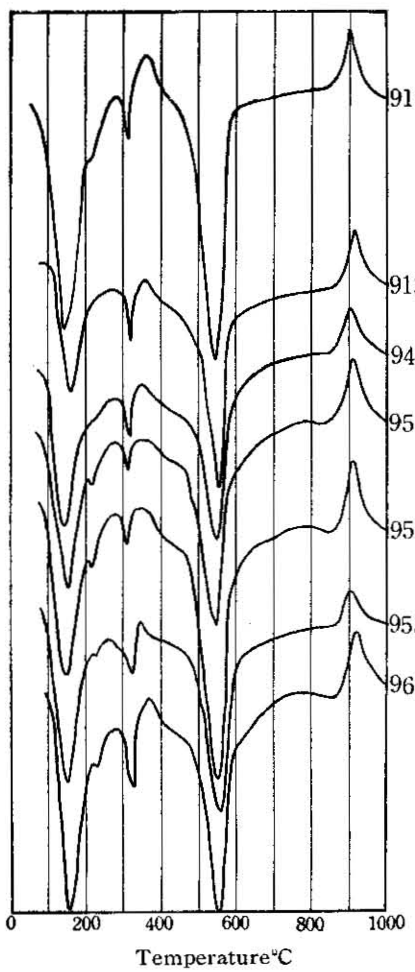
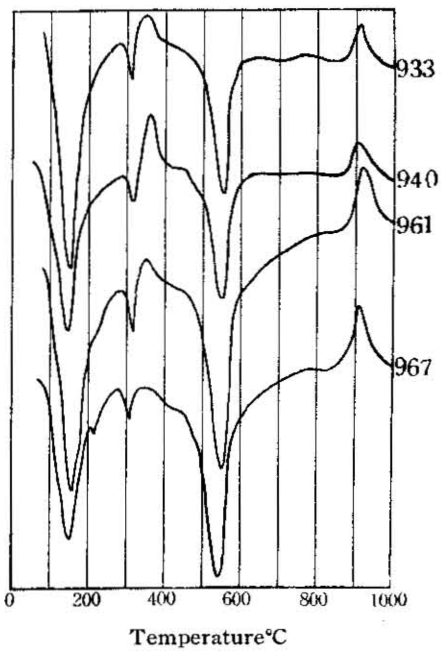


Fig. 1. Differential thermal curves of Ca-clays ($<2\mu$) of soils.

Fig. 2. Differential thermal curves of Ca-clays ($<2\mu$) of muds deposited by the flood water.



to each other, notwithstanding differences of location and age of deposition, inasmuch as they are in full agreement with the x-ray diffraction results.

In most clay separates, the first endothermic peak is as high as the third one. Since the clays were treated equally with 50 per cent H_2SO_4 prior to the thermal analysis, it is suggested that the fact shows the presence of allophane in addition to crystalline minerals. As one would expect from the x-ray diffraction results, the shape of the thermograms shows mixtures of halloysite, presumably hydrated halloysite, montmorin, gibbsite, and amorphous matter. The minerals of the clay fractions are of the same species as those of the mud of the Ariake Sea (2).

CHEMICAL ANALYSIS

Chemical composition of three clay separates is given in Table 5. Generally speaking, the clays are similar in chemical composi-

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

		912	940	967
SiO_2	(%)	47.92	40.16	42.30
Al_2O_3	(%)	25.60	26.24	25.63
Fe_2O_3	(%)	6.63	10.37	10.04
MnO	(%)	0.02	0.03	0.05
MgO	(%)	0.84	1.26	1.36
CaO	(%)	1.68	1.44	1.40
Na_2O	(%)	0.39	0.27	0.34
K_2O	(%)	0.75	0.85	0.98
TiO_2	(%)	0.23	0.24	0.26
P_2O_5	(%)	0.22	0.71	0.71
$H_2O(+)$	(%)	10.56	11.58	10.34
$H_2O(-)$	(%)	6.04	6.10	6.00
Total	(%)	100.88	99.25	99.41
Molecular ratio	SiO_2/Al_2O_3	3.18	2.60	2.80
	SiO_2/R_2O_3	2.73	2.07	2.24
C.E.C. (m.e./100 gm.)*		44.5	39.7	44.7

* Oven dry basis.

tion, although some chemical constituents of the separates vary appreciably from sample to sample. The molecular ratios of silica to alumina and to sesquioxide are 2.60 to 3.18 and 2.07 to 2.73, respectively. These figures of the molecular ratios are between those of allophane or kaolin and montmorin.

The clay fractions have fairly large amounts of potash and magnesia, and the former is almost equal to that of the Ariake mud (2), but the latter content is distinctly lower than that mud.

The clay separates have a cation-exchange capacity varying between 40 to 45 m.e. per 100 gm. clay dried at 110°C., which is considerably low in comparison to that of the mud.

Obviously from the results as mentioned above, the clay minerals in the samples are very similar in species to those of the mud in the Ariake Sea. The mineralogical composition, however, seems to be different. In general, the alluvial soils are more in hydrated halloysite and allophane, and less in montmorin than the Ariake mud.

ELECTRON MICROSCOPY

Electron micrographs taken of four clay separates are given in Figures 3, 4, 5, and 6. The micrographs show that the clay fractions have various particles of different shapes in addition to common tubular ones which belong to halloysite. Certain samples,

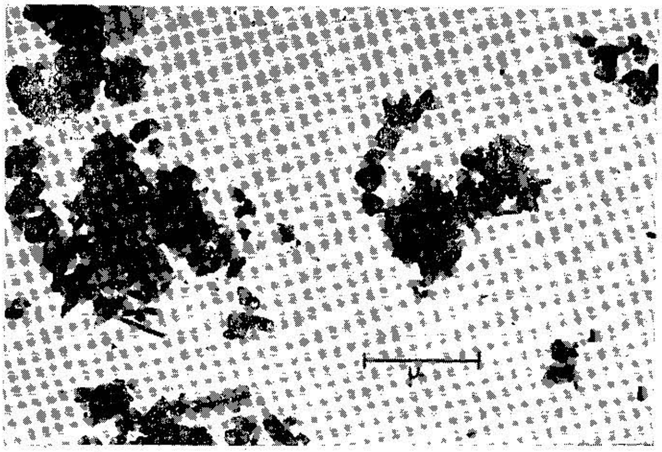


Fig. 3. Electron micrograph of Ca-clay ($<2\mu$). No. 912.

for instance no. 967, show irregular fluffy particles without distinct outlines. Other samples, for instance no. 940 a, have rounded particles having a nodule appearance. These particles may be allophane. Some soil clays show very large platy particles on which somewhat rounded holes regularly arranged are seen. These particles are remains of diatoms (no. 940 b).

The clay fractions also have some thin flakes with well-defined outlines, granular particles with an irregular shape, laths, and aggregates.

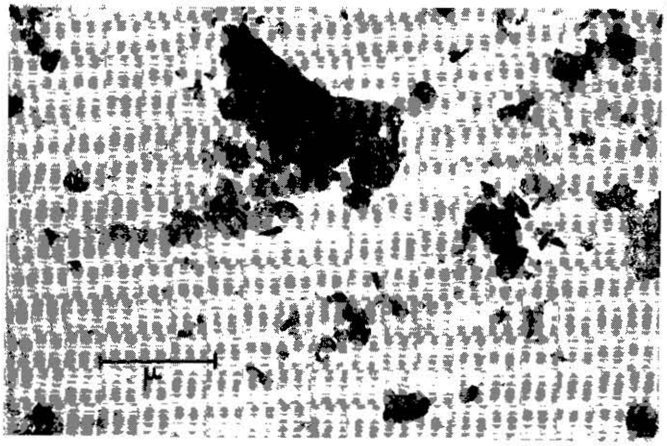


Fig. 4. Electron micrograph of Ca-clays ($<2\mu$). No. 967.

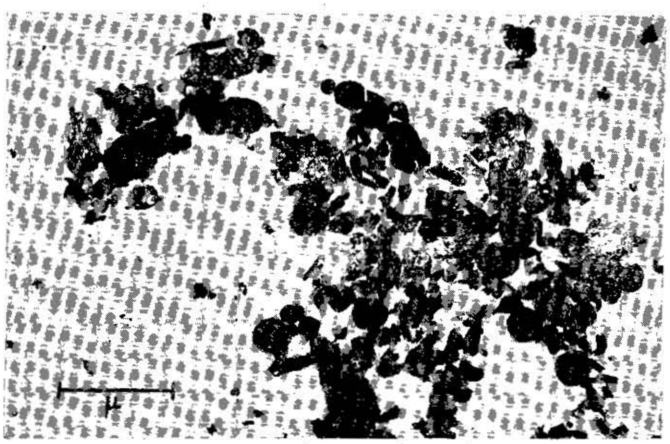


Fig. 5. Electron micrograph of Ca-clays ($<2\mu$). No. 940 a.

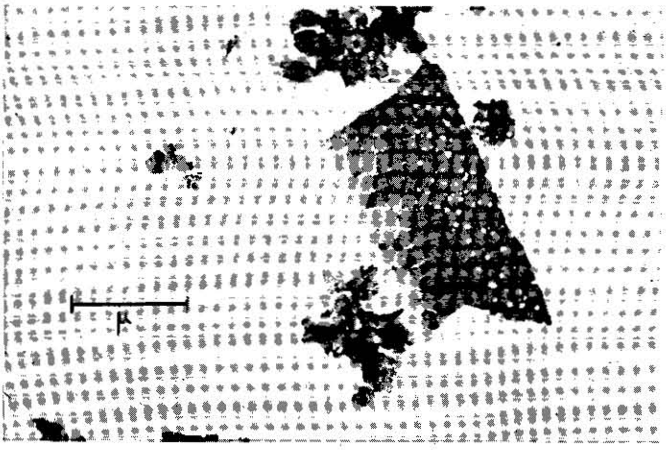


Fig. 6. Electron micrographs of Ca-clay ($<2\mu$) No. 940 b.

CONCLUSIONS AND SUMMARY

The alluvial soils of the Chikugo River are well-known as some of the most fertile ones in Japan, but the soils of the Shira River are not so fertile notwithstanding the fact that the rivers originate from very near districts. The flood in 1953 indicated a mode of alluvium by the rivers. Samples of soils and mud deposited from the flood water were collected, and their clay fractons ($<2\mu$) separated by a sedimentation method were examined by the thermal and chemical analyses, and the x-ray and electron microscopic methods.

The clay fractions of the alluvial soils of the Chikugo River all are very similar in mineralogical feature regardless of the location and horizon. They have montmorin, hydrated halloysite, allophane, halloysite, and illite with gibbsite and probably other amorphous R_2O_3 hydrates. This mineralogical composition is obviously different from that of the Shira River (1), which mainly consists of allophane and hydrated halloysite. The two rivers come from adjoining volcanic districts in the midsection of Kyushu; the Chikugo River originates from the atrio of Mt. Aso and near volcanoes and the Shira River from the central cone and the caldera of Mt. Aso. The basin of the former river is mantled with soils derived from andesitic aggromerates, tuffs, and volcanic ash, while that of the latter river largely consists of volcanic ash soils. It means that the difference between the mineralogical compositions of the clay fractions from the two districts is due to the difference in the parent materials of the soils; namely the lava and the volcanic ash.

Soils derived from lavas and others have montmorin and relatives in the clay fraction in addition to kaolin and allophane, but those from volcanic ash alone have allophane and kaolin in that fraction. Pregnancy of the former soils seems largely due to the presence of montmorin and relatives.

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