18. *Geology of Imaichi District with Special Reference to the Earthquake of Dec. 26, 1949 (III).*

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IV. Mineralogy of the clayey beds related to the changes of the surface

In the foregoing chapters[13),14)], were described the geology of the meizoseismic area and the changes of the surface mostly brought about by the earthquake which severely struck the town of Imaichi and its environs in Tochigi Prefecture about 100 *km* north of Tokyo on December 26, 1949. Many earth falls and landslips took place mainly on the area covered with Pleistocene clayey beds of volcanic origin. This chapter includes some results of the detailed mineralogical and chemical investigation of these clayey beds especially of the white greasy clay intercalated in "Kwantô Ash Formation or Kwantô Loam", which played an important *rôle* in breaking about the landslips.

The Pleistocene clayey beds in the meizoseismic area are enumerated as humus surface soil (O), yellow pumice bed or Kanuma soil bed (A)[15)], reddish brown pumice bed or Imaichi soil bed (B), upper Loam (C), white clay bed (D), and lower Loam (E), successively from the surface. Their geological relations in this district were schematically represented in Fig. 10 previously[16)]. Localities where each tested specimen was collected are designated as 100 (Shimo-kojiro), 101 (Azuma-cho, Imaichi town Fig. 17), 102 (Akama, Imaichi town Figs. 25, 26), 103 (Ushiro-yama Fig. 13), 104 (Yama-shita), 105 (Myôjin Fig. 28), 106

13) R. MORIMOTO, "Geology of Imaichi District with special reference to the earthquake of Dec. 26, 1949 (I)", *Bull. Earthq. Res. Inst.*, **28** (1950), 379-386.

14) R. MORIMOTO, "Ditto (II)", *Bull. Earthq. Res. Inst.*, **29** (1951), 349-358.

15) Recently Mr. Jun AKUTSU of Utsunomiya University investigated the distribution of these pumice beds in detail in relation to river terrace. The yellow pumice bed corresponds to his "Shichihon-zakura Yellow Pumice Bed". (J. AKUTSU, "The Kanto Ash Formation and the river terrace in the environs of Utsunomiya City, Tochigi Prefecture", *Bull. Utsunomiya Univ., Faculty of Liberal Arts*, No. 4 (1955), (ii), 33-46 (in Japanese).)

16) R. MORIMOTO, *op. cit.* 14), p. 354.

(Itabashi Figs. 12, 27), and 107 (Murose) on the following map (Fig. 16. Cf. Figs. 25, 27 and 28.).

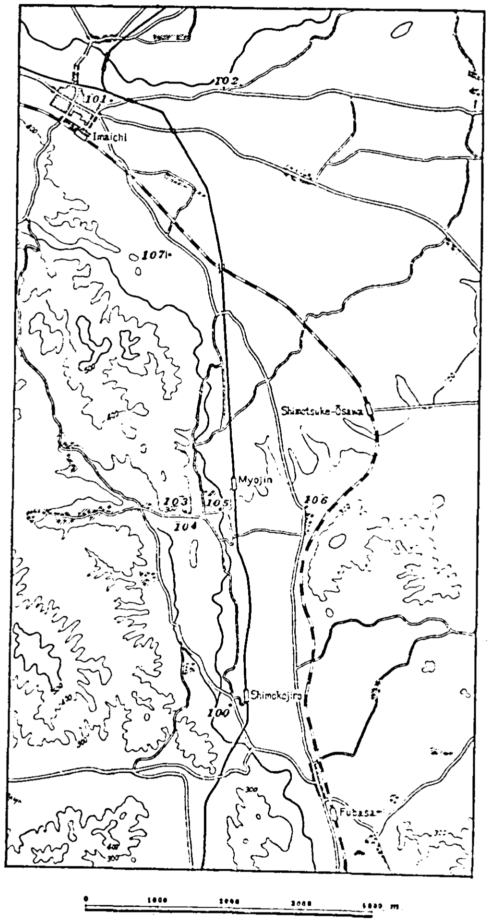

Fig. 16. Locality map of the collected specimens.

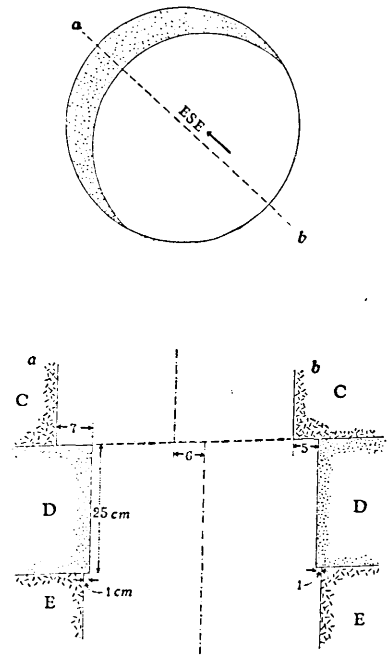

Fig. 17. Displacement of the stratum observed at the water well, Kashiwagi "Tofu" Shop, 1147, Azuma-cho, Imaichi town, Tochigi Pref..

(*1*) *Petrographic features of each clayey bed:*

These clayey beds are quite distinctive from each other in colour and in field occurrence (Fig. 29).

The black loose humus surface soil (O) is mainly composed of volcanic glass stained with dark organic matter in which minute patches of altered plagioclase, chert, and of pumice, and the broken crystals of hypersthene, augite, and plagioclase are found under the microscope.

The loose yellow pumice bed (A), 20-40 *cm* in thickness, consists of yellow pumice grains commonly of 5-10 *mm* in diameter. Each pumice grain remains its original porous rhyolitic structure of the clean volcanic glass (Fig. 30-A), which has partly been devitrified into clay mineral. Flakes of plagioclase, hypersthene, augite, iron ore, quartz, etc., are contained.

The reddish brown pumice bed (B), 0.5–1.5 *m* in thickness, is composed of pumice grains with comparatively uniform size of 2 *cm* or more in their diameters. Lithic fragments of 3–10 *mm* in size are often found. Each pumice grain shows a uniform fluidal structure with equigranular cavities (Fig. 30-B). Under the microscope a small amount of lithic or crystal fragments such as quartz-porphyry, aggregate of pyroxene-plagioclase, hypersthene, augite, iron ore, plagioclase, etc., are observed in the vitric groundmass stained into yellowish brown. Most of the plagioclase phenocrysts are decomposed into dirty matter. An electron micrograph of the pumice collected from the cliff of Myojin (105–B, Fig. 28) indicates clearly many particles 0.03–0.05μ in their diameters (Fig. 31 above)[17], which may be identified as allophane, results of the following X-ray and differential thermal analyses being considered. Both pumice beds are said to have been derived from the adjacent Nikko volcanoes northwest of the present meizoseismic area[18].

The upper Loam (C), 2–4 *m* in thickness, as well as the lower Loam (E), 2–5 *m* or more in thickness, forms the main portion of the Pleistocene beds in this area. The former is often intercalated by pumice beds and laminae of scoriae and lappili, and the latter by normal sediments. They belong to the so-called "Kwantô Ash Formation or Kwantô Loam" extensively distributed on the Kwantô plain and its surrounding mountainlands. The two beds (C and E) are mainly composed of the vitric ash partly decomposed into clay and stained with limonitic substance. Subordinate amount of lithic or crystal ash are contained. Minute fragments of the basal rocks such as chert, quartz-porphyry, liparite or silicified slate, etc., are locally recognizable. Plagioclase, hypersthene, augite, iron ore, hornblende, and quartz are extensively found in small amount under the microscope. These fragments are commonly of 0.1–0.5 *mm* in diameter. Particles of the partly devitrified volcanic glass are arranged in equigranular mosaic aggregates in

17) The electron micrographs of the reddish brown pumice and of the white clay are kindly prepared for the present writers by Dr. Hiroshi TAKAHASHI of the Department of Chemistry, Faculty of Science, University of Tokyo, to whom the writers' sincere thanks are due.

18) J. AKUTSU, *ibid.*, 44.

thin slices (Figs. 30-C and 30-E).

The bed of white greasy clay along which the upper Loam displaced several centimetres eastwards[19] at the time of the earthquake (Fig. 17) still remains its original pumice structure though the alteration into clay is more advanced in it than in the above-mentioned pumice beds (Fig. 30-A). Each pumice grain, 2-5 *mm* in dia., with fluidal texture, contains plagioclase phenocrysts of 0.5-1 *mm* in length, most of which have been replaced by some apparently amorphous clay mineral. Hypersthene, hornblende, and iron ore are found as scanty mafic porphyritic constituents of 0.5-1 *mm* in their diameters. Lithic fragments of the basal rocks are also included in the bed among its pumice grains. The electron micrograph of the white clay indicates the particles of 0.1-0.2μ in dia. with radial spines around them[20]. These spinose particles identified as hydrated halloysite owing to analyses of the following X-ray and DTA data have been reported by T. Sudo as "chestnut shell-like particles"[21] (Fig. 31 below).

(2) *Results of the X-ray analyses:*

Each collected specimen was sifted through the sieve of 115 mesh after being let under room condition for several weeks. Fine powders thus prepared were used to be tested in the following procedures. The X-ray powder pattern was taken with filtered Cr-radiation and a camera with radius of 27.8 *mm* on each specimen (Table Ia-b). Powder photographs of the pumice or ash from A-bed and B-bed do not show any clear diffraction lines except weak lines of felspars mixtured in the prepared fine powders of Kanuma and Imaichi soils. On the cherts of the geiger counter X-ray diffractometer, however, a broad band of peaks (A in Fig. 18) was recognized at 3.4-3.5Å, which may be a weak diffraction pattern of the allophane. Diffraction patterns of hydrated halloysite are found on the powder photographs of the clay from C-, D-, and E-beds: When the Cu-anticathode is used, diffraction line at 10.2-10.3Å is weak and broad on the photographs of C and E, and strong and sharp on that of D. Diffraction patterns of quartz are always found in them. (Table Ia-b, II).

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19) T. HONDA, "Land slip in the Imaichi District revealed from the breaks in the well tube", *Bull. Earthq. Res. Inst.*, **28** (1950), 449-456.

20) See foot note 17).

21) T. SUDO and H. TAKAHASHI, "Shapes of halloysite particles in Japanese clays", *Proc. 4th National Conference on Clay and Clay Minerals, National Research Council U.S.A.*, Publication No. 456 (1956), 67-79, Mineralogical Journal, **1** (1953), 66-68.

Table Ia. Lines of the X-ray powder photographs of the clays from each bed at Akama, Imaichi*.

	102-A		102-B		102-C		102-Du		102-Dl		102-E	
	d	I	d	I	d	I	d	I	d	I	d	I
H					10.0	6	10.0	10	10.2	10	10.4	4
	4.82	5b	4.79	6b								
H.Q.			4.28	10b	4.32	7	4.41	7	4.32	7	4.28	4b
	4.03	10b										
					3.66	3	3.75	1	3.71	1	3.69	1
A			3.52	4b								
A	3.45	5b										
Q					3.35	10b	3.36	4	3.35	2	3.31	10
											2.963	1
H					2.520	3b	2.548	3b	2.534	2b	2.513	2b
	2.250	1	2.228	1								
					1.810	2					1.821	1
					1.665	2b	1.671	1	1.674	1	1.665	1
					1.537	2						
					1.476	2	1.483	3	1.487	2	1.502	1
					1.376	3					1.376	3

* H: hydrated halloysite, A: allophane, Q: quartz
Cr-radiation, 30 KVP, 10 *mA*, 30-60 *minutes*, Radius of the camera being 27.8 *mm*.

Table Ib. Lines of the X-ray powder photographs of the white clays from Azuma-cho, Imaichi (101-D), Itabashi, Ochiai village (106-D), and from Murose, Imaichi (107-D)*.

	101-D		106-D		107-Dw		107-Db	
	d	I	d	I	d	I	d	I
H	9.9	10	10.1	10	10.2	10	10.2	10
	4.98	2	4.90	2	4.88	2	4.93	1
H	4.40	5	4.47	7	4.43	5	4.43	4
					4.12	2	4.13	2
			3.72	2	3.73	3	3.72	2
Q	3.34	1b	3.43	4	3.41	8	3.40	2b
H	2.58	1	2.59	3b	2.57	2b	2.58	2
					1.830	1	1.853	1
			1.698	2b			1.699	1
					1.543	2	1.547	2
			1.482	1	1.480	1	1.482	1
					1.376	2	1.370	2

* Cr-radiation, 30 KVP, 10 *mA*, 30-60 *min.*, Radius of the camera being 27.8 *mm*.

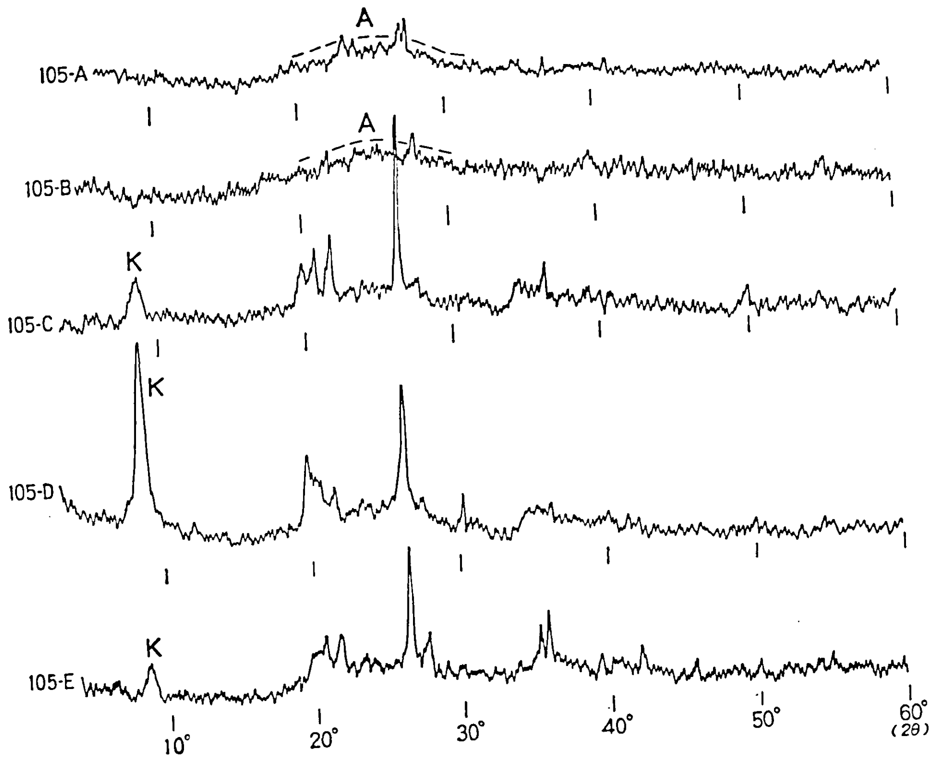

Fig. 18. X-ray powder diffraction patterns of the clays from Myojin, A: Diffraction patterns by allophane, K: Diffraction patterns at 001 of the hydrated halloysite, Cu-radiation, after T. Sudo. The patterns of the same sample of 105-D taken with Fe-radiation do not show such a distinctive sharp peak at 10Å. It appears with same intensities in every chert of 105-C, 105-D, and of 105-E.

(3) Differential thermal analyses:

Each specimen was filtered through a sieve of 80 mesh after being let under room temperature for several weeks. Fine powder thus prepared has been used in the following procedure results of which are represented by the differential thermal analyses curves shown in Figs. 19 and 20[22]. The thermal curves of the yellow pumice bed (105-A) and of the brown pumice bed (105-B) from the cliff exposed along the road from Myôjin station of Tôbu Line to Ushiroyama, Ochiai village indicate two peaks: one is the endothermic one between 140-150°C, another is the exothermic one near 950°C, which are identified as that

22) The equipment installed at the Geological and Mineralogical Institute, Tokyo University of Education was used by courtesy of Prof. Toshio SUDO.

Table II. X-ray powder diffraction data of the clays from Myojin*.

	105-A		105-B		105-C		105-D		105-E	
	d	I	d	I	d	I	d	I	d	I
K	Å	—	Å	—	10.3 Å	9b	10.2 Å	31	10.3 Å	7b
K	—	—	—	—	4.46	9b	4.46	15b	4.40	8b
Q	—	—	—	—	4.27	12	4.27	11	4.27	15
CF	—	—	4.06	8	4.04	14	4.08	9	4.08	20
F	3.82	9	—	—	—	—	—	—	—	—
F	3.71	8	?	?	3.71	6	3.75	7b	3.80	7b
A	3.4	7b	3.5	8b	—	—	—	—	—	—
Q	—	—	—	—	3.35	34	3.36	24	3.35	25
F	3.27	10	—	—	—	—	—	—	—	—
F	3.22	11	3.21	10	3.22	5b	3.22	6b	3.22	10
	—	—	—	—	—	—	2.93	7		
K	—	—	—	—	2.60	6b	2.57	5b	2.54	10
CQ	2.43	4	—	—	2.46	9	2.47	6b	2.50	13
Q	—	—	2.28	6b	2.29	6b	2.24	3b	2.29	5
	—	—	—	—	—	—	—	—	2.146	6
	1.191	3	—	—	—	—	—	—	1.981	4
	—	—	—	—	1.824	6	1.824	3	1.824	4
	—	—	1.658	4b	1.675	4b	1.67	3b	1.672	4

* K: hydrated halloysite, Q: quartz, C: cristobalite, F: felspar, A: allophane
Read from the cherts of a X-ray diffractometer (Fig. 18) being taken with filtered Cu-radiation by T. Sudo.

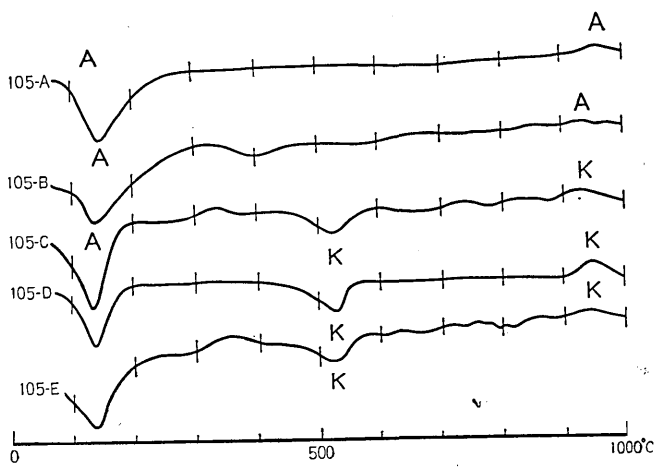

Fig. 19. Differential thermal curves of the clays from Myojin
A and K shows an endothermic or exothermic peak by allophane and hydrated halloysite respectively.

of allophane. The DTA curve of the Imaichi soil (105-B) shows an endothermic peak near 300°C slightly beside the aforementioned two peaks which may be ascribed to the existence of limonite contained in the Imaichi soil. The thermal curves of the clays from the bed of upper Loam (105-C), white clay (105-D), and lower Loam (105-E) collected at the same cliff show exclusively an exothermic reaction between 520-530°C in addition to an endothermic peak near 150°C and an endothermic one near 950°C which are of the same type as that of hydrated halloysite (Fig. 19). The curves of the white clay from Shimo-kojiro (100-D), Azuma-chô, Imaichi town (101-D), and Akama, Imaichi (102-D)

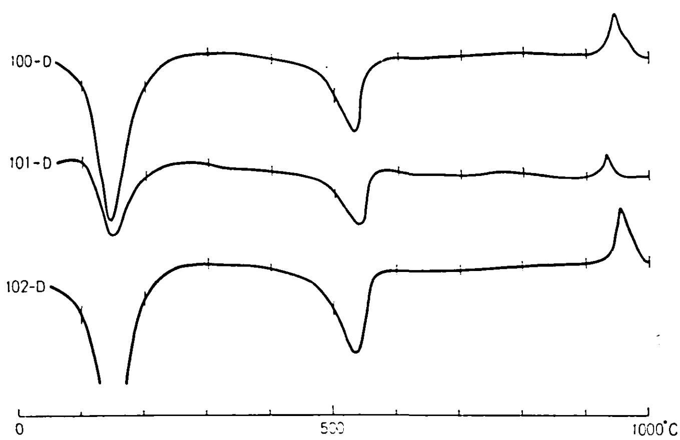

Fig. 20. Differential thermal curves of the white greasy clay from Shimo-kojiro, Ochiai village (100-D), Azuma-cho in the town of Imaichi (101-D), and Akama or Shichihonzakura, east of the town of Imaichi (102-D).

are also of the similar type as that of hydrated halloysite, but deviate from that of the typical hydrated halloysite: that is, an endothermic peak near 500°C indicated by the thermal curves of these clays of volcanic origin always situates at lower temperature than that indicated by typical hydrated halloysite. This deviation is generally shown in various extent by the quantity of hydrated halloysites contained in the slightly altered pyroclastics or volcanic sediments[23].

In order to check the results of these thermal differential analyses, test by a thermal balance was adopted. A thermal balance curve of the white clay collected from Itabashi (106-D) indicates twice dehydration:

23) T. SUDO and J. OSSAKA, "Hydrated halloysite from Japan", *Jap. Jour. Geol. Geogr.*, **22** (1952), 215-229.

the first continuously occurred towards 100°C and the second between 400–500°C. The two dehydration points correspond to the endothermic

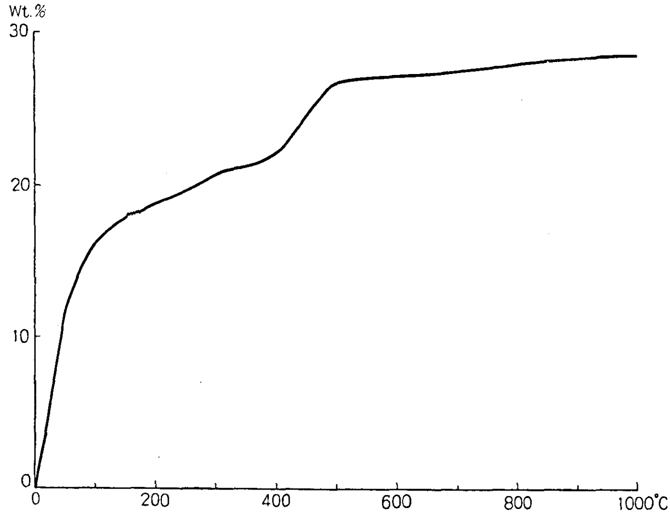

Fig. 21. Dehydration curve of the white clay from Itabashi (Fig. 27).

reactions near 150°C and near 550°C represented by the DTA curve of this white clay (Figs. 20 and 21).

(*4*) *Chemical analyses:*

Each specimen was filtered through a sieve of 115 mesh after natural drying under room temperature, and then treated in crucibles. Thus the results of the chemical analyses represent the compositions of the main matrix of the rocks, and those of the porphyritic minerals or of the included lithic fragments are excluded in the following discussion. According to the results of chemical analyses shown in Table III, the following conclusions may be drawn:

(a) Silica decreases and relative proportion of alumina increases in every bed when compared with their amounts in original volcanic rocks.

(b) Total iron is most abundant in reddish brown pumice of Imaichi soil, then in upper and lower brownish loam, less in surface soil and in yellow pumice, least in the white clay. Values of iron content in these pumice or ash may correspond to the colour of each bed.

(c) Ratio of ferric iron to total irons is maximum in the pumice of Imaichi soil and decreases its value in loam, surface soil, yellow pumice, and in white clay successively.

(d) Titania is comparatively rich in every specimen and changes its value corresponding to that of iron content in each sample.

(e) Values of potash and soda are quite small in every specimen. This fact suggests that the alkalies in the original rocks have been leached away during their alteration. It may be same

Table III. Chemical compositions of the pumice or ash beds from Myojin, Ochiai village, Kamitsuga, Tochigi Pref., Analysts J. Ossaka and T. Fukuda.

	105-O	105-A	105-B	105-C	105-D	105-E
SiO_2	28.29	37.66	25.61	39.20	39.15	38.12
TiO_2	0.85	0.60	1.35	0.99	0.39	1.11
Al_2O_3	19.89	26.21	27.28	25.23	29.94	23.17
Fe_2O_3	4.41	2.94	9.10	7.29	2.33	6.99
FeO	2.34	1.71	0.39	1.02	0.22	1.30
MgO	1.49	1.54	0.39	1.71	0.24	1.76
CaO	0.48	1.67	0.17	0.58	0.03	0.61
Na_2O	0.25	0.84	0.13	0.56	0.40	0.43
K_2O	0.33	0.56	0.05	0.51	0.15	0.51
H_2O-	16.30	15.22	24.66	12.80	15.92	15.87
H_2O+	25.23	11.13	11.08	10.27	11.41	10.05
Total.	99.86	100.08	100.21	100.16	100.18	99.92

Table IV. Molecular ratio calculated from the chemical analyses shown in Table III.

	105-O	105-A	105-B	105-C	105-D	105-E
SiO_2	0.471	0.627	0.426	0.653	0.652	0.634
TiO_2	0.011	0.008	0.017	0.012	0.005	0.014
Al_2O_3	0.195	0.257	0.268	0.248	0.294	0.227
Fe_2O_3	0.028	0.018	0.056	0.046	0.015	0.044
FeO	0.032	0.024	0.005	0.014	0.003	0.013
MgO	0.037	0.038	0.010	0.042	0.006	0.044
CaO	0.009	0.030	0.003	0.010	0.001	0.011
Na_2O	0.004	0.014	0.002	0.009	0.006	0.007
K_2O	0.004	0.006	0.001	0.005	0.002	0.005
H_2O-	0.904	0.845	1.368	0.710	0.883	0.881
H_2O+	1.400	0.618	0.615	0.570	0.633	0.558
$\frac{Al_2O_3+Fe_2O_3}{SiO_2}$	$\frac{0.95}{2.00}$	$\frac{0.88}{2.00}$	$\frac{1.52}{2.00}$	$\frac{0.90}{2.00}$	$\frac{0.95}{2.00}$	$\frac{0.85}{2.00}$

about the lime contents, though the yellow pumice contains 1.67% lime.

(f) Magnesia contents in them have never been leached so much as other constituents during alteration.

In order to estimate roughly the residual composition of these alteration products of volcanic origin, molecular ratios of each constituent in each specimen are calculated from Table III as shown in Table IV, where values of ignition loss are treated as $H_2O(+)$ conveniently. As to the white clay (105-D), $Al_2O_3:SiO_2:H_2O(+):H_2O(-)$ is roughly 2:1:2:2.5-3.0 and somewhat high value of the $H_2O(-)$ may be ascribed to hygroscopic water. This molecular ratio coincides with that of typical hydrated halloysite which is given as $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O(+) \cdot 2H_2O(-)$. As regards the yellow pumice (105-A) and loam (105-C and E) also, if the value of Fe_2O_3 be taken into Al_2O_3, $(Al_2O_3+Fe_2O_3):SiO_2:H_2O(+):H_2O(-)$ =1:2:2:3. For the surface soil (105-O), we have 1:2:6:4 in the same way. The excess water $H_2O(+)$ and $H_2O(-)$ may be ascribed to the coexisting organic matter, hygroscopic water, etc.. In the Imaichi soil (105-B), we have 1.5:2:3:6. The excess Fe_2O_3 may be contained as limonite in the soil. Molecular proportions of the residual constituents in these pumice or ash thus calculated accord with the results of the afore-mentioned X-ray and thermal analyses. It is noticeable that the ratio of $Al_2O_3+Fe_2O_3$ to SiO_2 is 1:2 in the matrix of these pumice or ash except in that of Imaichi pumice (Table IV). It may be concluded therefore that the clay minerals have never been highly recrystallized, especially in the upper member of the Pleistocene clayey beds, even though these pyroclastics have already been altered into a rather advanced state chemically in spite of there still remaining their original textures.

(5) *Size distribution of the clayey beds*[24]:

Air-dry samples of the clayey beds from Akama (102) and Myojin (105) were sorted through sieves of various mesh such as 2,000, 840, 250, 105, and 74 mesh on the oscillation table. Data for the size distribution of the finer particles ($<$ 0.0074 *mm*) were obtained from the measurements on sedimentograph. Data thus obtained are shown by the following cumulative curves of each bed (Figs. 22 and 23) and their schematical representations are found in the Fig. 24 (Table V and VI). Besides the Imaichi reddish brown pumice (B), each bed (O, A, C, D,

24) The writers were kindly instructed by Mr. K. UCHIDA of the Kôyô Co. during these experiments.

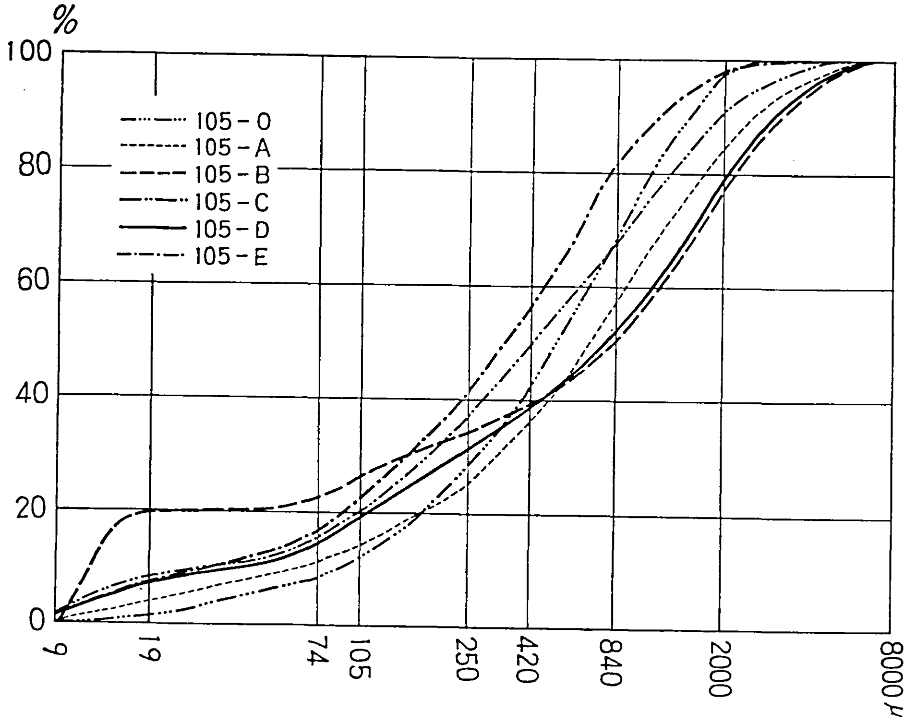

Fig. 22. Cumulative curves of each pumice or ash bed from the cliff at Myojin, Ochiai village, Kamitsuga-gun, Tochigi Pref. Notation of each bed is same in Fig. 18.

Table V. Data of the cumulative curves of the clayey beds from Akama, Imaichi town and Myojin, Ochiai village (Cf. Figs. 22 and 23).

Spec. No. \ Grain size *mm*	>2	2~0.84	0.84~0.42	0.42~0.25	0.25~0.105	0.105~0.074	0.074~0.014	0.014~0.009	<0.009 wt%
102-A	9.55	15.94	25.25	12.28	14.45	4.90	11.81	5.55	0.26
102-B	17.88	6.34	12.85	9.81	13.80	4.77	7.26	26.95	0.34
102-C	0.16	7.36	30.83	21.26	24.61	4.42	9.44	1.71	0.22
102-D	8.51	28.34	15.76	9.21	14.68	6.01	9.97	5.60	1.92
102-E	3.24	11.75	27.26	17.89	20.02	4.94	10.44	2.23	2.24
105-O	2.73	28.38	26.31	14.52	15.94	3.71	7.82	0.59	0.00
105-A	15.28	27.02	21.23	10.57	11.31	3.02	8.89	2.68	0.00
105-B	22.27	26.76	11.42	5.19	7.83	4.29	4.89	17.34	0.00
105-C	9.56	22.31	17.70	12.80	16.64	5.25	9.29	4.25	2.20
105-D	20.48	27.30	13.10	7.54	12.06	4.68	9.20	3.86	1.78
105-E	2.13	16.43	24.52	15.34	19.44	5.55	11.12	3.48	1.99

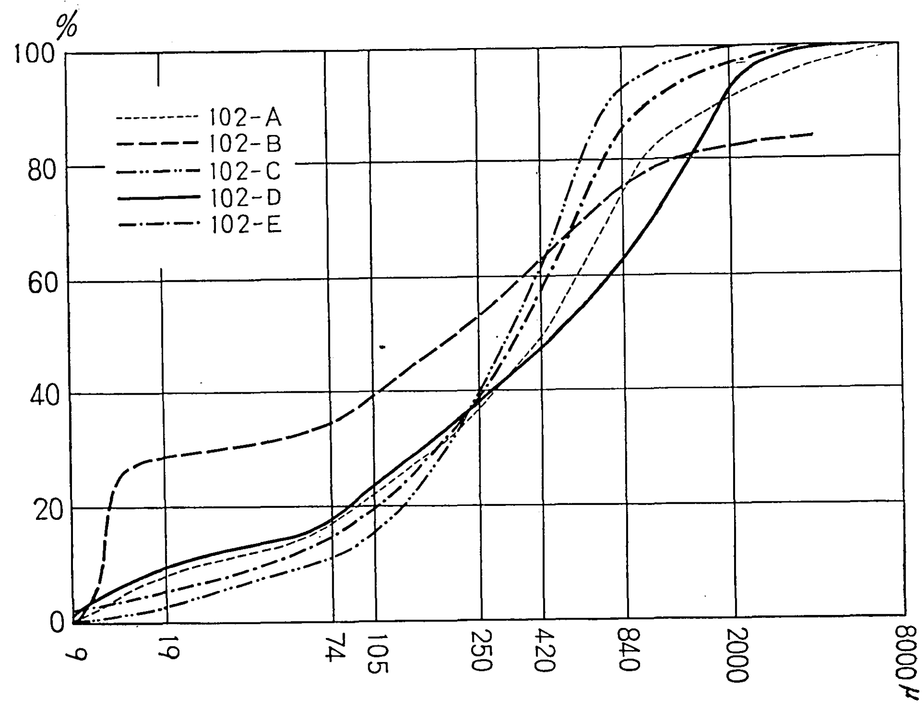

Fig. 23. Cumulative curve of each pumice or ash bed from the cliff at Akama, Imaichi town, Tochigi Pref.. Notation in the figure is the same as Fig. 18.

Table VI. Size distribution of the clayey beds from Akama, Imaichi town (102) and Myojin, Ochiai village (105) Cf. Fig. 24.

Spec. No. / Grain size *mm*	102-A	102-B	102-C	102-D	102-E	105-O	105-A	105-B	105-C	105-D	105-E
1/128 >	0.0%	0.0	0.0	1.5	2.1	0.0	0.0	0.0	2.0	1.6	1.8
1/128～1/64	7.1	28.0	2.2	6.9	2.9	1.0	3.2	18.7	5.3	4.4	4.3
1/64～1/32	4.2	2.8	4.0	4.4	3.5	2.8	3.5	1.8	3.4	4.2	4.1
1/32～1/16	4.4	2.6	4.0	3.3	4.9	3.7	3.1	1.5	3.4	3.0	4.6
1/16～1/8	9.4	9.1	9.1	10.7	9.7	7.4	5.4	6.3	8.9	8.6	11.5
1/8～1/4	11.7	10.5	21.0	11.4	16.6	13.3	9.6	6.0	14.5	9.7	15.4
1/4～1/2	18.4	13.5	30.8	12.8	25.5	21.0	15.4	7.7	17.3	10.5	21.3
1/2～1	25.1	11.5	24.4	17.5	24.0	27.1	22.6	13.2	18.6	15.2	23.0
1～2	10.3	4.3	4.0	23.0	7.6	21.0	20.7	22.6	16.9	22.3	11.8
2～4	6.2	2.2	0.5	8.0	3.2	2.7	8.9	16.5	8.7	15.5	2.2
4～8	3.2	0.5	0.0	0.5	0.0	0.0	6.6	5.7	1.0	5.0	0.0
8<	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

and E) is similar in its type of size distribution: they show the maximum distribution near or at the fraction 1/2–1 *mm*; their particles gradually decrease in amount towards the finer and coarser fractions. Imaichi

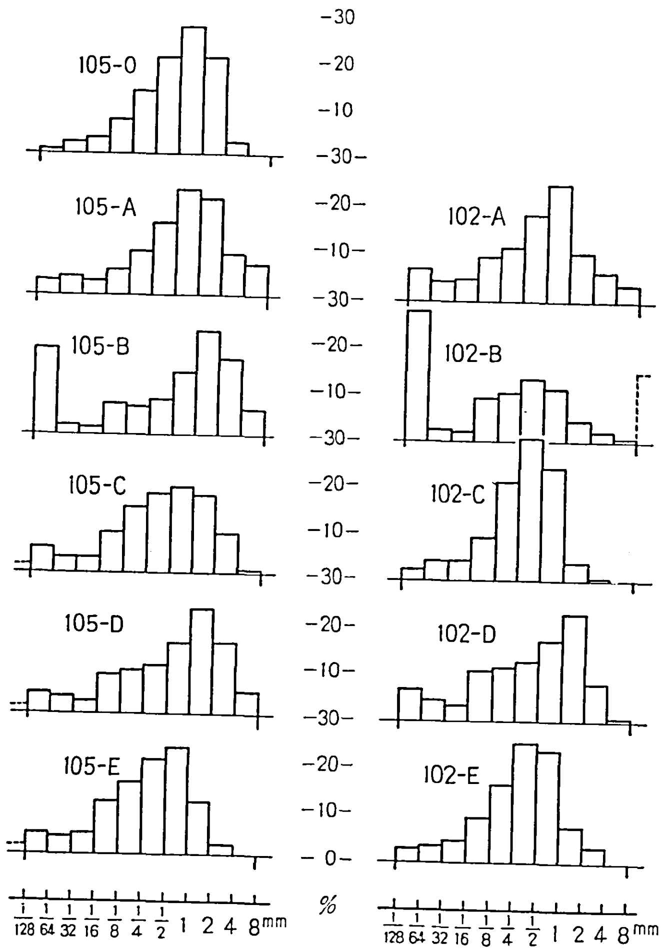

Fig. 24. Size distribution of the clayey beds from Myôjin, Ochiai village (105) and Akama, Imaichi town (102).

soil, however, is different in type of size distribution from other beds: abundance of the particles in the fraction 1/128–1/64 *mm* is conspicuous; the coarser particles ($>$ 8 *mm*) are also abundant in the soil from Akama (102–B). The finer particles ($<$ 1/128 *mm*) are lacking in the overlying O, A, and B beds and are contained in the underlying C, D, and E beds.

(6) Other physical properties of the clayey beds:

Bulk specific gravities were measured about each bed in the field *in situ*: a steel tube whose inner volume and weight are known is inserted into the soil in question; weighing the included soil with the tube, bulk specific gravity of the soil was calculated. The bulk specific gravities thus obtained are 0.9 for the surface humus soil and the yellow pumice and 1.2-1.4 for other beds (Table VII). The specific gravity of the white clay determined by means of pycnometer was 2.13. Weights of the specimens of these clayey beds were measured at the field soon after collection. Then their water contents were obtained in the laboratory from loss of heating at 150°C. Their values are enumerated in the same table (Table VII) with those represented by volume percentage which are calculated form the former being compared with bulk specific gravities. The white clay shows the maximum value 80%. Water absorption of the air-dryed specimens was measured in the laboratory, and the results are shown in Table VIII. The white clay of 100 *cc* may absorb 156.2 *cc* water.

Table VII.

Spec. No.	Bulk sp. gr.	Water content	
		wt%	vol%
102-A	1.42	46.03	65.36
102-B	0.98	68.10	66.74
102-Cl	1.49	46.20	68.84
102-Du	1.33	66.84	88.90
102-Dl	1.28	57.85	74.05
102-Eu	1.42	53.48	75.94
105-O	0.99	63.70	63.06
105-A	1.23	52.57	64.66
105-B	0.84	58.57	49.20
105-C	1.22	43.67	53.28
105-D	1.26	59.77	75.31
105-E	1.31	52.56	68.85

u: upper portion in a bed, l: lower portion.

Table VIII.

	wt. %	vol. %
105-A	75	92
105-B	139	117
105-C	77	94
105-D	124	156
105-E	87	114

V. Summary and conclusions

On the morning of December 26, 1949 at 08*h*18*m* and 08*h*26*m* successively, the town of Imaichi and its environs, Tochigi Prefecture, about 100 *km* north of Tokyo was struck by severe earthquakes followed by the numerous aftershocks with shallow foci. Many changes of the surface were brought about, among which the earthfalls and landslips on the area covered with thick Pleistocene formation of volcanic origin were most conspicuous. The surface humus soil, yellow pumice bed (Kanuma soil), and reddish brown pumice bed (Imaichi soil), the upper members of the Pleistocene formation in this area consist mainly of volcanic glass and allophane. Brownish loam and white clay, the lower members are composed mainly of lower crystalline hydrated halloysites and the latter is most enriched in the same clay mineral. This white greasy clay played an important *rôle* in the surface changes as a slipping plane of the landslips.

In conclusion, the writers express their cordial thanks to Prof. Toshio Sudo of the Tokyo University of Education for his kind instructions relating to this study. Their thanks are also due to Dr. Hiroshi Takahashi of the Department of Chemistry of the Tokyo University for his gift of photographs, and to Mr. Kenji Uchida of the Kôyô Co. for his kind assistance during the grain size analyses. A part of the expenses necessary for this study have been defrayed from the funds for Scientific Researches of the Ministry of Education, for which the authors here express their gratitude.

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18. 今市地震地域の地質 (3)

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小坂丈予
福田知子

昭和 24 年 12 月 26 日午前 8 時 18 分と 26 分に続いて起きた地震にともなつて，栃木県上都賀郡今市町 [現在今市市] を中心とする大約 20 km 四方の地域に地変を生じたが，そのうちでも火山噴出物起源の洪積層分布地域に生じた地崩れと地辷りが，ことに著しかつた．[地震研究所彙報 28 号 (昭和 25 年)，379-386 頁，同 29 号 (昭和 26 年)，349-358 頁]．この第 3 報では，その存在が地変を生じた素因の一つとなつた洪積世の火山噴出物の各堆積層——上より (O) 表土層・(A) 黄色浮石層 (鹿沼土層)・(B) 赤褐色浮石層 (今市土層)・(C) 上部ローム層・(D) 白粘土層・(E) 下部ローム層——の主体をなす火山玻璃の風化生成物である粘土の鉱物組成，化学成分などについて研

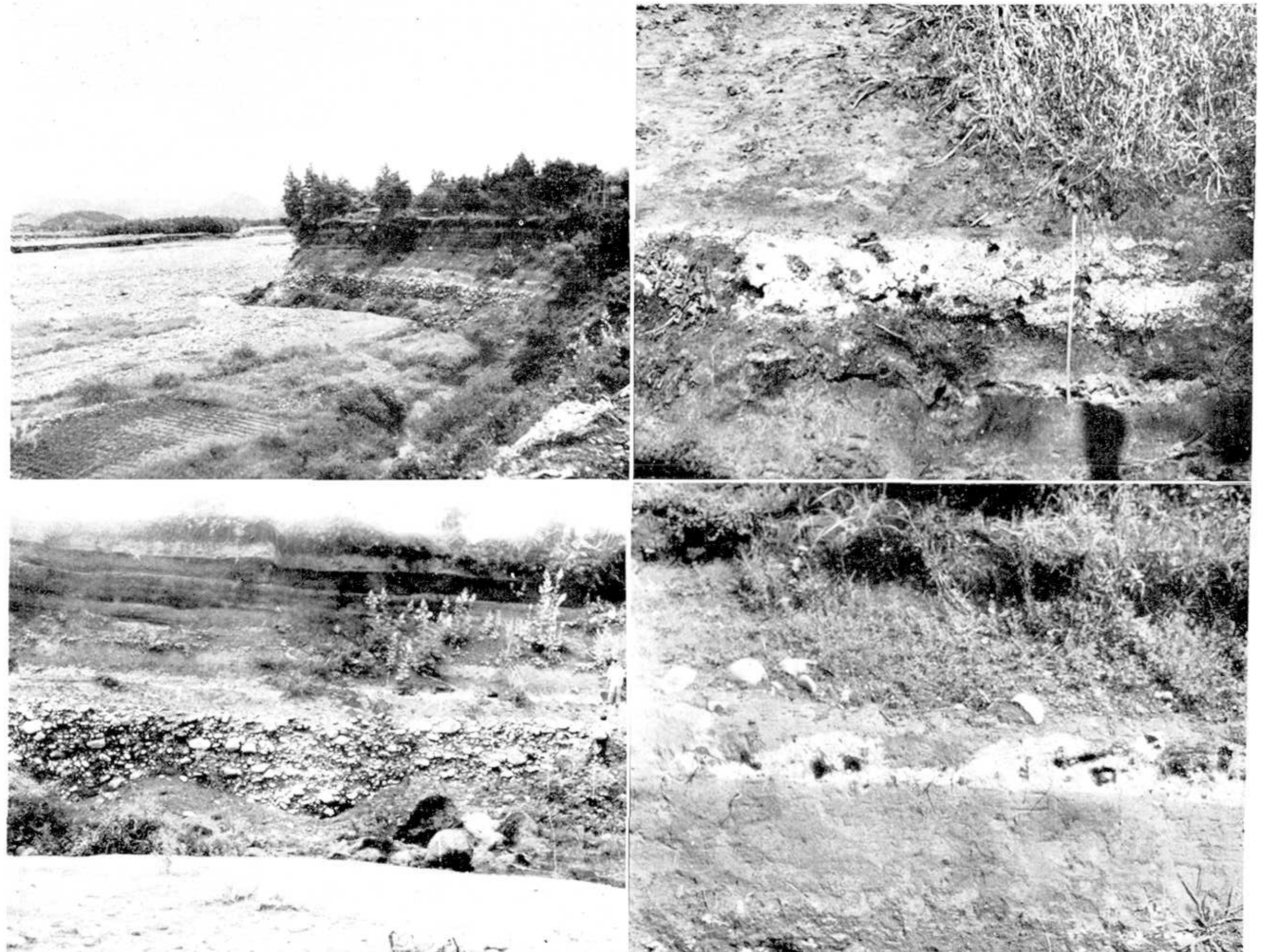


Fig. 25 (Upper left). Pleistocene beds exposed along the River Daiya observed at Akama or Shichihonzakura, Imaichi, Tochigi Pref. The pumice or ash beds are underlaid by gravel and sandy beds. Fig. 26 (Lower left). Closed view of the above figure. Fig. 27 (Upper right). A bed of white clay intercalating in loamy beds, at the cliff exposed along the road from Itabashi to Osawa, Ochiai village. Fig. 28 (Lower right). Ditto at Myojin, Ochiai village.

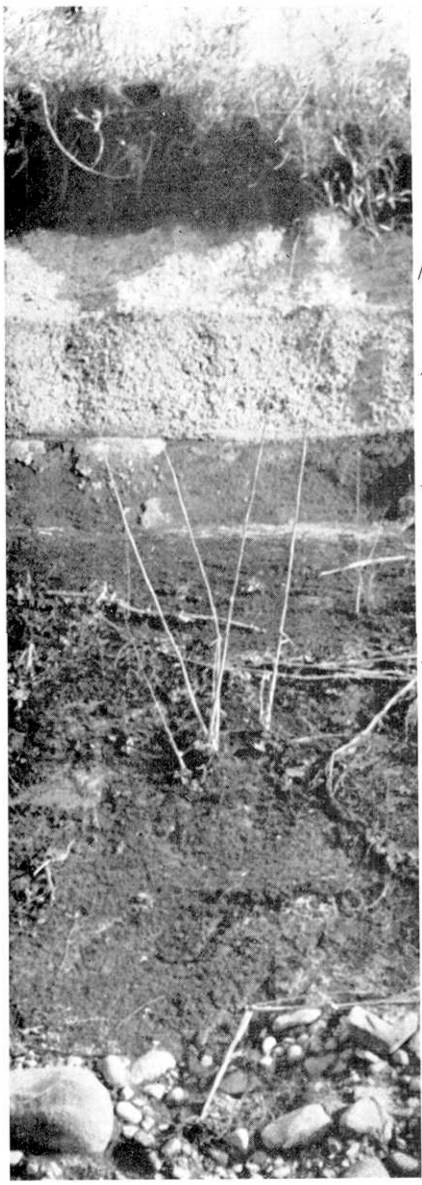
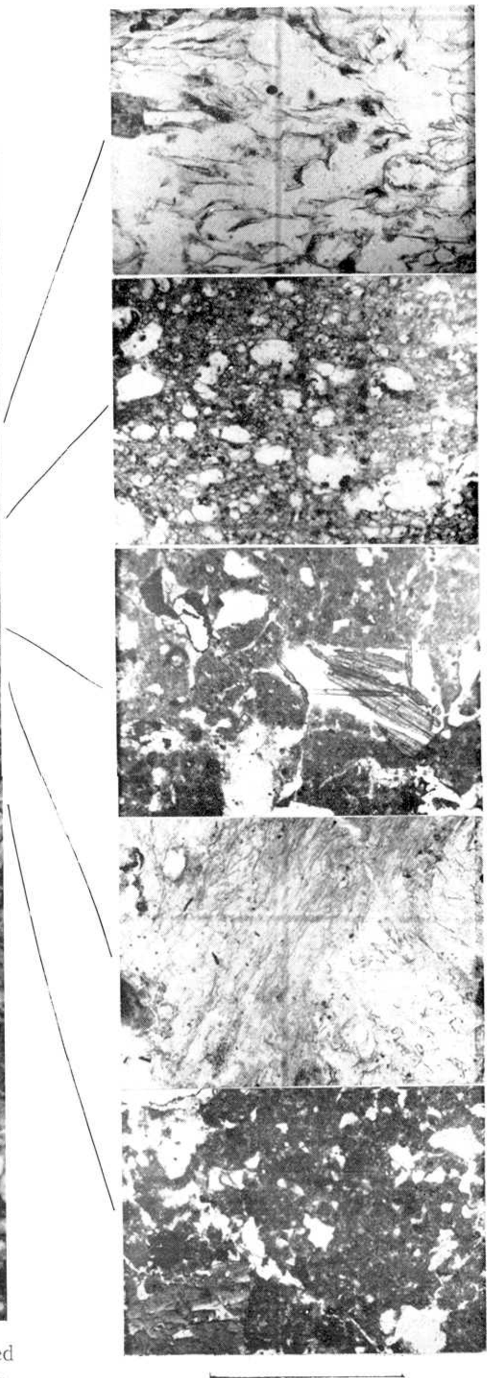
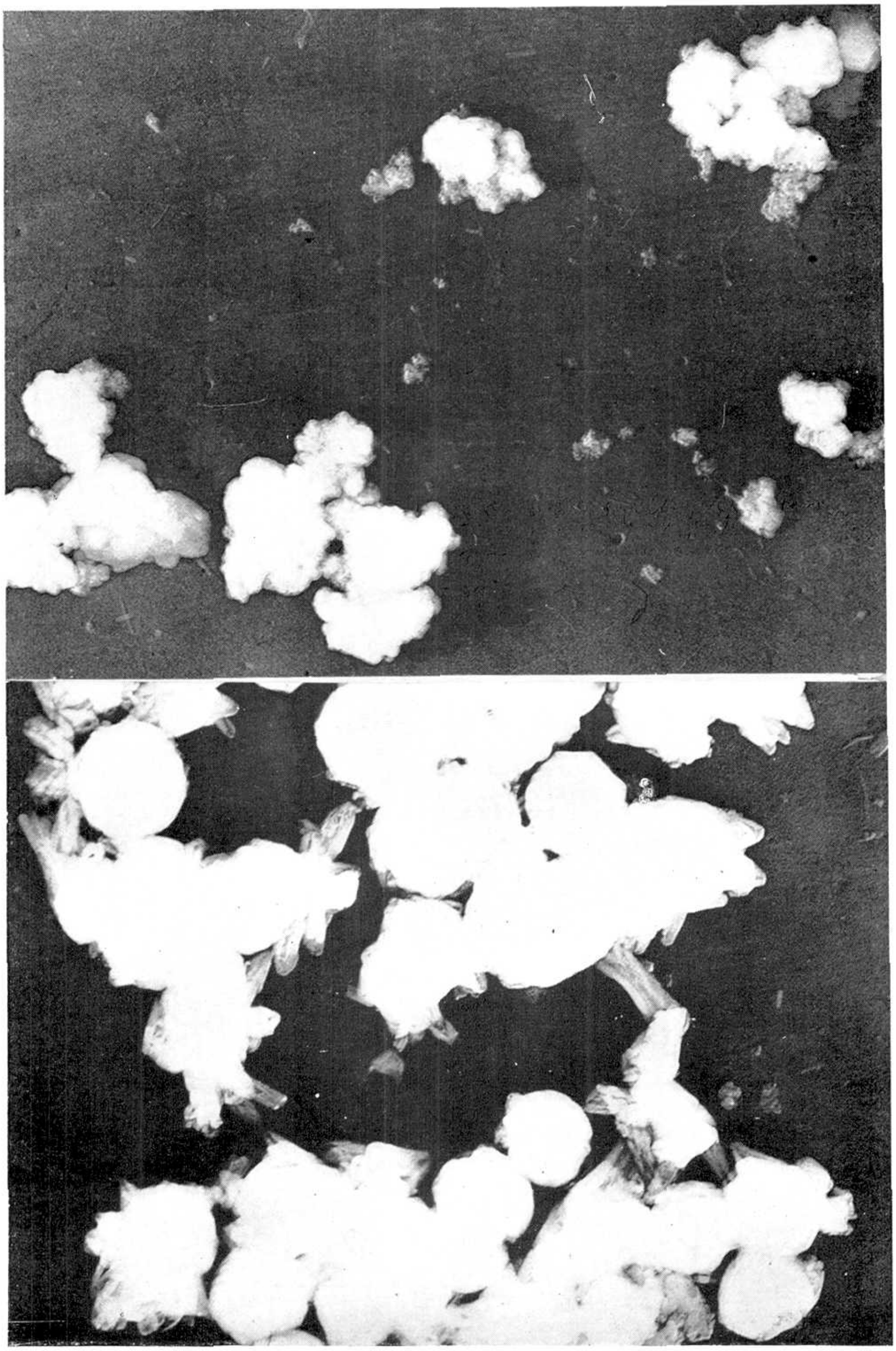


Fig. 29. Pumice or ash beds exposed at the cliff along the River Daiya, Akama, Imaichi.
O: Surface humus soil, A: Yellow pumice bed, B: Reddish brown pumice bed (Imaichi soil), C: Upper Loam, D: White clay bed, E: Lower Loam.



1 *mm*

Fig. 30. Microphotographs of the specimens collected from the beds photographed in Fig. 29. Polarizer only × about 40.



1 μ

Fig. 31. Electronmicrographs of the Imaichi soil (above) and of the white clay (below) from Myojin, Ochiai village. Photo. by Dr. H. Takahashi.

（震研彙報 第三十五号 図版 森本・小坂・福田）

究を行つた．各試料の微細な部分について X 線分析・示差熱分析・熱減量測定・化学分析を，また原土について粒度分析・比重・含水量・吸水率の測定などの結果を報告した [第 I-VIII 表]．これによると上層の表土層・鹿沼土層・今市土層はまだ再結晶の進まないアロフェンによつて，上部ローム層・白粘土層・下部ローム層などの下部層は再結晶度の低い加水ハロイサイトによつて代表されているが，そのうちでも白粘土層は，とくに多量の加水ハロイサイトを含んでいると考えられる．なおこれらの火山噴出物起源堆積層は，原岩の構造をよく残しているが，火山玻璃の部分は化学的にはきわめて変化が進んでいる．すなわち SiO_2 はいちぢるしく減少し，これに引きかえて Al_2O_3 の富む結果となり，また 1，2 の層では CaO が，いくつかの層では MgO がわづかにその一部を残して，大部分が失われ，Na_2O，K_2O はほとんど完全に溶脱していた．この結果，鉄の過剰な今市土層を除く他の各層の $Al_2O_3+Fe_2O_3$ と SiO_2 との比はいずれも 1:2 となつている．とくに加水ハロイサイトを多量に含む白粘土層は，その含水率，吸水能ともに最大の値を示し，地変に際しその地辷り面となつた．