9 Å Mineral Included in the Weathered Biotite

By

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with 2 Tables, 4 Text-figures and 1 Plate

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ABSTRACT: A mineral species revealing the basal reflection at about 9 Å was found in some flakes of the altered biotite collected from the weathered granite cropping out in the vicinity of Hiroshima City and mineralogically investigated in detail.

CONTENTS

I. INTRODUCTION

A mineral species with the basal reflection at about 9 Å (9.03~9.17 Å), found in some flakes of the altered biotite contained in the weathered granite, is named 9 Å mineral in the present paper. The mineral concerned also reveals the spacing at about 4.5 Å corresponding to the second order reflection but none of those higher than the second and seems to be constructed of a sort of layer structure. In some specimens with the intense reflection at 10 Å, the spacing at 9 Å is concealed with the former or emerges as its shoulder and merely recognizable through collapsing or disappearing of the former after treatment with dil. HCl for about half an hour. From the value of the basal spacing 9 Å mineral is inferable a species of pyrophyllite–talc group excepting a difference in lack of the third order reflection and the data for the structure factor calculated suggest a possibility of assumption that in its structure the Si–O tetrahedra lie alternately on the side opposite to those in the structure of kaolinite.

According to the studies concerned with the weathering of biotite by KANNO, HONJO and ARIMURA (1960), WILSON (1966), TSUZUKI, NAGASAWA and ISOBE (1968) and others, expansion of the interlayers with hydration is considered to result in transformation of biotite into vermiculite and hydrobiotite and finally into kaolinite and gibbsite etc. In the present work related to alteration of the weathered biotite in the coarse-grained granite grouped generally into the Hiroshima-type, a species of 9 Å mineral found included in some flakes is dealt with in detail with addition of some data obtained recently to the previous ones given briefly by KAKITANI and KOHNO (1972).

II. Experiments and Results

The specimens collected from a part of the weathered granite exposing in some places shown in Fig. 1. were provided for inspection through X-ray and electron diffraction.

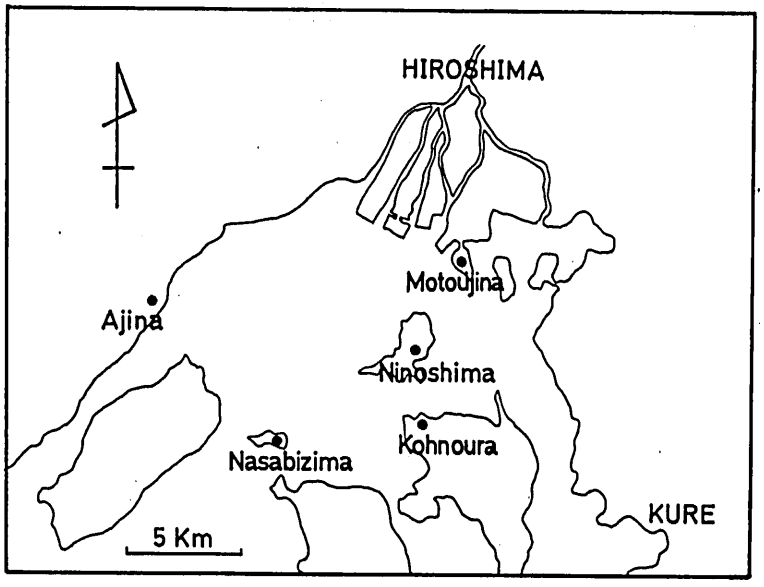

Fig. 1. Locality map

A. Results of X-ray diffraction

The X-ray diffraction patterns for some natural specimens numbered Na–1, Ko–1, Hi–1, Hi–2, Mu–1, Az–1 and Az–2 and those treated respectively with 1~6 N HCl are represented in Fig. 2, showing the presence or at least the trace of the secondary minerals such as vermiculite, kaolinite and 9 Å mineral etc. other than the original biotite.

The untreated specimens of Ko–1, Az–1 and Az–2 respectively indicate the isolated peak at about 9 Å and those of Na–1, Hi–1, Hi–2 and Mu–1 the shoulder on the side lower than the peak at 10 Å. In case of the latters treated with dil. HCl the peaks at 14 Å and 10 Å collapse or disappear and those at 9 Å become distinguishable. With conc. HCl treatment the peaks at 10 Å, 9 Å and 4.5 Å disappear or strongly collapse and those at 9 Å and 4.5 Å are considered to be related to a single kind of mineral.

The specimens without the spacing at 10 Å for biotite and at 14 Å for vermiculite but with the remainder of those for kaolinite after treatment with dil. HCl were heated at the temperatures increased per 100°C for an hour in pursuit of the behaviour of 9 Å mineral. Inspection of X-ray diffraction patterns obtained for the heated specimens clearly shows that the spacing at 9 Å does not collapse up to 300°C, diminishes a little at 400°C and markedly indicates the weakening and broadening at 500°C but that at 4.5 Å is kept a little in sharpness and that for kaolinite disappears at 500°C, culminating in the complete downfall of the spacings for 9 Å mineral at 600°C, as is conspicuous in Fig. 3. Such a behaviour of breakdown as is revealed in the crystal structure of 9 Å

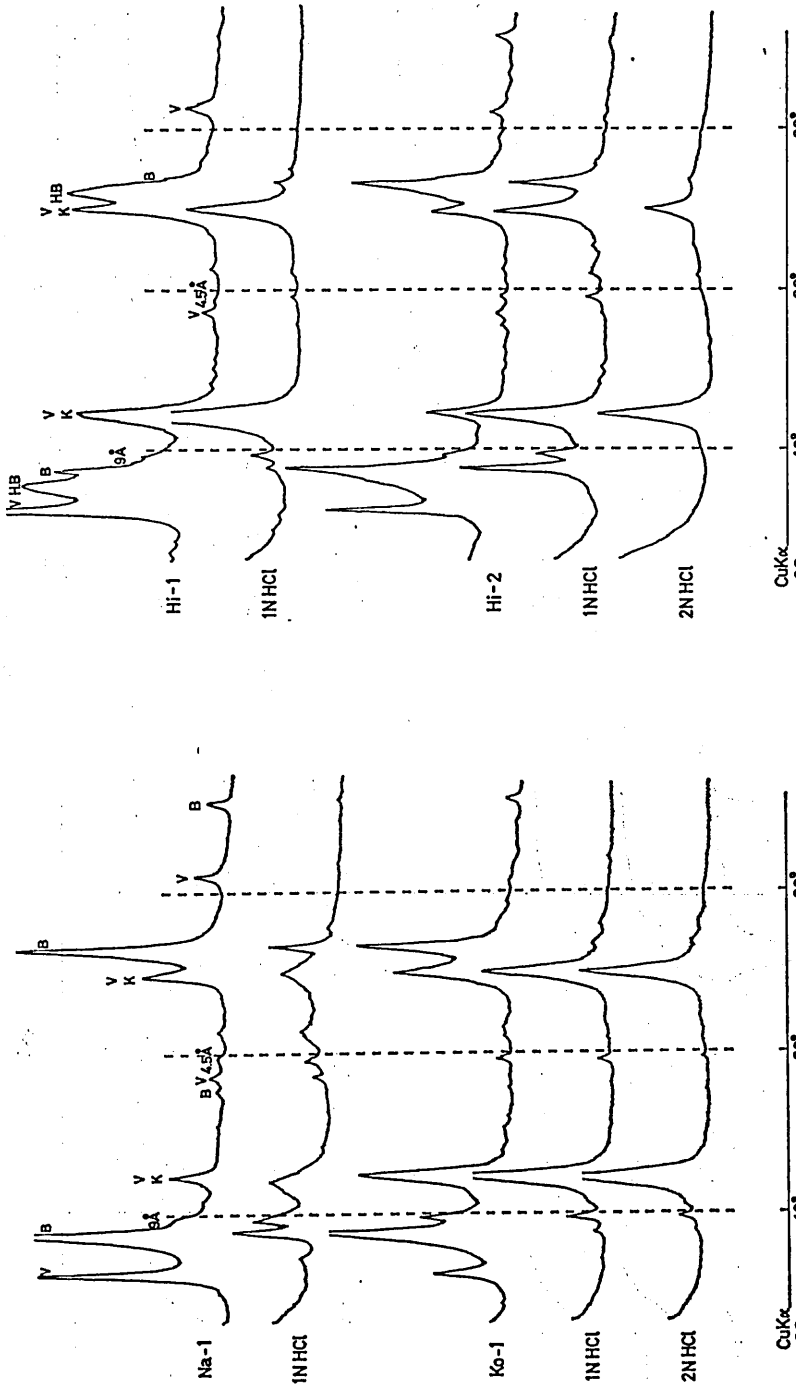

Fig. 2-a. X-ray diffraction patterns for the specimens from Nasabijima (Na-1), Kohnoura (Ko-1) and Hijiyama (Hi-1, Hi-2)
V: vermiculite, H.B: hydrobiotite, B: biotite, K: kaolinite

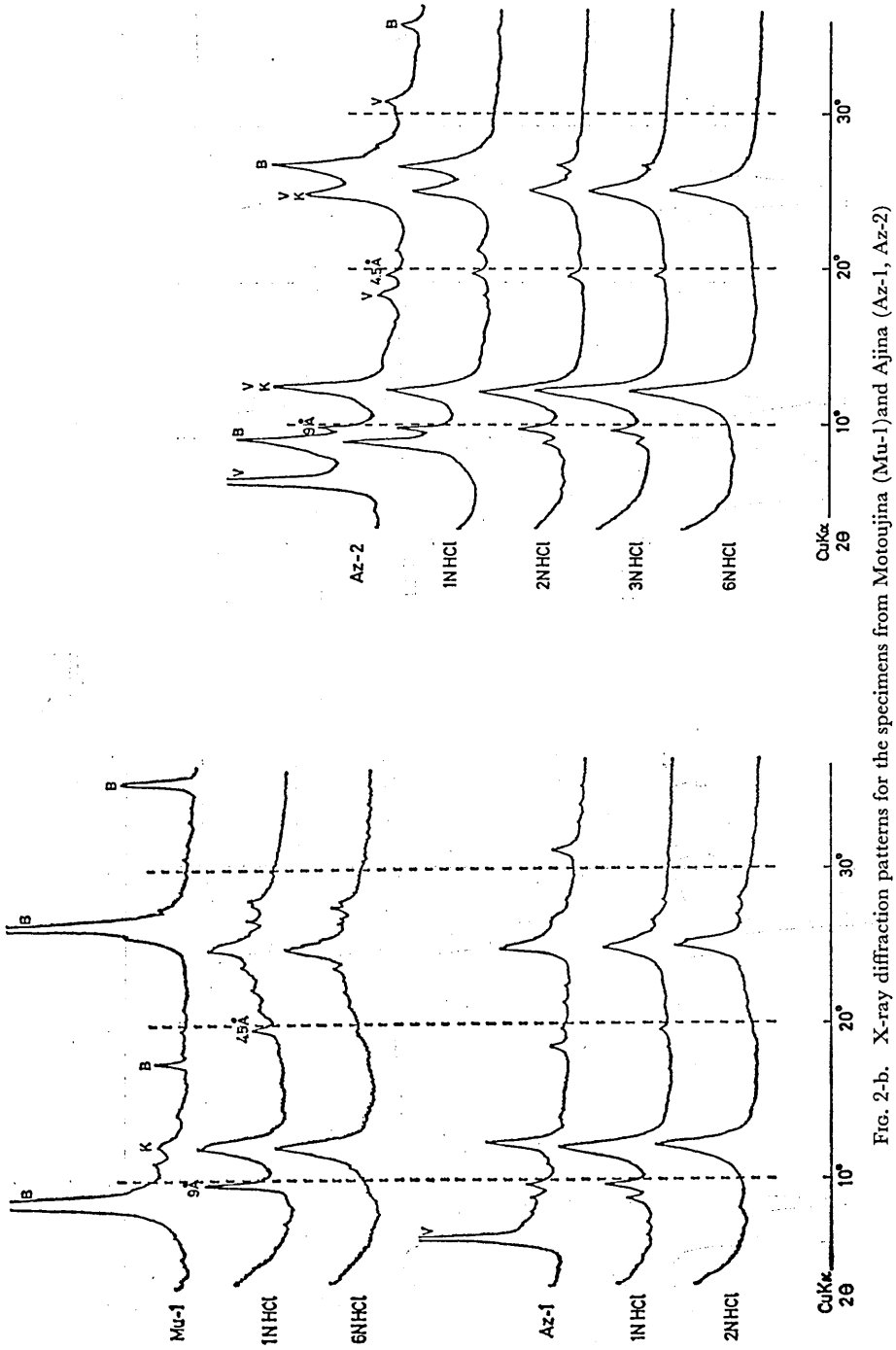

Fig. 2-b. X-ray diffraction patterns for the specimens from Motoujina (Mu-1)and Ajina (Az-1, Az-2)

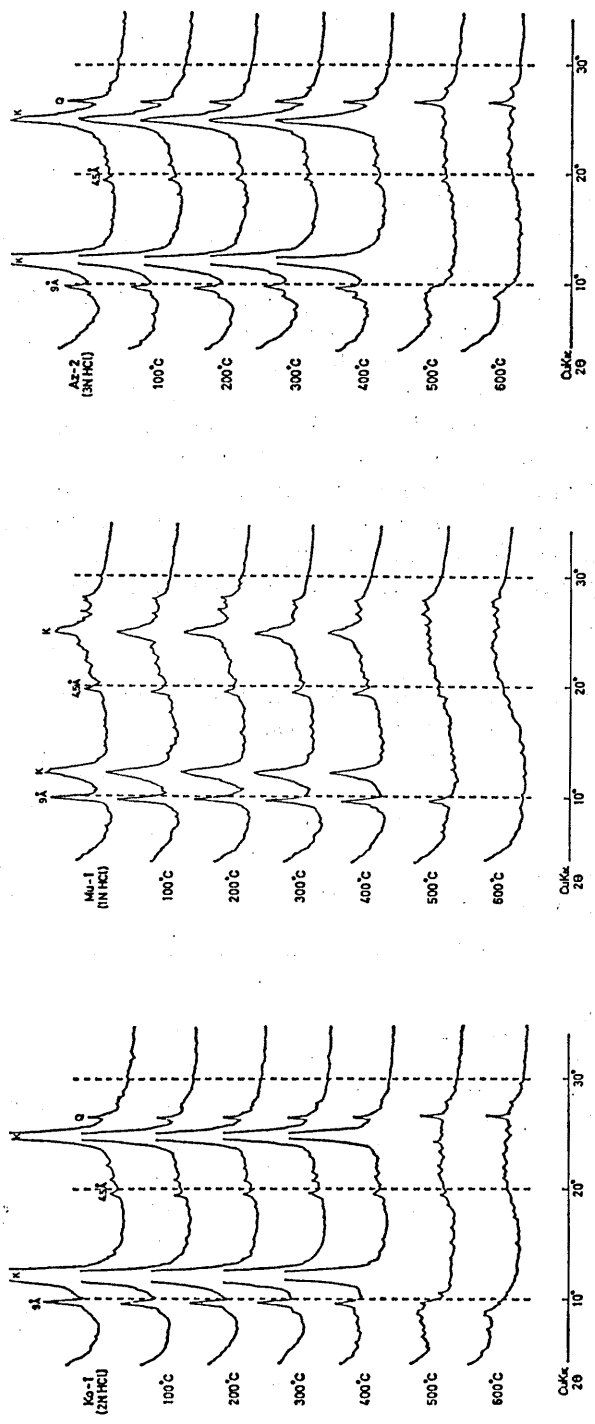

FIG. 3. X-ray diffraction patterns for the heated specimens

mineral through heating at 600°C seems analogous in case of kaolinite.

B. Results of Electron Diffraction

According to BRINDLEY and KIMPE (1961) the electron diffraction method for evaluating *b* parameter makes it possible to decide whether the clay minerals in question may be of dioctahedral or trioctahedral type. The present writers also tried to determine the type of the mineral under consideration by the same means. The specimen Mu-1 with the strongest peak at 9 Å in association with that at 7 Å of kaolinite was subjected to the experiments and that composed merely of kaolinite after treatment with 6N HCl was at the same time scrutinized for clarifying its own effect. Aluminum metal was involved for the internal standard in each experiment.

The electron diffraction patterns and the related photomicrographs of two specimens Mu-1 after treatment with 1N and 6N HCl are shown in Plate 1. The observed values of *b* parameter are, as are shown in Table 1, dividable into two groups: one is of dioctahedral type, corresponding to kaolinite with 8.961 Å and the other is of trioctahedral one, probably corresponding to 9 Å mineral with 9.222 Å. However, these two types happen to be recognized even only in kaolinite confirmed through X-ray method, suggesting the remaining of the original biotite. Accordingly it was impossible from the present data to decide clearly whether 9 Å mineral in question may be dioctahedral or trioctahedral in type.

Table 1. The Values of *b* parameter for the Specimen Mu-1 after Treatment with 1 N and 6 N HCl

	specimens	b in Å	
		1	2
a	Mu-1 (treated with 1 N HCl)	8.969	9.221
		8.976	9.249
		8.976	9.223
		8.964	9.214
	Mu-1 (treated with 6 N HCl)	8.927	
		8.931	
		8.987	
		8.955	9.202
	average	8.961	9.222
b	kaolinite	8.946	
	dickite	8.945	
	nacrite	8.935	
	muscovite	9.000	
	biotite		9.240
	chlorite		9.200

a: obtained by the present authors
b: given by BRINDLEY and KIMPE (1961)
1: dioctahedral type
2: trioctahedral type

III. Calculation of the Structure Factor and Consideration

From the values of the basal spacing 9 Å mineral under consideration is considered a mineral species characterized by three-layer structure of the pyrophyllite–talc type. On the basis of the ideal models of their crystal structures the structure factors of pyrophyllite, talc and the completely dehydrated phase of vermiculite as well as the theoretical values for intensity of the basal reflection are calculated. The calculated values for intensity of the oriented and randomly distributed specimens in association with the data given by some authors are shown in Table 2. It is however to be noted that the oriented specimens were used in the present work. Such patterns that, as is obvious in

Table 2. Values of the Structure Factor and Calculated Intensity for some minerals

specimens	00*l*	$\|F\|$	$\|F\|^2$	I_0	I_r	I^*
pyrophyllite	001	35.6	1335.6	36	100	40
$Al_4[Si_8O_{20}](OH)_4$	002	47.4	2250.6	29	41	13
	003	111.1	12345.1	100	94	100
	004	36.5	1332.7	8	5	25
talc	001	54.6	3177.2	63	100	70
$Mg_6[Si_8O_{20}](OH)_4$	002	28.0	782.9	8	6	10
	003	128.4	16478.5	100	53	70
	004	20.9	437.1	2	1	
9 Å phase of vermiculite	001	20.3	412.0	12	36	
$Mg_{0.7}Al_4[(Si, Al)_8O_{20}](OH)_4$	002	38.4	1475.4	21	31	
dioctahedral	003	106.0	11232.0	100	100	
	004	49.8	2478.8	15	11	
9 Å phase of vermiculite	001	40.1	1609.5	35	100	8
$Mg_{0.7}Mg_6[(Si, Al)_8O_{20}](OH)_4$	002	19.0	359.1	4	5	2
trioctahedral	003	123.2	15188.4	100	96	10
	004	34.2	1168.8	6	4	
9 Å mineral in question	001	75.5	5695.2	100	100	
$Al_4[Si_4O_8](OH)_{12}$	002	66.8	4465.4	38	19	
dioctahedral	003	39.5	1560.1	8	3	
	004	63.9	4087.5	15	4	
9 Å mineral in question	001	89.1	7941.7	100	100	
$Mg_6[Si_4O_8](OH)_{12}$	002	78.8	6203.1	38	19	
trioctahedral	003	55.9	3129.1	12	4	
	004	49.6	6217.0	7	2	

note: The values of intensity were derived

$$I_0 = |F|^2 \times \frac{1+\cos^2 2\theta}{\sin 2\theta} \quad \text{(oriented)}$$

$$I_r = |F|^2 \times \frac{1+\cos^2 2\theta}{\sin^2\theta\cos\theta} \quad \text{(random)}$$

I^*: observed intensity after Brindley (1951) and Brown (1961)

this table, the pyrophyllite–talc-like minerals with the three-layer structure manifest the remarkable reflection of the third order are noticeably different from those of 9 Å mineral. Their behaviour disappearing with heating at 600°C seems to be similar to that of kaolinite and their structures may be constructed of more content of OH compared with the pyrophyllite–talc group, as is presented in Fig. 4(a). The structure concerned is also analogous to that of halloysite proposed by EDELMAN and FAVEJEE (1940). To

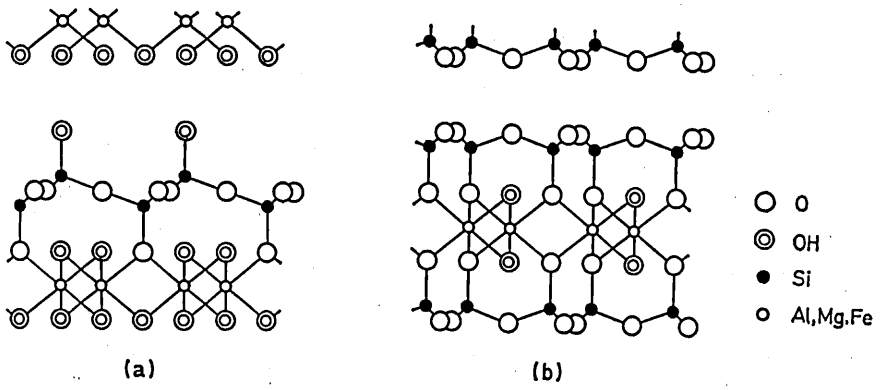

FIG. 4. Structure of 9 Å mineral illustrated schematically along *a* axis
(a) Assumed structure for 9 Å mineral
(b) Pyrophyllite–talc mineral

be noted is that the structure factor of the third order reflection related to such a structure with more amount of OH is considerably smaller than in case of those for pyrophyllite–talc group and the ratio of 001 to 002 in the calculated values of reflection intensity is in good concordance with that in the observed ones.

IV. SUMMARY

A mineral species contained in some flakes of the weathered biotite indicate the considerably sharp patterns of reflection at about 9 Å and 4.5 Å and characterized by absence of the third order reflection appearing conspicuously in cases of the pyrophyllite–talc group and analogy to kaolinite collapsing with heating at 600°C. The values estimated for its structure factor suggest that the structure assumed for the mineral in question resembles that of halloysite after EDELMAN and FAVEJEE and in consequence the Si–O tetrahedra in the kaolinite layer are considered to lie alternately on the opposite side.

REFERENCES

BRINDLEY G. W. (1951): X-ray identification and crystal structures of clay minerals, *Mineralogical Society, London*, Chap. VII, 220.

——— and KIMPE C. D. (1961): Identification of clay minerals by single crystal electron diffraction, *Amer. Miner.*, **46**, 1005–1016.

BROWN G. (1961): X-ray identification and crystal structures of clay minerals, *Mineralogical Society*, London, Chap. XIII, 475.

EDELMAN C. H. and FAVEJEE J. C. L. (1940): On the crystal structure of montmorillonite and halloysite, *Zeit. Krist.*, **102**, 417–431.

KAKITANI S. and KOHNO T. (1972): On the alteration of biotite in weathered granite (in Japanese), *Jour. Clay Sci. Soc. Japan*, **12**, 51–62.

KANNO I., HONJO Y. and ARIMURA S. (1960): Weathering of biotite in red-yellow soils derived from granite (in Japanese), *Advances in Clay Science*, **2**, 217–228.

TSUZUKI Y., NAGASAWA K. and ISOBE K. (1968): Weathered biotite from Matsuzaka, Central Japan, *Miner. Jour.*, **5**, 365–382.

WILSON M. J. (1966): The weathering of biotite in some Aberdeenshire soils, *Miner. Mag.*, **35**, 1080–1093.

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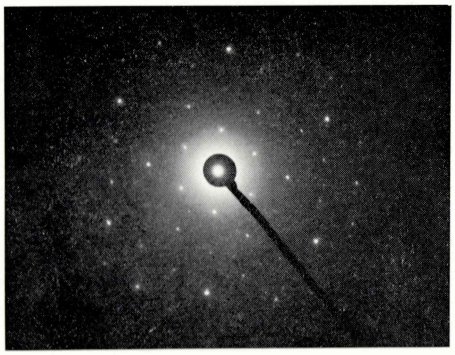
EXPLANATION OF PLATE VIII

Electron diffraction patterns with calibration rings of Al metal and electron micrographs of Mu–1 specimen

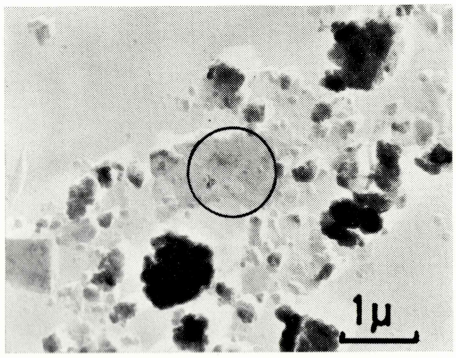
1–a and 1–b: treated with 1 N HCl

2–a and 2–b: treated with 6 N HCl

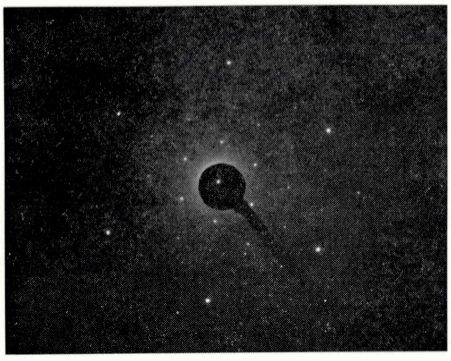
Remarks: Double spots representing kaolinite (lager-one on the outer side) and probably 9 Å mineral (smaller-one on the inner side) are observable in 1–a



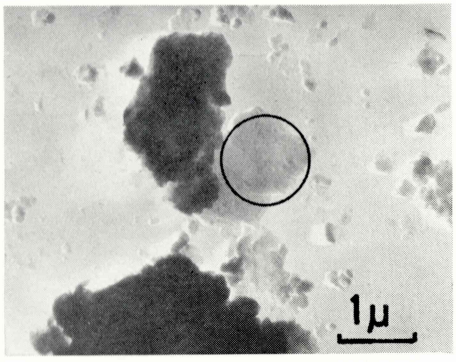
1–a



1–b



2–a



2–b