

Fe²⁺, Co, Ni, Zn and Cu analogues of berzeliite failed under the corresponding conditions. The products all came out as minerals of the adelite group, namely conichalcite CaCuAsO₄, austinite CaZnAsO₄, and the Fe²⁺, Co and Ni analogues of adelite, CaFeAsO₄, CaCoAsO₄ and CaNiAsO₄. Adelite occurs frequently in the localities where berzeliite is found. The absence of Fe²⁺-berzeliite in nature may not necessarily be due to the low concentration of Fe²⁺ ions in the environment, as was suspected by Blix and Wickman (1959).

The synthesis of berzeliite in air was not achieved. The starting materials for Mg berzeliite did not react in air up to around 800°C. An unidentified single phase was obtained by heating these starting materials at 900°C.

ACKNOWLEDGMENTS

The writer is indebted to Professor Clifford Frondel of Harvard University for his support and guidance, and Professor Frans E. Wickman of Pennsylvania State University for many helpful discussions and suggestions during this work. Thanks are also due to Mr. H. S. Peiser, Mr. Harry Parker and Mr. Williams S. Brower for assisting in the preparation of the manuscript.

This work was in part supported under U. S. Advanced Research Project Agency Grant SD-88.

REFERENCES

- BLIX, RAGNER AND FRANS E. WICKMAN (1959) A contribution to the knowledge of the mineral berzeliite. *Ark. Mineral. Geol.* **2**, 417-424.
- MACHATSCHKI, FELIX (1930). Berzeliite, ein Arsenate vom Formel und Strukturtypus Garnet (X₃Y₂Z₃O₁₂). *Z. Kristallogr.* **73**, 123-140.

THE AMERICAN MINERALOGIST, VOL. 53, JANUARY-FEBRUARY, 1968

AN ELECTRON MICROSCOPIC STUDY OF SOIL ALLOPHANE WITH AN ORDERED STRUCTURE

N. YOSHINAGA, *Faculty of Agriculture, Ehime University, Matsuyama, Japan* AND H. YOTSUMOTO AND K. IBE, *Japan Electron Optics Laboratory Company, Ltd., Tokyo, Japan.*

Allophane is known to possess different degrees of structural order. In the course of a study of soil allophane, Yoshinaga and Aomine (1962a, b) separated a low crystalline clay component, which they called "imogolite," from some volcanic ash soils. It was differentiated from coexisting X-ray amorphous component, "allophane," with a similar chemical composition (SiO₂/Al₂O₃ ≐ 1) in the following points: In an air-dry state, its parallel orientation specimen exhibited broad and relatively intense X-ray diffraction bands at about 14.5 Å and 7.5 Å and a weak one at

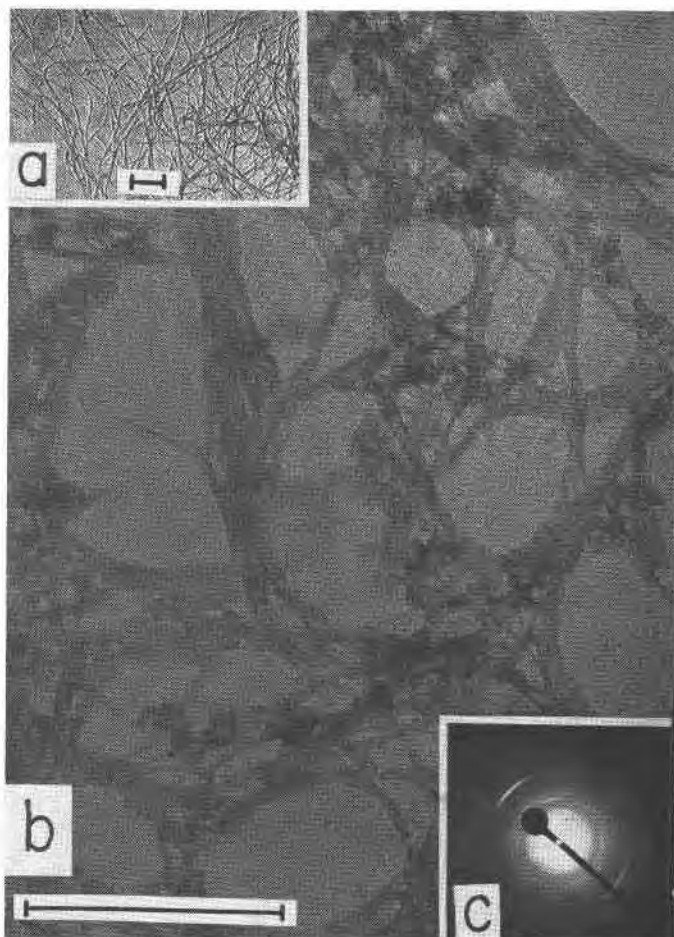


FIG. 1. Electron micrographs and electron diffraction pattern of "imogolite" from Uemura. Lines indicate 0.2μ . (a) Shadowed with Cr at an angle of 30° .

about 5.5 \AA . Upon heating at 100 to 300°C , a very strong and sharp diffraction peak developed at about 18 \AA from the first broad diffraction band. In the electron microscope, it appeared as well-defined threads of diameter 100 to 200 \AA (Fig. 1a). These attributes together with other data in DTA and infrared spectroscopy have been interpreted as indicating that "imogolite" has a more ordered structure than "allophane" (Yoshinaga and Aomine, 1962b; Aomine and Miyauchi, 1965; Miyauchi and Aomine, 1966; Wada, 1966; 1967). Although the use of the name "imogolite" as a distinct mineral species has been disapproved (Fleischer, 1963), it is used here only for convenience and tentatively, as a variety

name, to denote a component in soil allophane showing the characteristics described above.

In the present study, two "imogolite" specimens were examined at a high magnification using a JEM-7A electron microscope. The Uemura specimen was separated and dispersed from a glassy volcanic ash soil (Lab. No. 905) as described by Yoshinaga and Aomine (1962a, b), and the Kitakami specimen (Miyachi and Aomine, 1966), a gel film, was separated by hand-picking from the Kitakami pumice bed. Dispersion of the latter specimen for electron microscopy was effected by ultrasonic treatment (400kc, 10 min.).

"Imogolite" appeared at 210,000 \times magnification as shown in Figures

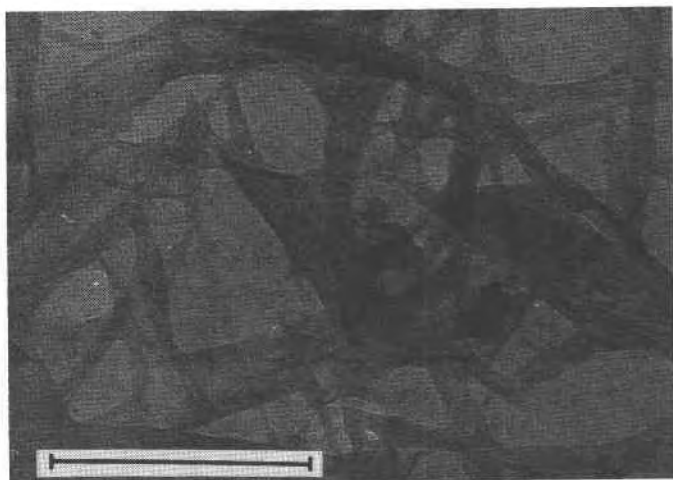


FIG. 2. Electron micrograph of "imogolite" from Kitakami. Line indicates 0.2 μ .

1b and 2, where a fiber structure unit is clearly seen in the respective threads. The individual units are about 18 to 20 \AA wide and several hundreds to thousands \AA long, aligning in parallel to each other. The width of the unit coincides approximately with the longest spacing in the X-ray diffraction analysis. This coincidence is important in indicating that the stacking of the fiber structure units causes the sharp and strong diffraction at about 18 \AA . The presence of a chain structure unit of about the same size in "imogolite" has recently been proposed by Wada (1967) on the basis of analysis of chemical, X-ray, and infrared spectroscopic data and electron micrographs obtained so far.

Electron diffraction of a selected area including threads aligned in parallel (*ca.* 0.5 \times 0.5 μ) yielded a powder diffraction pattern with considerable arcing of the reflections (Fig. 1c) due to preferred orientation of

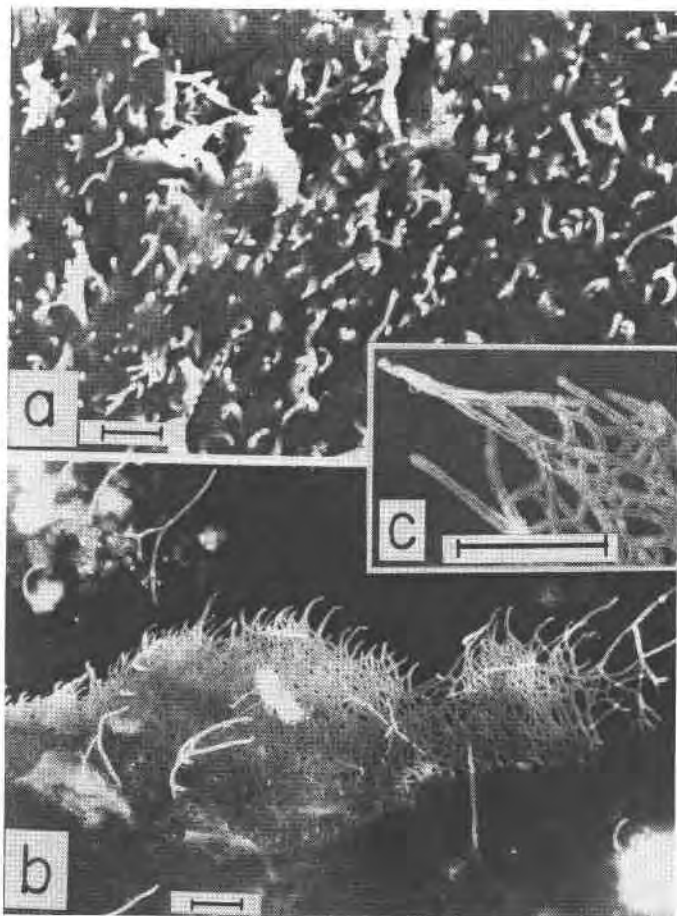


FIG. 3. One-stage carbon replicas of gel film from Kitakami. Lines indicate 1μ . (a) Protrusion of thread-ends, and (b) splitting of planar net of threads, from gel surface. (c) A part of the net enlarged.

the fiber structure units. The d -value of the diffraction lines, 7.7, 5.7, 4.15, 3.75, 3.28, 2.30, 2.10, and 1.41 \AA , coincides well with that of the X-ray powder lines (Yoshinaga and Aomine, 1962b).

The replica of the Kitakami gel film in Figure 3 shows conclusively that the threads exist as such in the film. The replica was prepared by casting carbon at an angle of 30 to 40° on a desiccated gel film on a glass slide and by dissolving the gel film in hydrofluoric acid. The ends of numerous threads protruding from the surface can be seen in Figure 3a. The threads show a fairly uniform size distribution, about $1,000 \text{ \AA}$, in diameter (Fig. 3b). A possibility of build up of a carbon structure around

the threads during replication (Fig. 3c), however, makes the estimation of their exact size difficult. Figure 3b illustrates also a planar net structure of threads splitting from the surface. The presence of such a net structure may account for the filmy appearance of the gel.

The authors wish to thank Dr. Koji Wada of Kyushu University for many helpful suggestions and for reading the manuscript.

REFERENCES

- AOMINE, S. AND N. MIYAUCHI (1965) Imogolite in Imogo-layers in Kyushu. *Soil Sci. Pl. Nutr. (Tokyo)* 11, 212-219.
- FLEISCHER, M. (1963) New mineral names. *Amer. Mineral.* 48, 434.
- MIYAUCHI, N. AND S. AOMINE (1966) Mineralogy of gel-like substance in the pumice bed in Kanuma and Kitakami districts. *Soil Sci. Pl. Nutr. (Tokyo)* 12, 187-190.
- WADA, K. (1966) Deuterium exchange of hydroxyl groups of allophane. *Soil Sci. Pl. Nutr. (Tokyo)* 12, 176-182.
- WADA, K. (1967) A structural scheme of soil allophane. *Am. Mineral.*, 52, 690-708.
- YOSHINAGA, N. AND S. AOMINE (1962a) Allophane in some Ando soils. *Soil Sci. Pl. Nutr. (Tokyo)* 8, 6-13.
- YOSHINAGA, N. AND S. AOMINE (1962b) Imogolite in some Ando soils. *Soil Sci. Pl. Nutr. (Tokyo)* 8, 114-121.

THE AMERICAN MINERALOGIST, VOL. 53, JANUARY-FEBRUARY, 1968

A STUDY OF GRAIN CONTACTS IN SOME
HIGH-GRADE METAMORPHIC ROCKS

SHEILA M. MAHAN AND JOHN J. W. ROGERS, *Department of Geology,
Rice University, Houston, Texas.*

PURPOSE AND METHOD

Precise determination of the medium of crystallization of silicate rocks is a classic petrologic problem. In particular, efforts have been made for many years to distinguish rocks formed by crystallization of a melt from those formed by grain growth in an essentially solid medium. The problem clearly hinges on accurate interpretation of textural relationships.

A number of papers have recently attempted to develop a quantitative approach to the study of rock textures. The grain size distribution of individual minerals has been studied, for example, by Kretz (1966a) and in a series of papers by K. A. Jones and A. K. Galwey (*e.g.*, Jones and Galwey, 1966). These studies have not been applied specifically to the distinction between solid and liquid media of growth, but they have yielded information concerning the growth process of the minerals and the process of migration of their component elements through the rocks in which they occur. A different line of investigation based on interfacial