

EVIDENCE FOR IMOGOLITE IN CANADIAN SOILS

Key Words—Canadian soils, Electron micrographs, Fibers, Imogolite, Soils.

Imogolite, a fibrous aluminosilicate with a characteristic X-ray and electron diffraction pattern (Russell *et al.*, 1969; Wada and Yoshinaga, 1969) and a structure closely related to that of gibbsite (Cradwick *et al.*, 1972) has most frequently been found as a weathering product of pyroclastic materials in soils derived from volcanic ash (Yoshinaga and Aomine, 1962; Kanno *et al.*, 1968; Besoain, 1968; Dingus *et al.*, 1973; Wada and Harward, 1974; Wada, 1977). Occasionally, imogolite has been found in soils derived from parent materials other than volcanic ash (Giménez and Jaritz, 1966; Jaritz, 1967; Tait *et al.*, 1978). Thus, imogolite is not unique to volcanic ash soils and Tait *et al.* (1978), prompted by their detection of imogolite in several Scottish Podzol and Brown Forest soils, suggested that it may be more widely distributed than is at present recognized. Hitherto, imogolite has not been positively identified in Canadian soils, although Sneddon (1973) observed material having a morphology similar to that of imogolite in Canadian soils derived from volcanic ash. The present report gives positive evidence for the occurrence of imogolite in Canadian soils.

The samples were taken from the southwestern area of British Columbia and are from the Bhfgj horizon of a well-drained Ferro-Humic Podzol developed on marine-deposited material and from a Bf₂ horizon of a well-drained Humo-Ferric Podzol developed on loess over alluvial material (Table 1). The parent materials contain abundant mafic minerals (amphiboles, pyroxenes, chlorites) which were derived from the volcanic, sedimentary, and igneous rocks of the British Columbia coastal mountains (Lord *et al.*, 1978). The B horizon samples have low pH and low contents of clay and exchangeable bases and relatively high contents of organic matter (Table 2). Petrographic examination of the dithionite-treated (Mehra and Jackson, 1960) light-sand fractions (S.G. < 2.5) showed the presence of a few volcanic ash grains which comprised approximately 0.1% and 1% of the Haney and Marble Hill total sand fractions, respectively.

The samples were treated with H₂O₂ to destroy organic matter and were dispersed at pH 4. The <2- μ m fraction was separated by sedimentation, and the <0.2- μ m fraction was obtained by centrifugation. Analyses of these clays by X-ray powder diffraction and extraction of amorphous clay constituents with Tiron solution (Biermans and Baert, 1977) indicated that approximately 70% of the Haney <2- μ m and 45% of the Marble Hill <2- μ m fraction was amorphous or very poorly crystalline. Presumably due to its low concentration, imogolite was not detected by X-ray powder diffraction. After Tiron extraction, chlorite and an interstratified chlorite-vermiculite were virtually the only layer silicates present in both soil clays.

The electron micrographs in Figures 1 and 2 were obtained

with a Philips 300 electron microscope; they show fine clay dispersed at pH 4, treated only with H₂O₂. The micrographs show threads characteristic of imogolite. These threads were still present after dithionite treatment, but were absent after boiling the clay for 10 min in 2% Na₂CO₃ solution. This indicates that iron was not a principal component and that the threads were not similar to the fibrous iron mineral particles found in some soils of Japan and Scotland (Nakai and Yoshinaga, 1978). Dissolution of imogolite in 2% Na₂CO₃ is not characteristic of this mineral (Yoshinaga and Aomine, 1962) and indicates that the imogolite in our samples is less crystalline than typical imogolite.

The electron diffraction pattern in Figure 1e shows reflections at spacings of 4.11, 3.5 (diffuse), 2.44, 2.10, and 1.39 Å. The arching of the 1.39 Å reflection is characteristic of the fibrous imogolite structure and is due to the alignment of the threads parallel to the arch direction (Russell *et al.*, 1969). Additional reflections cited for imogolite at 5.7, 7.8, 11.8, and 21–23 Å (Russell *et al.*, 1969) cannot be seen in Figure 1e. These reflections apparently are also missing in the electron diffraction pattern shown by Tait *et al.* (1978) for imogolite in Scottish soils. It is not yet clear in our investigation if this was due to blocking of these reflections by the size of the diffraction aperture used (10–20 μ m), to insufficient concentration of imogolite (less than 3 to 5% of the fine clay), to inadequate crystallinity and unsuitable orientation of the material, or to slight differences from the true imogolite structure.

Figure 1f shows a typical aluminosilicate gel particle that constitutes a major part of the fine clay. Its electron diffraction pattern gives reflections at 1.16 and 2.02 Å and, except for the absence of a 3.3 Å spacing, resembles the pattern of allophane (Wada and Yoshinaga, 1969). High magnification of these particles failed to show the aggregation of 30–50 Å diameter "spherules" characteristic of allophane weathered from volcanic ash and pumice (Wada, 1977). Although the circular particles in Figures 1a, 1c, and 1e suggest the presence of spheroidal halloysite, these particles in highly magnified photographs do not show the curved shell structure, or the so-called onion structure, which is typical of halloysite. Furthermore, electron diffraction did not show these particles to be halloysite, nor did X-ray powder diffraction of the original untreated clay indicate the presence of halloysite.

Because a small amount of volcanic ash was detected in the Haney and Marble Hill samples, the imogolite may have formed from volcanic ash. However, considering that this origin is not necessary for imogolite (Tait *et al.*, 1978), it may have formed from the weathering of other minerals, including the abundant mafic minerals, in these soils. More evidence is needed to clarify the origin of imogolite in these soils.

Table 1. Description of the soil samples.

Soil name and location	Horizon	Depth (cm)	Major soil group	Parent material	References
Haney, Haney Forest, B.C. 49°15'50"N, 122°33'40"W	Bhfgj	67–89	Orthic Ferro-Humic Podzol	Stony littoral deposit	Kowall and Glinka (1978)
Marble Hill, Abbotsford Station, B.C. 49°01'20"N, 122°33'40"W	Bf ₂	17–29	Sombric Humo-Ferric Podzol	Silty loess over gravel	Lord <i>et al.</i> (1978)

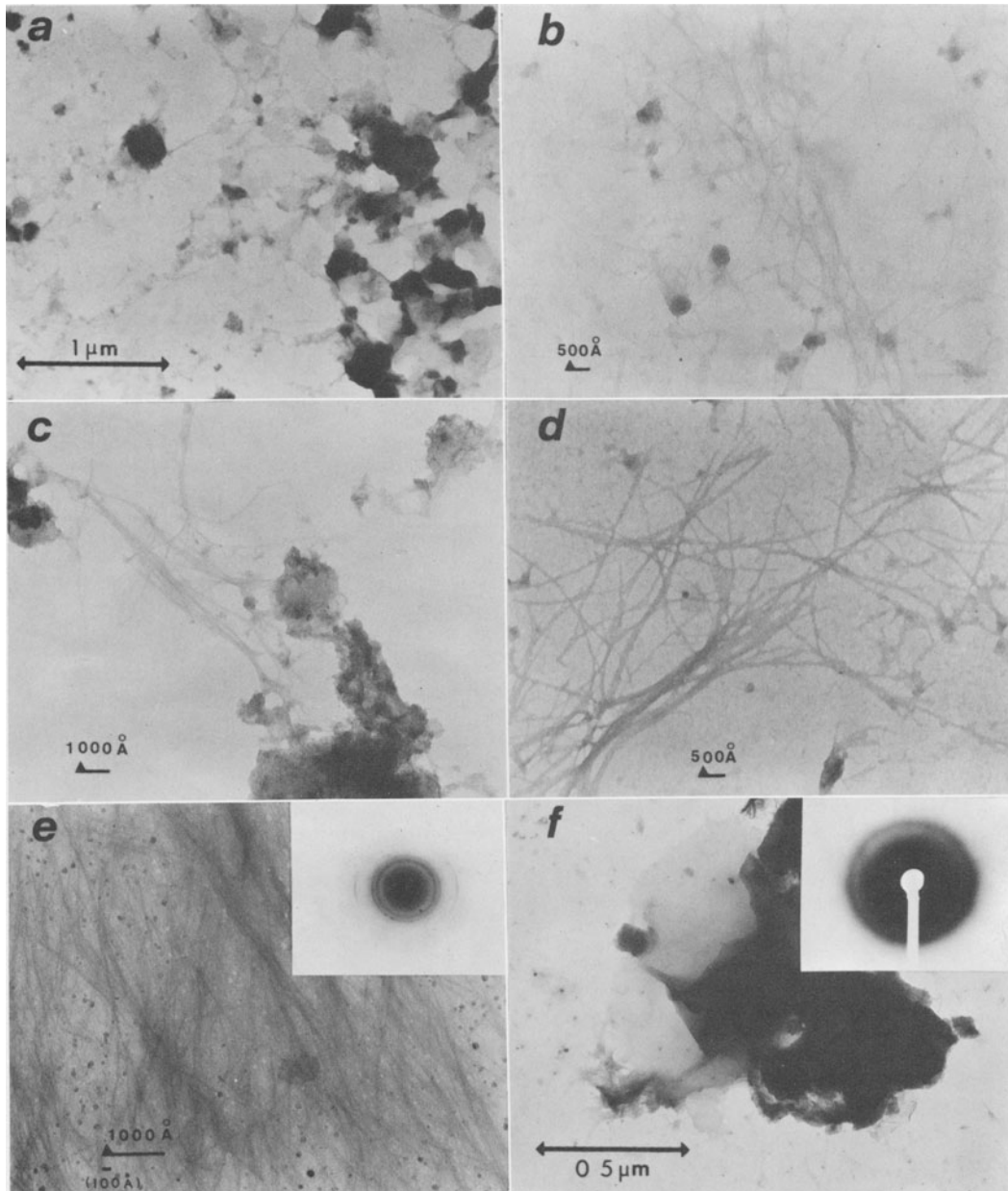


Figure 1. Electron micrographs of the fine clay of the Haney Bhfgj horizon in a, b, and f and of the Marble Hill Bf₂ horizon in c, d, and e.

Table 2. Some physical and chemical properites of the soil samples.

Soil name	Horizon	pH		Clay %	Silt %	Exchangeable bases (meq/100 g)				Oxalate extractable %		Organic matter %
		H ₂ O	0.01 N CaCl ₂			Ca	Mg	K	Na	Fe	Al	
Haney	Bhfgj	5.04	4.77	5	23	0.20	0.03	0.04	0.04	0.75	4.54	9.10
Marble Hill	Bf ₂	5.14	4.80	6	68	2.25	0.58	0.34	0.02	0.86	1.28	4.95

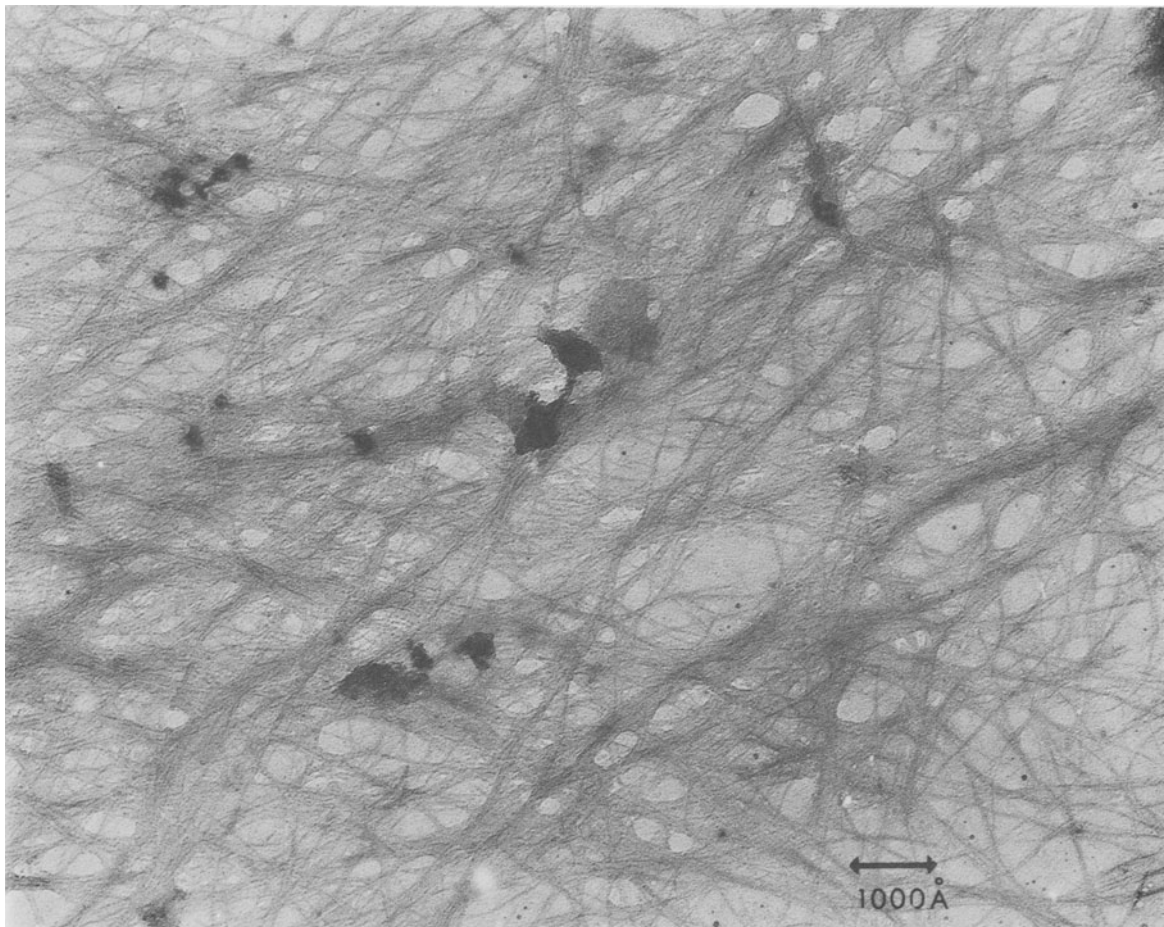


Figure 2. Electron micrograph of imogolite in the fine clay of the Marble Hill Bf₂ horizon.

ACKNOWLEDGMENTS

The authors thank T. M. Lord for collecting the samples, R. G. Hill and R. Guertin for technical help and advice, and J. A. McKeague and N. M. Miles for critically reviewing the manuscript.

Chemistry and Biology Research Institute
Agriculture Canada
Ottawa, Ontario, Canada K1A 0C6

G. J. ROSS
H. KODAMA

REFERENCES

- Besoain, E. (1968) Imogolite in volcanic soils of Chile: *Geoderma* **2**, 151–169.
- Biermans, V. and Baert, L. (1977) Selective extraction of the amorphous Al, Fe, and Si oxides using an alkaline tiron solution: *Clay Miner.* **12**, 127–135.
- Cradwick, P. D. G., Farmer, V. C., Russell, J. D., Masson, C. R., Wada, K., and Yoshinaga, N. (1972) Imogolite, a hydrated aluminum silicate of tubular structure: *Nature (London)* **24**, 187–189.
- Dingus, D. D., Jones, R. C., and Harward, M. E. (1973) Nature and properties of amorphous clay formed in the Mazama pumice deposit of Oregon: *Prog. Abstracts, Annu. Meet. Am. Soc. Agron., Las Vegas, Nev.*, p. 152 (Abstract).
- Giménez, F. and Jaritz, G. (1966) Amorphe and kristalline Bestandteile einiger typischer Bodenbildungen Skandinaviens: *Z. Pflanzenernähr. Düng. Bodenk.* **114**, 27–45.
- Jaritz, G. (1967) Ein Vorkommen von Imogolit in Bimsböden Westdeutschlands: *Z. Pflanzenernähr. Düng. Bodenk.* **117**, 65–77.
- Kanno, I., Onikura, Y., and Higashi, T. (1968) Weathering and clay mineralogical characteristics of volcanic ashes and pumices in Japan: *Trans. Ninth Int. Congr. Soil Sci., Adelaide, Australia* **3**, 111–122.
- Kowall, R. D. and Glinka, K. (1978) Podzolic soils and management in the Maple Ridge research forest: Tours V1–V3, 11th Congr., Int. Soil Sci. Soc., Edmonton, Alberta, p. 36.
- Lord, T. M., Luttmerding, H. A., Knapic, L. J., and Coen, G. H. (1978) Soils and landscapes in the Cordilleran Region of Western Canada: Tour 3, 11th Congr. Int. Soil Sci. Soc., Edmonton, Alberta, p. 169.
- Mehra, O. P. and Jackson, M. L. (1960) Iron oxide removal from soils and clays by a dithionite-citrate system buffered with sodium bicarbonate: *Clays & Clay Minerals* **7**, 317–327.
- Nakai, M. and Yoshinaga, N. (1978). Occurrence of a fibrous iron mineral in some soils from Japan and Scotland: *Book of Summaries of the Sixth Int. Clay Conf., Oxford, England*, p. 653.

- Russell, J. D., McHardy, W. J., and Fraser, A. R. (1969) Imogolite: a unique aluminosilicate: *Clay Miner.* **8**, 87–99.
- Sneddon, J. I. (1973) A study of two soils derived from volcanic ash in southwest British Columbia: Ph.D. Thesis, University of British Columbia, Vancouver, B.C., 149 pp.
- Tait, J. M., Yoshinaga, N., and Mitchell, B. D. (1978) The occurrence of imogolite in some Scottish soils: *Soil Sci. Plant Nutr. (Tokyo)*, **24**, 145–151.
- Wada, K. and Yoshinaga, N. (1969) The structure of imogolite: *Am. Mineral.* **54**, 50–71.
- Wada, K. and Harward, M. E. (1974) Amorphous clay constituents of soils: *Adv. Agron.* **26**, 211–260.
- Wada, K. (1977) Allophane and imogolite: in *Minerals in Soil Environments*, J. B. Dixon and S. B. Weed, eds., Soil Sci. Soc. Am., Madison, Wisconsin, 603–638.
- Yoshinaga, N. and Aomine, S. (1962) Imogolite in some Ando soils: *Soil Sci. Plant Nutr. (Tokyo)* **8**, 22–29.

(Received 30 December 1978; accepted 26 February 1979)