Warwickite $(Mg, Ti, Al)_2O(BO_3)$

Crystal Data: Orthorhombic. *Point Group:* $2/m\ 2/m\ 2/m$. Crystals are prismatic, {010}, {100}, {110}, {130}, {310}, with rounded terminations, to 5 mm; anhedral granular.

Physical Properties: *Cleavage:* On {100}, good. *Fracture:* Uneven. *Tenacity:* Brittle. Hardness = 3.5–4 D(meas.) = 3.34–3.36 D(calc.) = 3.40

Optical Properties: Opaque, transparent in thinnest edges. *Color:* Dark brown to black; deep yellow, pale brown, reddish brown in thin section. *Streak:* Bluish black. *Luster:* Subvitreous to pearly, submetallic on cleavages, commonly dull if altered.
Optical Class: Biaxial (+). *Pleochroism:* Slight; X = yellow-brown; Y = reddish brown; Z = cinnamon-brown. *Orientation:* $X = c$; $Y = b$; $Z = a$. *Absorption:* $X > Y > Z$. $\alpha = 1.806(5)$ $\beta = 1.809(5)$ $\gamma = 1.830(5)$ 2V(meas.) = Small, variable.

Cell Data: *Space Group: Pnam.* $a = 9.037$–9.255 $b = 9.358$–9.450 $c = 3.01$–3.116 Z = 4

X-ray Powder Pattern: Edenville, New York, USA.
2.57 (10), 2.75 (5), 6.55 (4), 4.20 (4), 2.97 (3), 1.979 (3), 1.721 (3)

Chemistry:

	(1)	(2)		(1)	(2)
B_2O_3	21.29	[25.8]	FeO	9.15	
SiO_2	1.39		MgO	35.71	39.3
TiO_2	24.86	20.4	CaO		0.3
Al_2O_3	2.91	7.7	Total	100.07	[100.6]
Fe_2O_3	4.76	7.1			

(1) Edenville, New York, USA; average of two analyses; corresponds to $(Mg_{1.28}Ti_{0.45}Fe^{2+}_{0.18}Al_{0.08}Fe^{3+}_{0.09})_{\Sigma=2.08}O(B_{0.88}O_3)$. (2) Do.; by electron microprobe, partial analysis, here converted to oxides from an elemental analysis; total Fe as Fe_2O_3, B_2O_3 calculated for stoichiometry; corresponds to $(Mg_{1.33}Ti_{0.34}Al_{0.21}Fe^{3+}_{0.12})_{\Sigma=2.00}O(B_{1.00}O_3)$.

Occurrence: A rare accessory mineral in boron-metasomatized limestone and associated skarns; in lamproitic rocks and carbonatitelike veinlets cutting them.

Association: Chondrodite, szaibélyite, sinhalite, spinel, diopside, titanite, dravite, apatite, fluorite, scapolite, graphite, magnetite, ilmenite, pyrite, pyrrhotite.

Distribution: From about 4 km southwest of Edenville, near Warwick, Orange Co., New York, USA. Found near Bancroft, Ontario, Canada. At La Ceila, near Jumilla, Murcia Province, Spain. In the Tayozhnoye iron deposit, 550 km south of Yakutsk, and the Taiga borate-magnetite deposit, Sakha, Siberia, Russia. At the Hol Kol Au–Cu mine, about 75 km southeast of Pyongyang, Suan Co., North Korea.

Name: For its first-noted occurrence near Warwick, New York, USA.

Type Material: Natural History Museum, Paris, France, 74217, 99697; National Museum of Natural History, Washington, D.C., USA, 128712.

References: (1) Palache, C., H. Berman, and C. Frondel (1951) Dana's system of mineralogy, (7th edition), v. II, 336–337. (2) Moore, P.B. and T. Araki (1974) Pinakiolite, $Mg_2Mn^{3+}O_2[BO_3]$; warwickite, $Mg(Mg_{0.5}Ti_{0.5})O[BO_3]$; wightmanite, $Mg_5(O)(OH)_5[BO_3]\bullet nH_2O$: crystal chemistry of complex 3 Å wallpaper structures. Amer. Mineral., 59, 985–1004. (3) Bigi, S., M.F. Brigatti, and S. Capedri (1991) Crystal chemistry of Fe- and Cr-rich warwickite. Amer. Mineral., 76, 1380–1388. (4) Thompson, R.M. and J.A. Gower (1954) A magnesium borate from Isère, France, and Swift River, Yukon Territory, with X-ray powder data for some anhydrous borates. Amer. Mineral., 39, 522–524.