Footemineite, the Mn-analog of atencioite, from the Foote mine, Kings Mountain, Cleveland County, North Carolina, U.S.A., and its relationship with other roscherite-group minerals

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**ABSTRACT**

Footemineite, ideally Ca$_3$Mn$_2$Mn$_3^{2+}$Be$_3$(PO$_4$)$_6$(OH)$_2$·6H$_2$O, triclinic, is a new member of the roscherite group. It occurs on thin fractures crossing quartz-microcline-spodumene pegmatite at the Foote mine, Kings Mountain, Cleveland County, North Carolina, U.S.A. Associated minerals are albite, analcime, cophosporite, siderite/rhodochrosite, fairfieldite, fluorapatite, quartz, milarite, and pyrite. Footemineite forms prismatic to bladed generally rough to barrel-shaped crystals up to about 1.5 mm long and 1 mm in diameter. Its color is yellow, the streak is white, and the luster is vitreous to slightly pearly. Footemineite is transparent and non-fluorescent. Twinning is simple, by reflection, with twin boundaries across the length of the crystals. Cleavage is good on {0 1 0} and {1 0 0}. Density (calc.) is 2.873 g/cm$^3$. Footemineite is biaxial (−), $n_a = 1.620(2)$, $n_b = 1.627(2)$, $n_c = 1.634(2)$ (white light). $2V_{obs} = 80^\circ$, $2V_{calc} = 89.6^\circ$. Orientation: $X \sim b \sim 12^\circ$, $Y \sim c \sim 15^\circ$, $Z \sim a \sim 15^\circ$. Elongation direction is $c$, dispersion: $r > v$ or $r < v$, weak. Pleochroism: $\beta$ (brownish yellow) > $\alpha$ = $\gamma$ (yellow). Mössbauer and IR spectra are given. The chemical composition is (EDS mode electron microprobe, Li and Be bound by ICP-OES, Fe$^{2+}$/Fe$^{3+}$ by Mössbauer, H$_2$O by TG data, wt%): Li$_2$O 0.23, BeO 9.54, CaO 9.43, SrO 0.23, BaO 0.24, MgO 0.18, MnO 26.16, FeO 2.77, Fe$_3$O$_4$ 0.62, Al$_2$O$_3$ 0.14, P$_2$O$_5$ 36.58, SiO$_2$ 0.42, H$_2$O 13.1, total 99.64. The empirical formula is (Ca$_{0.85}$Sr$_{0.05}$Ba$_{0.02}$)$_{12}$[Mn$_{3.20}$Mn$_{2.80}$Al$_{0.03}$P$_{1.41}$Si$_{0.59}$O$_{23}$]$\cdot$[OH]$_{1.60}$[H$_2$O]$_{13.36}$]$_{24}$·6.00H$_2$O. The strongest reflection peaks of the powder diffraction pattern [$d$, Å ($I$, %) (hkI)] are 9.575 (53) (010), 5.998 (100) (01I), 4.848 (26) (021), 3.192 (44) (210), 3.003 (14) (022), 2.803 (38) (103), 2.650 (29) (202), 2.424 (14) (231). Single-crystal unit-cell parameters are $a = 6.788(2)$, $b = 9.972(3)$, $c = 10.014(2)$ Å, $\alpha = 73.84(2)^\circ$, $\beta = 85.34(2)^\circ$, $\gamma = 87.44(2)^\circ$, $V = 648.74$ Å$^3$, $Z = 1$. The space group is $P\bar{T}$. Crystal structure was refined to $R = 0.0347$ with 1273 independent reflections ($F > 2\sigma$). Footemineite is dimorphous with roscherite, and isostructural with atencioite. It is identical with the mineral from Foote mine described as “triclinic roscherite.” The name is for the Foote mine, type locality for this and several other minerals.

Keywords: Footemineite, new mineral, roscherite-group, Mn-phosphate, crystal structure, atencioite, Foote mine, North Carolina

**INTRODUCTION**

As it was demonstrated by our recent investigations (Chukanov et al. 2002, 2006, 2007; Rastsvetaeva et al. 2002, 2004a, 2004b, 2005; Barinova et al. 2004; Atencio et al. 2005; Chukanov and Möckel 2005), roscherite-group minerals are notable for a wide diversity of their chemical composition and cation ordering. Most of them are monoclinic, with predominance of Mn, Mg, Fe$^{2+}$, Fe$^{3+}$, or Zn in the group of octahedral cations. Up to now only one triclinic member of this group, atencioite, has been approved by the IMA-CNMMN. In this mineral lowering of symmetry is connected with the ordering of Fe$^{3+}$, Fe$^{2+}$, Mg, and vacancies in sites with octahedral coordination. Footemineite, Ca$_3$Mn$_2^{3+}$Mn$_3^{2+}$Be$_3$(PO$_4$)$_6$(OH)$_2$·6H$_2$O, is a new, Mn-rich triclinic species of the roscherite group. The name is for the Foote mine, type locality for this mineral and also brannockite, eakerite, earlshannonite, kingsmountite, lithiomarsturite, mangangordonite, metaswitzerite, swinefordite, switzerite, and tetrawickmanite. The name “footeite” was used for a mineral (later discredited as connellite) in honor of the mineral dealer A.E. Foote who started the Foote Mineral Company. The new mineral has been approved by the CNMMN-IMA (vote 2006-029).