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Makarochkinite, $Ca_2Fe^{2+}_4Fe^{3+}TiSi_4BeAlO_{20}$, a new beryllosilicate member of the aenigmatite-sapphirine-surinamite group from the Il'men Mountains (southern Urals), Russia

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ABSTRACT

Makarochkinite, $^{[VII]}(Ca_{1.64}Na_{0.25}Mn_{0.11})^{[VI]}(Fe^{2+}_{3.56}Fe^{3+}_{1.46}Ti_{0.61}Mg_{0.25}Mn_{0.02}Nb_{0.038}Ta_{0.007})^{[IV]}(Si_{4.48}Be_{0.91}Al_{0.54}Fe_{0.07}O_{18})O_2$ (end-member $Ca_2Fe^{2+}_4Fe^{3+}TiSi_4BeAlO_{20}$) from electron-microprobe data, Mössbauer spectroscopy, and single-crystal structure refinement, occurs in a granitic pegmatite near Lake Ishkul', Il'men Mountains (Southern Urals), Il'men State Reserve, Chelyabinsk Oblast', Russia. Associated minerals include danalite, phenakite, titanite, potassian calcic amphibole (ferro-edenite and hastingsite), biotite, ilmenite, magnetite, ferrocolumbite, fergusonite-(Y), and samarskite-(Y). Makarochkinite forms equant masses 5–50 mm across, black in hand specimen; luster vitreous; it is opaque except in slivers <1 μm thick. It is brittle; Moh's hardness 5.5–6, and has no discernable cleavage; fracture is uneven. Twinning is absent. The measured density is 3.93(1) g/cm^3; calculated density 3.933 g/cm^3. It is optically biaxial, $\alpha = 1.835 \pm 0.014$ and $\gamma = 1.865 \pm 0.015$ from reflectance data, pleochroism marked: X = greenish brown, Y = yellowish brown, Z = reddish brown; $Y \leq X < Z$. Single-crystal X-ray diffraction gives triclinic symmetry, space group $P\bar{1}$, $Z = 2$, $wR(F^2)$ (all) = 0.096 for 6497 reflections, $a = 10.355(2)$, $b = 10.751(3)$, and $c = 8.873(2)$ Å, $\alpha = 105.707(8)$, $\beta = 96.227(6)$, $\gamma = 124.861(6)°$, $V = 735.7(3)$ Å^3. The eight strongest lines in the powder pattern [d-spacing (Å),(I),(hkl)] are 7.997(57)(100), 4.779(29)(011), 3.120(32)(012), 2.924(69)(0$\bar{1}$3), 2.676(77)($\bar{2}$03), 2.530(100)($\bar{2}$1$\bar{3}$), 2.410(28)(2$\bar{2}$3), 2.075(39)(4$\bar{1}$1).

Of the aenigmatite-sapphirine-surinamite group minerals, makarochkinite is compositionally closest to rhönite and høgtuvaite. It is distinguished from rhönite by $Fe^{2+} > Mg$ and by the presence of 0.91–0.98 Be per 20 cations; Be occupies the two most polymerized T sites in roughly equal amounts. Distinction from høgtuvaite is based on occupancy of the M7 site, which is dominated by Fe^{3+} in høgtuvaite and by Ti in makarochkinite.