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# Scandio-fluoro-eckermannite, $NaNa_2(Mg_4Sc)(Si_8O_{22})F_2$, a new Sc-dominant amphibole-supergroup mineral from the Bayan Obo deposit, China

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## Abstract

Scandio-fluoro-eckermannite (IMA 2024-002), a new Sc-dominant amphibole-supergroup mineral, has been discovered in the Bayan Obo REE-Nb-Fe polymetallic deposit, China. The new mineral was collected from banded Fe-REE ores that have formed due to the fenitization caused by carbonatite intrusion, in the Main and East open pits at Bayan Obo. Associated minerals include monazite, bastnäsite, magnetite, biotite, fluorite, bazzite, thortveitite, and magnesio-fluoro-arfvedsonite. The new mineral occurs as euhedral to subhedral crystals and aggregates, appearing both as inner zones of a crystallization sequence from scandio-fluoro-eckermannite to magnesio-fluoro-arfvedsonite as well as homogeneous fine-grained particles, reaching up to 350 μm in size and ~7 wt% in $Sc_2O_3$ content.

Scandio-fluoro-eckermannite displays a light yellow to light blue color under plane-polarized transmitted light, with perfect cleavage on {110}, non-magnetic, and no fluorescence. The hardness is 5–6 by analogy to eckermannite, and the calculated density is 3.097 g/cm$^3$. Electron microprobe analyses determined the main components (average value in wt%): $Sc_2O_3$ 6.39; $SiO_2$ 54.30; MgO 13.42; $Na_2O$ 8.38; $Al_2O_3$ 1.29; MnO 1.47; CaO 1.21; $K_2O$ 0.47; $FeO_{calc}$ 6.43; $Fe_2O_{3calc}$ 3.80; F 3.01; $H_2O^+_{calc}$ 0.67; F≡O –1.27; total 99.74. The composition normalized on the basis of 24 anions (O, OH, F, Cl), with the assumption of (OH, F, Cl) = 2 apfu, corresponds to the empirical formula $^{A}(Na_{0.52}K_{0.09}\square_{0.39})_{\Sigma1.00}$ $^{B}(Na_{1.81}Ca_{0.19})_{\Sigma2.00}$ $^{C}(Mg_{2.87}Fe^{2+}_{0.77}Mn^{3+}_{0.18}Sc_{0.80}Fe^{3+}_{0.41})_{\Sigma5.03}$ $^{T}(Si_{7.78}Al_{0.22})_{\Sigma8.00}$ $O_{22}$ $^{W}[F_{1.36}(OH)_{0.64}]_{\Sigma2.00}$. It leads to the simplified formula $(Na,\square)(Na,Ca)_2[(Mg,Fe^{2+})_4(Sc,Fe^{3+},Mn^{3+})][(Si,Al)_8O_{22})](F,OH)_2$ and the ideal formula $NaNa_2(Mg_4Sc)Si_8O_{22}F_2$. The crystal structure was refined in the monoclinic system, space group *C*2/*m* (#12). Its unit-cell parameters are: $a$ = 9.8212(3) Å, $b$ = 18.0866(5) Å, $c$ = 5.3091(2) Å, β = 103.767(4)°, and $Z$ = 2, with the *a*:*b*:*c* ratio of 0.543:1:0.294. The crystal-structure refinement indicates that Na is the dominant cation at the *A*(*m*) and *M*(4) sites, Mg is the dominant cation at the *M*(1) and *M*(3) sites, Sc is the dominant trivalent cation at the *M*(2) site, and F is the dominant cation at the O(3) site. Therefore, this is the Sc-dominant variety of fluoro-eckermannite. This discovery highlights the importance of amphibole in controlling Sc in this type of ore-forming system. Scandio-fluoro-eckermannite might also be used as a potential recorder to investigate the enrichment process of Sc in the Bayan Obo deposit.

**Keywords:** Scandium, scandio-fluoro-eckermannite, new species of amphibole, Bayan Obo