American Mineralogist, Volume 98, pages 1617–1623, 2013

Lead-tellurium oxysalts from Otto Mountain near Baker, California: XI. Eckhardite, $(Ca,Pb)Cu^{2+}Te^{6+}O_5(H_2O)$, a new mineral with HCP stair-step layers

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Abstract

Eckhardite, $(Ca,Pb)Cu^{2+}Te^{6+}O_5(H_2O)$, is a new tellurate mineral from Otto Mountain near Baker, California, U.S.A. It occurs in vugs in quartz in association with Br-rich chlorargyrite, gold, housleyite, khinite, markcooperite, and ottoite. It is interpreted as having formed from the partial oxidation of primary sulfides and tellurides during or following brecciation of quartz veins. Eckhardite is monoclinic, space group $P2_1/n$, with unit-cell dimensions a = 8.1606(8), b = 5.3076(6), c = 11.4412(15) Å, β = 101.549(7)°, V = 485.52(10) Å^3, and Z = 4. It forms as needles or blades up to about 150 × 15 × 5 μm in size, typically in radial or sub-radial aggregates, but also as isolated needles. The color is light bluish green and the streak is very pale bluish green. Crystals are transparent with vitreous to subadamantine luster. The Mohs hardness is estimated at between 2 and 3. Eckhardite is brittle with an irregular fracture and one likely (but not observed) cleavage on {101}. The calculated density based on the empirical formula is 4.644 g/cm^3. The mineral is biaxial (–), with indices of refraction of α = 1. 770 (calc), β = 1.860 (calc), and γ = 1.895(5). The measured $2V$ is 61.2(5)°, dispersion is $r < v$, perceptible and the optical orientation is Z = **b**; $X \approx$ [101]. The pleochroism is: Z (light blue green) < Y (very pale blue green) < X (colorless). The normalized electron microprobe analyses (average of 4) provided: PbO 4.79, CaO 15.90, MgO 0.06, CuO 22.74, Fe_2O_3 0.06, TeO_3 51.01, H_2O 5.45 (structure), total 100 wt%. The empirical formula (based on 6 O apfu) is: $Ca_{0.962}Pb_{0.073}Cu^{2+}_{0.971}Mg_{0.005}Fe^{3+}_{0.002}Te^{6+}_{0.986}O_6H_{2.052}$. The Raman spectrum exhibits prominent features consistent with the mineral being a tellurate, as well as an OH stretching feature confirming a hydrous component. The eight strongest powder X-ray diffraction lines are [d_{obs} in Å (*hkl*) *I*]: 5.94 (101) 100, 3.287 (112) 80, 2.645 (020,$\bar{2}$13) 89, 2.485 ($\bar{1}$14,301,014) 48, 2.245 (114,122) 46, 1.809 (223,$\bar{4}$13,321,$\bar{4}$04) 40, 1.522 (413,$\bar{5}$12,421,133) 42, and 1.53 ($\bar{2}$17,$\bar{2}$33,$\bar{4}$06) 43. The crystal structure of eckhardite (R_1 = 0.046 for 586 reflections with $F_o > 4\sigma F$) consists of stair-step-like octahedral layers of $Te^{6+}O_6$ and $Cu^{2+}O_6$ octahedra parallel to {101}, which are linked in the [10$\bar{1}$] direction by bonds to interlayer Ca atoms. The structure can be described as a stacking of stepped HCP layers alternating with chains of CaO_7 polyhedra. The structures of bairdite, timroseite, and paratimroseite also contain stair-step-like HCP polyhedral layers.

Keywords: Eckhardite, new mineral, tellurate, crystal structure, Raman spectroscopy, HCP layers, bairdite, timroseite, paratimroseite, Otto Mountain, California