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Whelanite, $Cu_2Ca_6[Si_6O_{17}(OH)](CO_3)(OH)_3(H_2O)_2$, an (old) new mineral from the Bawana mine, Milford, Utah

Anthony R. Kampf,[1,*] Stuart J. Mills,[2] Stefano Merlino,[3] Marco Pasero,[3] Andrew M. McDonald,[4] William B. Wray,[5] and James R. Hindman[6]

[1]Mineral Sciences Department, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007, U.S.A.
[2]Geosciences, Museum Victoria, GPO Box 666, Melbourne 3001, Australia
[3]Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, 56126 Pisa, Italy
[4]Department of Earth Sciences, Laurentian University, Sudbury, Ontario P3E 2C6, Canada
[5]2700 Las Vegas Boulevard South, no. 3310, Las Vegas, Nevada 89109, U.S.A.
[6]715 East Glendale Street, Dillon, Montana 59725, U.S.A.

Abstract

The new mineral whelanite, $Cu_2Ca_6[Si_6O_{17}(OH)](CO_3)(OH)_3(H_2O)_2$, was approved by the Commission on New Minerals and Mineral Names (IMA) in 1977, but until now a description has not been published. The mineral is orthorhombic with space group *Pn*2*n* and cell parameters $a = 5.6551(4)$, $b = 3.683(3)$, $c = 27.1372(7)$ Å, $V = 565.3(5)$ Å^3, and $Z = 1$. The mineral occurs with thaumasite, stringhamite, and kinoite in a copper-rich, diopside–garnet–magnetite skarn at the Bawana mine, Beaver County, Utah, and has also been confirmed to occur at other localities. At the Bawana mine, it is found as irregular clusters and radial aggregates of platy to lath-like crystals up to 1 mm in length, flattened on {001} and elongated on [100]. The color and streak are pale blue and the luster is vitreous. The laths are flexible, but not elastic. Cleavage is perfect on {001} and good on {010}, producing splintery fracture. The Mohs' hardness is about 2½. The measured density is 2.74(3) g/cm^3 and the calculated density is 2.737 g/cm^3 based upon the empirical formula. The mineral is biaxial (–), $\alpha = 1.612(2)$, $\beta = 1.622$(calc), and $\gamma = 1.626(2)$, and $2V_{meas} = 64(1)°$. The pleochroism is weak: X = Y (pale blue) < Z (light blue). The optical orientation is X = **a**, Y = **c**, Z = **b**. A combination of electron microprobe analyses and thermogravimetric analyses (for CO_2 and H_2O) yielded: CaO 34.46, CuO 12.09, FeO 1.52, SiO_2 37.96, CO_2 5.93, H_2O 8.86, total 100.82 wt%, providing the empirical formula (based on O = 26): $Cu_{1.41}Fe_{0.20}Ca_{5.68}Si_{5.84}C_{1.25}O_{26}H_{9.09}$. Raman spectroscopy shows evidence of $(CO_3)^{2-}$, $(OH)^-$, and H_2O. The strongest powder X-ray diffraction lines are [*d*(*hkl*)*I*]: 6.79(004)52, 3.072(111)43, 3.013(112)100, 2.921(113)39, 2.802(114)45, 2.522(116,205)44, and 1.839(020,1.1.12)37. The crystal structure (R_1 = 3.89% for 567 $F_o > 4\sigma F$) contains two different types of polyhedral layers parallel to {001}, which alternate along [001] and are linked to one another by sharing corners with wollastonite-like silicate chains running parallel [010]. One polyhedral layer, consisting of edge-sharing CaO_7 polyhedra, is identical to that in the structures of the tobermorites (tobermorite 9Å, tobermorite 11Å, tobermorite 14Å, and clinotobermorite). The other layer is brucite-like, with alternating ribbons of edge-sharing $Cu^{2+}O_6$ and CaO_6 octahedra. Disordered CO_3 and H_2O groups are also located in the interlayer region. The crystal structure of whelanite exhibits OD character.

Keywords: Whelanite, new mineral, crystal structure, order-disorder structure, Raman spectroscopy, Bawana mine, Milford, Utah