

New Mineral Names*†

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This New Mineral Names has entries for 8 new minerals, including baličžuničite, bobcookite, byrudite, campostriniite, canutite, ericlxmanite, kozyrevskite, and wetherillite.

BALIČŽUNIČITE*

D. Pinto, A. Garavelli, and D. Mitolo (2014) Bi₂O(SO₄)₂, a new fumarole mineral from La Fossa crater, Vulcano, Aeolian Islands, Italy. Mineralogical Magazine, 74(4), 1043–1055.

Baličžuničite (IMA 2012-098), ideally Bi₂O(SO₄)₂, is a new mineral found as a high-temperature fumarole sublimate ($T = 600\text{ }^{\circ}\text{C}$) at La Fossa crater, Vulcano, Aeolian Islands, Italy. It occurs as aggregates of prismatic and elongated along [100] crystals (~50 μm across and up to 200 μm long) associated with anglesite, leguermite, lillianite, galenobismutite, bismoclite, Cd-sphalerite, wurtzite, pyrite, pyrrotite and one other potentially new Bi-oxysulfate mineral with probable composition Bi₁₄O₁₆(SO₄)₅. Baličžuničite is colorless to white or pale brown, with white streak. The mineral is transparent with vitreous luster. It is brittle with no cleavage, fracture or parting observed. Hardness, density and optical properties were not measured. $D_{\text{calc}} = 5.911\text{ g/cm}^3$; $n_{\text{calc}} = 2.09$. Average of ten electron probe WDS analyses is [wt% (range)]: Bi₂O₃, 68.68 (67.85–69.78), SO₃, 23.73 (23.17–24.45), total 94.41. The empirical formula, calculated on the basis of 9 O apfu, is: Bi_{1.99}S_{2.09}. The strongest lines of the X-ray powder diffraction pattern [$d\text{ } \text{Å}$ ($P\%$; hkl)] are: 3.146 (100; 033), 3.486 (21; 004), 3.409 (12; 031), 3.366 (7; 200), 5.562 (4; 111), and 5.433 (4; 111). The unit-cell parameters refined from powder data are: $a = 6.739(4)$, $b = 11.184(7)$, $c = 14.176(9)\text{ } \text{Å}$, $\alpha = 80.06(5)^{\circ}$, $\beta = 88.47(8)^{\circ}$, and $\gamma = 89.46(7)^{\circ}$. X-ray single-crystal diffraction study [refined to $R_1 = 0.0507$ for 3856 unique $F > 4\sigma(F)$ reflections] on a crystal fragment 50 × 110 × 150 μm shows the mineral is triclinic, space group $P\bar{1}$; with unit-cell parameters $a = 6.7386(3)$, $b = 11.1844(5)$, $c = 14.1754(7)\text{ } \text{Å}$, $\alpha = 80.082(2)^{\circ}$, $\beta = 88.462(2)^{\circ}$, $\gamma = 89.517(2)^{\circ}$, and $V = 1052.01\text{ } \text{Å}^3$; $Z = 6$. The crystal structure of baličžuničite consist of clusters of five Bi atoms forming nearly planar Bi₅O₃⁹⁺ with nearly regular trapezoidal shape and O atoms situated at the trigonal holes of the Bi₅ trapezoids. Trapezoidal groups are linked along [100] by SO₄²⁻ groups forming infinite Bi₅O₃(SO₄)₅ columns. Baličžuničite is the natural analogue of the stable low-temperature α form of synthetic Bi₂O(SO₄)₂. The name is in honor of Tonci Balič-Žunič, Professor of Mineralogy at the Natural History Museum of the University of Copenhagen. The holotype specimen is deposited in the Museum “C.L. Garavelli”, Dipartimento di Scienze della Terra e Geoambientali, Università di Bari, Italy. F.C.

BOBCOOKIE* AND WETHERILLITE*

A.R. Kampf, J. Plášil, A.V. Kasatkin, and J. Marty (2015) Bobcookite, NaAl(UO₂)₂(SO₄)₄·18H₂O and wetherillite, Na₂Mg(UO₂)₂

(SO₄)₄·18H₂O, two new uranyl sulfate minerals from the Blue Lizard mine, San Juan County, Utah, USA. Mineralogical Magazine, 79(3), 695–714.

Bobcookite (IMA 2014-030), ideally NaAl(UO₂)₂(SO₄)₄·18H₂O, and wetherillite (IMA 2014-044), ideally Na₂Mg(UO₂)₂(SO₄)₄·18H₂O, are two new minerals found at the Blue Lizard mine, San Juan County, Utah, U.S.A. The new minerals occur together and originate from the oxidation of primary ores in the relatively humid underground environment which has produced a variety of secondary minerals as efflorescent crusts on the surfaces of mine walls. Associated minerals include boyleite, chalcantite, dietricite, gypsum, hexahydrate, johannite, pickeringite, and rozenite. Bobcookite occurs as irregular columnar crude prismatic crystals, often more or less curved and sometimes composite. Prisms are up to 2 mm long, are elongated on [101] and have irregular terminations. Forms observed are in the [101] zone: {010}, {101}, {111}, and {111}. Wetherillite occurs as prisms or blades with irregular terminations up to ~1 mm long in subparallel intergrowths, divergent sprays and jackstraw aggregates. Crystals are elongated on [010], more or less flattened on {101} and exhibit the forms {100}, {101}, and {101}. Neither mineral shows twinning. Crystals of bobcookite are lime green to greenish-yellow, have very pale yellowish-green streak, are transparent with a vitreous luster, are brittle with no cleavage and conchoidal fracture and have a Mohs hardness of ~2½. The mineral is moderately hygroscopic and is easily soluble in room temperature H₂O. As a result, its density could not be measured. $D_{\text{calc}} = 2.669\text{ g/cm}^3$. The mineral fluoresces bright greenish white under both long- and short-wave UV light (stronger under short-wave). Bobcookite is biaxial (–) with $\alpha = 1.501(1)$, $\beta = 1.523(1)$, $\gamma = 1.536(1)$, $2V_{\text{meas}} = 78(1)^{\circ}$, and $2V_{\text{calc}} = 74^{\circ}$; $Z^{\wedge}[101] \approx 10^{\circ}$. Dispersion is $r < v$, moderate. Pleochroism is X colorless, Y very pale yellow-green, Z pale yellow-green; $X < Y < Z$. Crystals of wetherillite are pale greenish-yellow, transparent, with a white streak and a vitreous luster. The mineral is brittle with cleavages on {101} (perfect) and {010} (fair). It has conchoidal or curved fracture and a Mohs hardness of ~2. Wetherillite is also easily soluble in room-temperature H₂O and its density could not be measured. $D_{\text{calc}} = 2.626\text{ g/cm}^3$. Wetherillite is optically biaxial (+) with $\alpha = 1.498(1)$, $\beta = 1.508(1)$, $\gamma = 1.519(1)$, $2V_{\text{meas}} = 88(1)^{\circ}$, and $2V_{\text{calc}} = 87.9^{\circ}$; $Z = \mathbf{b}$; $X^{\wedge}\mathbf{a} = 54^{\circ}$ in obtuse β . Dispersion is $r < v$, distinct. Pleochroism is X colorless, Y pale yellow-green, Z pale yellow-green; $X < Y \approx Z$. The Raman spectrum of bobcookite (wetherillite; if different) shows bands at ~3600–3000 cm⁻¹ [$\nu(\text{O-H})$ stretching vibration of free or weakly hydrogen-bonded H₂O molecules], 1640 (1610) cm⁻¹ [$\nu_2(\delta)$ H-O-H bending modes of H₂O], 1210, 1145 and 1110 cm⁻¹ (1230, 1180, 1120, 1105, and 1080 cm⁻¹) [split triply degenerate $\nu_3(\text{SO}_4^{2-})$ antisymmetric

* All minerals marked with an asterisk have been approved by the IMA CNMNC.
† For a complete listing of all IMA-validated unnamed minerals and their codes, see <http://pubsites.uws.edu.au/ima-cnmmc/>.

stretching vibrations], strong broad bands at 1035 and 1010 (1010, 995) cm^{-1} [$\nu_1(\text{SO}_4^{2-})$ symmetric stretching vibration], a shoulder at 990 cm^{-1} [$\delta(\text{U-OH})$ bending or $\nu_1(\text{SO}_4^{2-})$], a very strong band at 845 (830) cm^{-1} [$\nu_1(\text{UO}_2^{2+})$ symmetric stretching vibration], bands at 630 and 600 (640, 615, shoulder at 580) cm^{-1} [split, triply degenerate $\nu_4(\delta)(\text{SO}_4^{2-})$ bending vibrations], bands at 470 and 450 (506, 445) cm^{-1} [split doubly degenerate $\nu_2(\delta)(\text{SO}_4^{2-})$ bending vibrations], band at 330 (385) cm^{-1} [$\nu(\text{U-O}_{\text{equatorial}})$ stretching vibrations or to Na-O stretching frequencies], and a medium intensity composite band at 210 (240) cm^{-1} [split doubly degenerate $\nu_2(\delta)(\text{UO}_2^{2+})$ bending vibration]. The average of 7 electron probe EDS analyses on a crystal of bobcookite is [wt% (range)]: Na_2O 2.29 (2.03–2.57), Al_2O_3 4.26 (4.14–4.32), UO_3 44.47 (44.08–44.92), SO_3 23.96 (23.48–24.63), H_2O (calc) 24.75, total 99.73. This gives the empirical formula $\text{Na}_{0.97}\text{Al}_{1.09}\text{U}_{2.04}\text{S}_{3.92}\text{O}_{38.00}\text{H}_{36.00}$, or $\text{Na}_{0.97}\text{Al}_{1.09}(\text{U}_{1.02}\text{O}_2)_2(\text{S}_{0.98}\text{O}_4)_4(\text{H}_2\text{O})_{18}$ based on 38 O apfu. The average of 8 electron probe EDS analyses on a crystal of wetherillite is [wt% (range)]: Na_2O 4.56 (4.01–4.92), MgO 1.75 (1.28–2.04), FeO 0.49 (0–1.29), CuO 0.62 (0–2.01), ZnO 1.43 (0.82–2.53), UO_3 44.24 (42.29–45.39), SO_3 23.35 (22.54–24.11), H_2O (calc) 24.13, total 100.57. This gives the empirical formula $\text{Na}_{1.98}\text{Mg}_{0.58}\text{Zn}_{0.24}\text{Cu}_{0.11}\text{Fe}_{0.09}\text{U}_{2.08}\text{S}_{3.92}\text{O}_{38.00}\text{H}_{36.00}$, or $\text{Na}_{1.98}(\text{Mg}_{0.58}\text{Zn}_{0.24}\text{Cu}_{0.11}\text{Fe}_{0.09})_{2.12}(\text{U}_{1.04}\text{O}_2)_2(\text{S}_{0.98}\text{O}_4)_4(\text{H}_2\text{O})_{18}$ based on 38 O apfu. The H_2O content was calculated by stoichiometry on the basis of 38 O apfu for each mineral. The strongest lines in the X-ray powder-diffraction pattern [d_{obs} (Å) ($I_{\text{obs}}\%$; hkl)] of bobcookite are: 9.82 (100; 010), 7.14 (99; 101), 5.25 (83; $\bar{1}\bar{1}$, 012, 021), 3.082 (57; $\bar{2}01$, 213, $\bar{1}\bar{1}$, $\bar{2}$, $\bar{1}30$), 6.33 (55; 111), and 3.563 (52; 212, 202, $\bar{2}\bar{1}$). The unit-cell parameters refined from powder-diffraction data are: $a = 7.784(2)$, $b = 10.567(2)$, $c = 11.230(2)$ Å, $\alpha = 68.884(7)$, $\beta = 70.909(7)$, $\gamma = 87.056(6)^\circ$, and $V = 812.0$ Å³. The strongest lines in the X-ray powder-diffraction pattern [d_{obs} (Å) ($I_{\text{obs}}\%$; hkl)] of wetherillite are: 9.74 (100; 200), 4.80 (64; 400, 211, $\bar{3}\bar{1}\bar{1}$), 6.46 (50; 102, 002, $\bar{2}02$), 3.510 (50; 411, 013, $\bar{5}\bar{1}\bar{1}$, $\bar{3}\bar{1}\bar{3}$), 6.01 (48; 011, 210, 111), 3.202 (47; 600, 204, 220, 121, $\bar{2}\bar{2}\bar{1}$, $\bar{1}04$, 304). The unit-cell parameters refined from powder-diffraction data are: $a = 20.364(4)$, $b = 6.817(4)$, $c = 12.908(4)$ Å, $\beta = 107.994(5)^\circ$, and $V = 1704$ Å³. Single-crystal X-ray diffraction data collected on a crystal of size $150 \times 100 \times 80$ μm refined to $R_1 = 0.0165$ for 3603 unique reflections with $I \geq 4\sigma(I)$ shows bobcookite is triclinic, $P\bar{1}$, $a = 7.7912(2)$, $b = 10.5491(3)$, $c = 11.2451(8)$ Å, $\alpha = 68.961(5)$, $\beta = 70.909(5)$, $\gamma = 87.139(6)^\circ$, and $V = 812.79$ Å³; $Z = 1$. For wetherillite, single-crystal X-ray diffraction data collected on a crystal of size $200 \times 50 \times 30$ μm refined to $R_1 = 0.0139$ for 3625 unique reflections with $I \geq 4\sigma(I)$ shows the mineral is monoclinic, $P2_1/c$, $a = 20.367(1)$, $b = 6.8329(1)$, $c = 12.903(3)$ Å, $\beta = 107.879(10)^\circ$, and $V = 1709.0$ Å³; $Z = 2$. The structure of bobcookite consists of $[(\text{UO}_2)(\text{SO}_4)_2(\text{H}_2\text{O})]$ chains linked by $\text{NaO}_4(\text{H}_2\text{O})_2$ octahedra to form layers, where hydrogen bonds to insular $\text{Al}(\text{H}_2\text{O})_6$ octahedra and isolated H_2O groups hold the structure together. Wetherillite contains $[(\text{UO}_2)(\text{SO}_4)_2(\text{H}_2\text{O})]$ sheets parallel to $\{100\}$ and edge-sharing chains of $\text{Na}(\text{H}_2\text{O})_3\text{O}$ polyhedra that link adjacent uranyl sulfate sheets, forming a weakly bonded three-layer sandwich. The sandwich layers are linked to one another by hydrogen bonds through insular $\text{Mg}(\text{H}_2\text{O})_6$ octahedra and isolated H_2O groups. Bobcookite is named after Robert (Bob) B. Cook (b. 1944), a professor emeritus in the Department of Geology and Geography at Auburn University in Auburn, Alabama, U.S.A., in honor of his career's work. Wetherillite is named in honor of John Wetherill (1866–1944), who is responsible for the discovery of the deposit that would later be exploited as the Blue Lizard mine, as well as for George W. Wetherill (1925–2006) for his seminal work on the spontaneous fission of uranium, which led to breakthrough research on the dating of rocks based on radioactive decay. The holotype specimen of bobcookite and two cotype specimens of wetherillite are deposited in the Natural History Museum of Los Angeles County, Los Angeles, U.S.A. A cotype specimen of each mineral is housed in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **O.C.G.**

BYRUDITE*

G. Raade, T. Balić-Žunić, and C.J. Stanley (2015) Byrudite, $(\text{Be}, \square)(\text{V}^{3+}, \text{Ti})_3\text{O}_6$, a new mineral from the Byrud emerald mine, South Norway. *Mineralogical Magazine*, 79(2), 261–268.

Raade, G. and Balić-Žunić, T. (2006) The crystal structure of $(\text{Be}, \square)(\text{V}, \text{Ti})_3\text{O}_6$, a mineral related to kyzylkumite. *Canadian Mineralogist*, 44(5), 1147–1158.

Byrudite (IMA 2013-045), $(\text{Be}, \square)(\text{V}^{3+}, \text{Ti})_3\text{O}_6$, is a new mineral found at Byrud farm, near Minnesund, Eidsvoll municipality, Akershus County, South Norway. The mineral occurs in emerald-bearing syenitic pegmatites of Permian age embedded in quartz as a primary, magmatic phase. Associated minerals include microcline, beryl (emerald), muscovite, fluorite and fluorapatite. Byrudite occurs sparingly as single or intergrown prismatic crystals up to ~1 mm long and 0.1 mm thick, needle- or lath-shaped, sometimes striated along the length due to twinning on $\{210\}$, and have six-sided cross sections. Crystal faces tend to be uneven and indistinct. The new mineral is black, opaque with a metallic luster and a black streak. The mineral is brittle with uneven fracture and no cleavage or parting. The microhardness (4 indentation) $\text{VHN}_{100} = 1493$ (1480–1506) kg/mm^2 corresponding to Mohs hardness of ~7. Density could not be measured because of paucity of material; $D_{\text{calc}} = 4.29$ g/cm^3 . Byrudite is gray in polarized reflected light with no internal reflections. It is nonpleochroic with a weak bireflectance and anisotropism. Reflectance values were measured between 400 and 700 nm in 20 nm intervals. The values for COM wavelengths [R_{min} , R_{max} % (λ in nm)] are: 16.6, 17.5 (470); 16.7, 17.9 (546); 16.8, 18.3 (589); 16.8, 18.6 (650) in air. The mineral is non-fluorescent in UV light. The average of 6 electron probe WDS analyses is [wt% (range)]: BeO 8.04 (by structure refinement), Al_2O_3 1.44 (1.29–1.63), V_2O_5 37.86 (37.27–38.82), Cr_2O_3 8.79 (8.33–9.54), Fe_2O_3 2.66 (2.54–2.79), TiO_2 38.36 (38.13–38.96) total 97.15. This gives the empirical formula $(\text{Be}_{0.84}\square_{0.16})(\text{V}_{1.32}^{3+}\text{Ti}_{1.25}\text{Cr}_{0.29}\text{Fe}_{0.09}\text{Al}_{0.07})_{\Sigma 3.02}\text{O}_6$ based on O = 6 apfu. The presence of Be was verified by secondary ion mass spectrometry but could not be quantified. Iron was treated as trivalent based on its ionic radius, and H_2O and CO_2 were not present according to the structure refinement. There is a strong inverse correlation between V and Cr. The strongest lines in the X-ray powder-diffraction pattern [d_{obs} (Å) ($I_{\text{obs}}\%$; hkl)] are: 3.721 (72; 111), 2.965 (100; 121), 2.561 (50; 311), 2.464 (41; 230), 2.167 (24; 231), 1.681 (34; 402), 1.671 (66; 232), 1.435 (23; 630). Single-crystal X-ray diffraction data refined to $R_1 = 0.045$ for 1413 unique reflections with $I \geq 4\sigma(I)$ shows byrudite is orthorhombic, space group $Pnma$, $a = 9.982(1)$, $b = 8.502(1)$, $c = 4.5480(6)$ Å, and $V = 385.97$ Å³; $Z = 4$. Byrudite is isotypic with norbergite [by analogy the ideal byrudite formula can be written $\text{V}_3^{3+}\text{Ti}(\text{BeO}_4)_2\text{O}_2$]; the structure consists of kinked chains of edge-sharing V and Ti octahedra interconnected by individual BeO_4 tetrahedra. Byrudite is named after the type locality at Byrud farm. Two cotype specimens are deposited in the Natural History Museum, University of Oslo, Norway. **O.C.G.**

Comment: The mineral is isotypic with norbergite which can have OH^- groups or F. Considering that no quantitative data for Be were obtained by direct measurements nor the absence of F, OH, or H_2O was confirmed by EMPA and FTIR or Raman, it is not evident why there should not be (OH) groups or F in this structure. Nevertheless, if the “sellaite” (MgF_2) component of norbergite is substituted by “rutile” (TiO_2) component, there would not be room for O-F, OH substitution. Charge balance from the Be-Si substitution would come from the M^{2+} - M^{3+} substitution in octahedra. Therefore, the ideal formula should be $\text{V}_3^{3+}(\text{BeO}_4)\text{TiO}_2$.

CAMPOSTRINIITE*

F. Demartin, C. Castellano, and C.M. Gramaccioli (2015) Campostriniite, $(\text{Bi}^{3+}, \text{Na})(\text{NH}_4, \text{K})_2\text{Na}_2(\text{SO}_4)_6 \cdot \text{H}_2\text{O}$, a new sulfate isostructural with górgeyite, from La Fossa Crater, Vulcano, Aeolian Islands, Italy. *Mineralogical Magazine*, 2015, 79(4), 1007–1018.

Campostriniite (IMA 2013-086a), with a general chemical formula $(\text{Bi}^{3+}, \text{Na})_3(\text{NH}_4, \text{K})_2\text{Na}_2(\text{SO}_4)_6 \cdot \text{H}_2\text{O}$, is a new mineral found at La Fossa Crater, Vulcano, Aeolian Islands, Sicily, Italy. Campostriniite was collected from an active fumarole (fumarole FA, temperature $\sim 350^\circ\text{C}$) on a pyroclastic breccia in association with adranosite, demicheleite-(Br), demicheleite-(I), argesite, and sassolite. Campostriniite occurs as prismatic crystals up to 0.2 mm long and shows no apparent twinning. The most commonly observed forms are: $\{20\bar{1}\}$, $\{221\}$, $\{102\}$, $\{112\}$. The mineral is white with white streak, has a vitreous luster and shows no cleavage or fracture. Density could not be measured due to solubility in the Clerici solution; $D_{\text{calc}} = 3.87 \text{ g/cm}^3$. Campostriniite is biaxial (sign undetermined), with the mean refractive index of $n > 1.68$ (the mineral reacts in a few minutes with liquids having a refractive index close to 1.70). No fluorescence was observed under SW or LW ultraviolet radiation. The FTIR spectrum shows absorption bands at 3071 and 1418 cm^{-1} , consistent with the presence of an NH_4^+ ion, together with absorptions due to the presence of sulfates and water. The average of 18 electron probe EDS analyses is [wt% (range)]: Bi_2O_3 46.65 (46.23–46.90), SO_3 40.33 (40.01–40.88), Na_2O 6.21 (6.10–6.60), K_2O 1.88 (1.75–1.91), $(\text{NH}_4)_2$ 3.28, H_2O 1.50, total 99.85. This gives the empirical formula $\text{Bi}_{2.41}\text{N}_{1.52}\text{Na}_{2.41}\text{K}_{0.48}\text{S}_{6.07}\text{H}_{8.08}\text{O}_{25}$ based on 25 anions pfu. The $(\text{NH}_4)_2\text{O}$ and H_2O content were calculated by stoichiometry. The strongest lines in the X-ray powder-diffraction pattern [d_{obs} Å ($I_{\text{obs}}\%$; hkl)] are: 6.396 (100; 110), 7.507 (75; $2\bar{0}2$), 2.766 (60; $3\bar{1}6$), 3.380 (57; 312), 5.677 (55; 111), 3.166 (50; 402). The unit-cell parameters refined from powder-diffraction data are: $a = 17.718(2)$, $b = 6.962(1)$, $c = 18.216(2)$ Å, and $\beta = 113.96(1)^\circ$. Single-crystal X-ray diffraction data refined to $R_1 = 0.051$ for 3025 unique reflections with $I \geq 2\sigma(I)$ shows campostriniite is monoclinic, space group $C2/c$ with $a = 17.748(3)$, $b = 6.982(1)$, $c = 18.221(3)$ Å, $\beta = 113.97(1)^\circ$, and $V = 2063 \text{ \AA}^3$; $Z = 4$. Campostriniite is isostructural with görgeyite. The structure contains two independent ninefold-coordinated sites occupied by Bi^{3+} atoms and significant amounts of Na^+ ions, an eightfold-coordinated site fully occupied by Na^+ ions and another eightfold-coordinated site occupied by NH_4^+ and K^+ ions, three independent sulfate anions and a water molecule coordinated to Bi^{3+} . The charge-balanced formula resulting from the structure refinement is $(\text{Bi}_{3.50}^{3+}, \text{Na}_{0.50})_{23}(\text{NH}_4)_{1.43}, \text{K}_{0.57}]_{22}\text{Na}_2(\text{SO}_4)_6 \cdot \text{H}_2\text{O}$. Campostriniite is named in honor of Italo Campostrini (b. 1959), a very active mineralogist especially in the study of volcanic sublimates. The holotype material is deposited in the Reference Collection of the Dipartimento di Chimica, Università degli Studi di Milano. **O.C.G.**

CANUTITE*

A.R. Kampf, S.J. Mills, F. Hatert, B.P. Nash, M. Dini, and A.A. Molina Donoso (2014) Canutite, $\text{NaMn}_3[\text{AsO}_4][\text{AsO}_3(\text{OH})]_2$, a new protonated alluaudite-group mineral from the Torrecillas mine, Iquique Province, Chile. *Mineralogical Magazine*, 78(4), 787–795.

Canutite (IMA 2013-070), ideally $\text{NaMn}_3[\text{AsO}_4][\text{AsO}_3(\text{OH})]_2$, is a new mineral found at two different locations at the Torrecillas mine, Salar Grande, Iquique Province, Chile. The Torrecillas deposit, which the Torrecillas mine exploits, consists of two main veins rich in secondary As and Cu minerals that intersect metamorphosed marine shales and lavas, genetically related to andesites and porphyritic lavas of the La Negra Formation. Canutite occurs as a secondary alteration phase in association with anhydrite, halite, lavendulan, magnesiokoritnigite, pyrite, quartz and scorodite, in three main sites in Torrecillas Hill: an upper pit measuring ~ 8 m long and 3 m deep, a lower pit ~ 100 m from the upper pit and measuring ~ 5 m long and 3 m deep and a mine shaft adjacent to the lower pit and lower on the hill. Crystals of canutite are reddish brown (light reddish brown in transmitted light) and occur as tapering prismatic to bladed crystals up to ~ 0.2 mm long along $[20\bar{1}]$ in radial aggregates (upper pit) and as isolated and intergrown thin to

thick diamond-shaped tablets flattened on $\{102\}$ up to ~ 0.2 mm across (small spot in the lower shaft). Crystals are transparent with vitreous luster and pale tan streak. It is brittle, with splintery fracture with perfect cleavages on $\{010\}$ and $\{101\}$. Mohs hardness ~ 2.5 . $D_{\text{calc}} = 4.112 \text{ g/cm}^3$. The mineral is slowly soluble in cold, dilute HCl. Optically, canutite is biaxial (+) with $\alpha = 1.712(3)$, $\beta = 1.725(3)$, $\gamma = 1.756(3)$ (white light), $2V_{\text{meas}} = 65.6(4)^\circ$; $Z = \mathbf{b}$; $X^{\wedge}\mathbf{a} = 18^\circ$ in obtuse β . The dispersion is $r < v$ (slight) and pleochroism is imperceptible. Average electron probe WDS analyses is [wt% (range), data for the specimens from upper pit and near shaft, respectively]: Na_2O 3.82 (3.05–4.44), 5.54 (4.86–6.30), CaO 0.52 (0.43–0.61), 0.04 (0.00–0.15), MgO 2.91 (2.35–3.28), 2.31 (1.43–4.31), MnO 27.88 (26.86–28.49), 31.80 (27.32–34.40), CoO 2.52 (2.12–2.77), 0.43 (0.28–0.61), CuO 1.40 (1.00–1.71), 1.88 (1.24–2.62), As_2O_5 60.27 (58.99–61.40), 58.45 (56.24–60.24), H_2O (on the basis of charge balance) 3.59, 2.48, total 102.91, 102.93. The empirical formula, calculated on the basis of 3 As and 12 O apfu for material from the upper pit is $(\text{Na}_{0.71}\text{Ca}_{0.05}\text{Mn}_{2.25}\text{Mg}_{0.41}\text{Co}_{0.19}\text{Cu}_{0.10})_{23.71}\text{As}_3\text{O}_{12}\text{H}_{2.28}$ and that for material from near the shaft is $(\text{Na}_{1.05}\text{Mn}_{2.64}\text{Mg}_{0.34}\text{Co}_{0.03}\text{Cu}_{0.14})_{24.20}\text{As}_3\text{O}_{12}\text{H}_{1.62}$. The strongest X-ray powder diffraction (pseudo-Gandolfi) lines [d Å ($I\%$; hkl)] are: 6.33 (34; 020), 4.12 (26; 221), 3.608 (29; 310, $\bar{1}31$), 3.296 (57; $\bar{1}12$), 3.150 (28; 002, $\bar{1}31$), 2.819 (42; 400, 041, 330), 2.740 (100; 240, $\bar{4}02$, 112), 1.5364 (31; multiple). The unit-cell parameters refined from the powder data are: $a = 12.352(3)$, $b = 12.623(3)$, $c = 6.881(3)$ Å, $\beta = 113.491(7)^\circ$, and $V = 984.1 \text{ \AA}^3$. X-ray single-crystal diffraction study of canutite [refined to $R_1 = 0.023$ for 1089 unique $F > 4\sigma(F)$ reflections] on crystal fragments of $170 \times 110 \times 70 \mu\text{m}$ shows the mineral is monoclinic, space group $C2/c$; $a = 12.3282(4)$, $b = 12.6039(5)$, $c = 6.8814(5)$ Å, $\beta = 113.480(8)^\circ$, and $V = 980.72(10) \text{ \AA}^3$, $Z = 4$. Canutite is isostructural with protonated members of the alluaudite group. The mineral name honors Claudio Canut de Bon Urrutia (b. 1937), Chilean mining engineer and Senior Professor of Geology and Mineralogy at La Serena University. Two cotype specimens are deposited in the Natural History Museum of Los Angeles County, California, U.S.A. **F.C.**

ERICLAXMANITE* AND KOZYREVSKITE*

I.V. Pekov, N.V. Zubkova, V.O. Yapaskurt, D.I. Belakovskiy, M.F. Viganina, E.G. Sidorov, and D.Yu. Pushcharovsky (2014) New arsenate minerals from the Arsenatnaya fumarole, Tolbachik volcano, Kamchatka, Russia. II. Ericlaxmanite and kozyrevskite, two natural modifications of $\text{Cu}_4\text{O}(\text{AsO}_4)_2$. *Mineralogical Magazine*, 78(7), 1553–1569.

Two new natural polymorphs of $\text{Cu}_4\text{O}(\text{AsO}_4)_2$, triclinic ericlxmanite (IMA 2013-022) and orthorhombic kozyrevskite (IMA 2013-023), were discovered among sublimates of the Arsenatnaya fumarole at the Second scoria cone of the Northern Breakthrough of the Great Tolbachik Fissure Eruption, Tolbachik volcano, Kamchatka, Russia. They are closely associated with each other and with urusovite, lammerite, lammerite- β , popovite, and alarsite. Other associated minerals include anhydrous arsenates (johillerite, bradaczekite, shchurovskite dmsokolovite) and sulfates (aphthalite, langbeinite, anhydrite, calciolangbeinite, arcanite, wulfite, krashenninnikovite, steklite, palmierite), as well as tenorite, hematite, As-orthoclase, Cu-gahnite, and OH-free fluoborite. All listed minerals form complex incrustations up to 0.5 cm thick on the surface of basalt scoria in open pockets uncovered in the interval from 0.3 to 0.8 m deep from the surface. The temperature measured inside these pockets during collecting in July 2013 was $360\text{--}380^\circ\text{C}$. It is supposed that all minerals listed above were deposited directly from the gas or were formed as the result of gas-rock interactions at temperatures not less than 380°C . The sequence of minerals deposition demonstrates an increase of the Cu/Al ratio in arsenates formed in the fumarole which probably related to a decrease in gas temperature. Ericlaxmanite forms green to dark green tabular, lamellar, equant or short prismatic crystals up to

0.1 mm, their clusters and partial pseudomorphs after urusovite crystal crusts up to 1.5×2 cm. Kozyrevskite occurs as bright grass green to light yellowish green individual prismatic crystals up to 0.3 mm elongated by [010] or their clusters overgrowing other arsenates. Both minerals are transparent with a vitreous luster and are brittle, with Mohs hardness ~3. Density was not measured because of the paucity of pure material; D_{calc} is 5.036 (ericlaxmanite) and 4.934 (kozyrevskite) g/cm³. Both minerals are optically biaxial (-). Ericlaxmanite is strongly pleochroic Z (bright green) $> Y$ (green) $> X$ (very pale green); $\alpha = 1.870(10)$, $\beta = 1.900(10)$, $\gamma = 1.915(10)$ (589 nm); estimated $2V = 60(15)^\circ$, $2V_{\text{calc}} = 70^\circ$, $r > v$ weak. Kozyrevskite has distinct pleochroism $X > Y, Z$ (yellowish-green); $\alpha = 1.885(8)$, $\beta = 1.895(8)$, $\gamma = 1.900(8)$ (589 nm); estimated $2V = 75(10)^\circ$, $2V_{\text{calc}} = 70^\circ$, $r > v$ strong, $X = \mathbf{b}$. The Raman spectra of ericlaxmanite and kozyrevskite are quite different. In both bands at 700–900 cm⁻¹ correspond to As⁵⁺-O stretching vibrations of AsO₄³⁻ ions and bands with frequencies lower than 550 cm⁻¹ correspond to As⁵⁺-O bending vibrations and Cu²⁺-O stretching vibrations. An absence of bands with frequencies greater than 950 cm⁻¹ indicates the absence of groups with O-H, C-H, C-O, N-H, N-O, and B-O bonds. The average values of the electron probe WDS analysis [wt% (range)] for ericlaxmanite (6 points) and / kozyrevskite (4 points) are: CuO 57.55 (56.95–57.88) / 58.06 (56.67–58.79), ZnO 0.90 (0.58–1.27) / 1.04 (0.69–1.31), Fe₂O₃ 0.26 (0–0.90) / 0.12 (0–0.49), SiO₂ n.d. / 0.12 (0–0.46), P₂O₅ 0.23 (0–0.49) / 1.23 (0–2.89), V₂O₅ 0.14 (0–0.43) / 0.37 (0–0.84), As₂O₃ 40.57 (39.54–41.82) / 38.78 (36.82–39.58), SO₃ 0.17 (0–0.57) / 0.43 (0–0.86), total 99.82 / 100.15. The corresponding empirical formulae, based on 9 O apfu, are: (Cu_{3.97}Zn_{0.06}Fe_{0.02})_{24.05}(As_{1.94}P_{0.02}V_{0.01}Si_{0.01})_{21.98}O₉ for ericlaxmanite and (Cu_{3.95}Zn_{0.07}Fe_{0.01})_{24.03}(As_{1.83}P_{0.09}S_{0.03}V_{0.02}Si_{0.01})_{21.98}O₉ for kozyrevskite. The strongest reflections of the X-ray powder diffraction patterns [d Å (hkl)] for ericlaxmanite: 3.868 (46; 101), 3.685 (100; 020), 3.063 (71; 012), 2.957 (58; 022), 2.777 (98; 212, 211), 2.698 (46; 212), 2.201 (51; 013, 031); and for kozyrevskite: 3.728 (34; 013), 3.455 (100; 004), 3.194 (72; 020, 104), 2.910 (69; 022), 2.732 (82; 122), 2.712 (87; 301), 2.509 (92; 123). According to the single-crystal X-ray study

ericlaxmanite is triclinic, $P\bar{1}$, $a = 6.4271(4)$, $b = 7.6585(4)$, $c = 8.2249(3)$ Å, $\alpha = 98.396(4)$, $\beta = 112.420(5)$, $\gamma = 98.397(5)^\circ$, $V = 361.11$ Å³; $Z = 2$. Kozyrevskite is orthorhombic, $Pnma$, $a = 8.2581(4)$, $b = 6.4026(4)$, $c = 13.8047(12)$ Å, $V = 729.90$ Å³; $Z = 4$. The structure models were obtained by direct methods and refined to $R = 0.0358$ for ericlaxmanite and to $R = 0.1049$ (due to poor quality of the divergent crystals) for kozyrevskite based on 1616 and 629 independent [$I > 2\sigma(I)$] reflections. The ericlaxmanite structure is based on an interrupted framework of edge- and corner-sharing Cu-centered, distorted tetragonal pyramids, trigonal bipyramids and octahedra. There are 4 main independent Cu sites. The Cu(1–4) polyhedra form layers coplanar to (010). The linkage between the layers is reinforced by isolated AsO₄ tetrahedra of two independent As sites. AsO₄ tetrahedra share common vertices with Cu polyhedra of adjacent layers. The crystal structure of kozyrevskite is based on complicated ribbons of Cu-centered polyhedra running along the \mathbf{b} axis. Each ribbon consists of two zigzag chains formed by edge-sharing Cu(1)-centered, distorted trigonal bipyramids and Cu(2)-centered square pyramids. Cu(3) trigonal bipyramids link adjacent chains sharing edges with two Cu(2)-centered polyhedra belonging to the same chain and one Cu(1)-centered polyhedron belonging to another chain. As(1) tetrahedra link adjacent ribbons of Cu-centered polyhedra forming heteropolyhedral layers coplanar to (001) while As(2) tetrahedra link neighboring layers to form a three-dimensional quasi-framework. The structure data obtained is very close to that of the synthetic analog of kozyrevskite. Ericlaxmanite is named in honor of the Russian mineralogist, geologist, geographer, biologist and chemist Eric Laxman (1737–1796) for his great contributions to the study of the Eastern Siberia natural history. Kozyrevskite is named in honor of the Russian geographer and traveler, Cossack officer Ivan Petrovich Kozyrevskiy (1680–1734), one of the first researchers of Kamchatka and the Kuril Islands who made the first map of the East Coast of the Kamchatka Peninsula in 1726. The type specimens of ericlaxmanite and kozyrevskite are deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **D.B.**

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