

New Mineral Names*†‡

DMITRIY I. BELAKOVSKIY¹ AND YULIA UVAROVA²¹Fersman Mineralogical Museum, Russian Academy of Sciences, Leninskiy Prospekt 18 korp. 2, Moscow 119071, Russia²CSIRO Mineral Resources, ARRC, 26 Dick Perry Avenue, Kensington, Western Australia 6151, Australia

IN THIS ISSUE

This New Mineral Names has entries for 11 new species, including bohushlavite, fanfaniite, ferrierite-NH₄, feynmanite, hjalmarite, kennigottite, potassic-richterite, rockbridgeite-group minerals (ferrirockbridgeite and ferro-rockbridgeite), rudabányaite, and strontioferlofite.

BOHUSHLAVITE*

D. Mauro, C. Biagoni, E. Bonaccorsi, U. Hälenius, M. Pasero, H. Skogby, F. Zaccarini, J. Sejkora, J. Plášil, A.R. Kampf, J. Filip, P. Novotný, R. Škoda, and T. Witzke (2019) Bohushlavite, Fe₃⁺(PO₄)₃(SO₄)(OH)(H₂O)₁₀·*n*H₂O, a new hydrated iron phosphate-sulfate. European Journal of Mineralogy, 31(5-6), 1033–1046.

Bohushlavite (2018-074a), ideally Fe₃⁺(PO₄)₃(SO₄)(OH)(H₂O)₁₀·*n*H₂O, triclinic, was discovered in two occurrences, in the Buca della Vena baryte ± iron oxides ± pyrite ore deposit, Stazzema, Apuan Alps, Tuscany, Italy (43°59'55"N; 10°18'37"E), and at the abandoned adit (Petr's level, area of Reichenglück shaft and t. Anton de Padua Gallery) at the Horní Město deposit near Rýmařov, Czech Republic (49°54'40.2"N; 17°13'04.6"E). The Buca della Vena mine (BdV) is located at the contact between a metavolcanic-metasiliciclastic sequence of the Paleozoic basement and the Triassic metadolostone. The Horní Město (HM) ore deposit is represented by metamorphosed Fe–Zn–Pb–(Ag) sulfide mineralization of Devonian age in Devonian volcano-sedimentary rocks of the Vrbno group. In the BdV bohushlavite occurs in fractures in pyrite-rich phyllite in association with gypsum, and occasionally, in vugs of quartz-albite veins in association with pyrite. At the HM it was found in fissures of quartz-carbonate veins with gypsum. Bohushlavite forms globular aggregates up to 1 mm of pseudo-hexagonal tabular {001} crystals up to 250 μm. Minor forms are: {100}, {111}, {111}, {110}, {010}, {011}. Bohushlavite is colorless to pinkish or lilac under incandescent light and white to yellowish under sunlight. It has a white streak, vitreous luster, and does not fluoresce under UV light. The mineral is brittle with an irregular fracture, perfect cleavage on {001}, Mohs hardness ~3; *D*_{meas} = 2.05(2) (BdV) and 2.09(1) g/cm³ (HM) (fitting higher H₂O content than calculated ones); *D*_{calc} is 1.856 and 1.782 g/cm³, respectively. Bohushlavite is non-pleochroic, optically biaxial (–), α = 1.537(2), β = 1.567 (1), γ = 1.568(1) (white light), 2*V*_{meas} = 16(3)°, (BdV) and α = 1.550(2), β = 1.579(1), γ = 1.579(1) (white light), 2*V*_{meas} = 15–10° (HM). The dispersion of optical axes is slight, *r* > *v* (BdV), and was not observed in the samples from HM; *X* ≈ *c*. The Raman spectra of bohushlavite of both localities are similar and show broad band between 3600 and 3000 cm⁻¹ with two main features at ~3450 and 3230 cm⁻¹; at 1630; and at (cm⁻¹): 1102 (SO₄ stretching), 1010 (PO₄ stretching), 612, 453 (*v*₂ and *v*₄ SO₄ bending), 381 (PO₄ bending); 326, 286, 193 (Fe–O stretching and bending and the lattice modes). Unpolarized FTIR spectra (BdV) also

show a very strong and broad absorption in the O–H stretching region (3600–3000 cm⁻¹) and a prominent band at 1630 (H–O–H bending) with a shoulder indicating two slightly different H₂O environments in the structure. The weaker band at ~5100 cm⁻¹ is assigned to H₂O combination mode (bending + stretching). The IR spectrum of bohushlavite from HM shows bands at: 3350, 3103, 1626, 1100, 977, 828, 750, 570, and 472 cm⁻¹. Polarized optical absorption spectra show absorption bands due to electronic transitions in octahedrally coordinated Fe³⁺ at 23 475, 22 000, and 18 250 cm⁻¹. The averaged 10-point WDS electron probe analyses are [wt% (range) (BdV) / wt% (range) (HM)]: SO₃ 10.92 (10.31–11.62) / 9.32 (8.38–10.64), P₂O₅ 25.34 (24.42–26.74) / 24.84 (23.85–25.61), Al₂O₃ 0.26 (0.11–0.56) / 0.30 (0–0.75), Fe₂O₃ 40.70 (39.61–41.43) / 36.63 (35.30–37.84), H₂O (TGA) (35.96 / 32.49, total 113.18 / 103.58. Mössbauer spectra for both localities show no evidence of the Fe²⁺ presence. The empirical formulae based on 4 (Fe³⁺+Al) pfu are: (Fe_{3.96}Al_{0.04})(SO₄)_{1.06}(PO₄)_{2.77}(OH)_{1.56}(H₂O)₁₀·7.90H₂O / (Fe_{3.95}Al_{0.05})(SO₄)_{1.00}(PO₄)_{3.02}(OH)_{0.94}(H₂O)₁₀·5.08H₂O. The strongest lines of the powder X-ray diffraction pattern (BdV) are [*d* Å (*I*%; *hkl*)]: 11.34 (100; 110,001), 8.01 (13, 101), 5.71 (14; 111,121,211), 5.14 (10; 021,221,221,012), 4.359 (16; 310,120,112). The crystal structure was solved by direct methods and refined to *R*₁ = 2.32% on the holotype specimen. Bohushlavite is triclinic, *P*1, *a* = 13.376(3), *b* = 13.338(3), *c* = 10.863(4) Å, α = 92.80(2), β = 91.03(2), γ = 119.92(2)°, *V* = 1675.7 Å³, *Z* = 2. Its crystal structure is based on {001} heteropolyhedral [Fe₃(PO₄)₃O(OH)(H₂O)₁₀] layers decorated on both sides by SO₄ groups. Additional H₂O groups are hosted in the interlayers and in the [001] channels. The name honors Czech mineralogist and geologist Bohuslav Fojt for his contributions to mineralogy and economic geology. The holotype specimen (BdV) is deposited in the Museo di Storia Naturale, University of Pisa, Pisa, Italy. A cotypes specimens from both localities are housed in the Natural History Museum of Los Angeles County, Los Angeles, U.S.A. Cotype from HM is deposited in the Department of Mineralogy and Petrology, National Museum Prague, Prague, Czech Republic. **Yu.U.**

FANFANIITE*

I.E. Grey, A.R. Kampf, J.B. Smith, C.M. Macrae, and E. Keck (2019) Fanfaniite, Ca₄Mn²⁺Al₄(PO₄)₆(OH,F)₄·12H₂O, a new mineral with a montgomeryite-type structure. European Journal of Mineralogy, 31(3), 647–652.

Fanfaniite (IMA2018-053), ideally Ca₄Mn²⁺Al₄(PO₄)₆(OH,F)₄·12H₂O, monoclinic, is a new secondary phosphate mineral discovered at two famous mineral localities: Foote Lithium Company mine, Kings Mountain district, Cleveland Co., North Carolina, USA (35°12'40" N, 81°21'20" W). and Hagendorf-Süd pegmatite, Hagendorf, Oberpfalz,

* 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://cnmnc.main.jp/> (click on "IMA list of minerals").

Bavaria, Germany (49°39'1" N, 12°27'35" E). The mineral was first reported by Mücke (1987) from Hagendorf-Süd pegmatite under the name "kingsmountite-Mn" with the proposed the formula $(\text{Ca},\text{Zn})_4\text{MnAl}_4(\text{PO}_4)_6(\text{OH},\text{Cl})_4 \cdot 12\text{H}_2\text{O}$ and later characterized by electron probe analyses (Grey et al. 2010). The new sample from Foote mine allowed to perform crystal structure study and finish the new mineral proposal. Fanfaniite from the Foote mine forms radial aggregates up to 0.5 mm in diameter of thin, translucent white pearly blades up to $10 \times 50 \times 200 \mu\text{m}$ flattened on {010} and elongated on [001], with {010} the only discernible form. It is associated with whiteite-(CaMnMn). At Hagendorf-Süd, the mineral occurs as isolated very thin laths on the surface of fibrous spheroids of kayrobertsonite and is associated with altered triplite-zwieselite, whiteite-(CaMnMn), fluorapatite, nordgauite, morinite, fluellite, and Al-bearing strunzite. The blades are flexible and elastic with good cleavage on {010}. Hardness is not reported; $D_{\text{meas}} = 2.58(2)$, $D_{\text{calc}} = 2.58 \text{ g/cm}^3$. Fanfaniite (Foot mine) is optically biaxial (-), $\alpha = 1.573(2)$, $\beta = 1.582(2)$, $\gamma = 1.585(2)$ (white light), $2V = 57(1)^\circ$; $Z = \mathbf{b}$, $X \wedge c \approx 40^\circ$ in β obtuse. Dispersion was not observed. Pleochroism was not evident. The averages of 14 (Foot mine) and 8 (Hagendorf-Süd) electron probe WDS analysis [wt% (range) Foot mine / wt% (SD) Hagendorf] are: ZnO 0.15 (0–0.39) / 0.52 (0.30), MnO 4.51 (3.85–4.78) / 4.26 (0.85), MgO 0.33 (0.20–0.51) / 0.85 (0.14), CaO 18.10 (17.55–18.72) / 16.5 (1.5), Al_2O_3 16.39 (15.27–17.06) / 15.6 (1.0), Fe_2O_3 1.39 (0.85–2.43) / 1.84 (0.18), P_2O_5 35.14 (34.12–36.44) / 33.50 (0.85), F n.d. / 1.64 (0.29), $-\text{O}=\text{F}_2 \text{ O} / 0.69$, subtotal 76.01 / 74.02; H_2O 21.5 (by structure), total 97.51 / 95.52. The low totals are most likely due to the electron beam penetrating the very thin blades. The empirical formulae normalized to 6 P and 40 anions, with OH adjusted for charge balance are $\text{Ca}_{3.91}\text{Mn}_{0.77}^{2+}\text{Mg}_{0.10}\text{Zn}_{0.02}\text{Al}_{3.89}\text{Fe}_{0.21}^{3+}(\text{PO}_4)_6(\text{OH})_{3.90}(\text{H}_2\text{O})_{12.10}$ (Foote mine) and $\text{Ca}_{3.73}\text{Mn}_{0.76}\text{Mg}_{0.25}\text{Zn}_{0.08}\text{Al}_{3.89}\text{Fe}_{0.29}^{3+}(\text{PO}_4)_6\text{F}_{1.10}(\text{OH})_{3.08}(\text{H}_2\text{O})_{11.82}$ (Hagendorf-Süd). The strongest peaks in the powder X-ray diffraction pattern are [$d \text{ \AA}$, (I %; hkl)]: 12.14 (33; 020), 5.13 (97; 111), 3.137 (28; 260), 2.938 (100; 112), 2.817 (19; 261), 2.618 (70; 052,341), 2.249 (25; 302), 1.740 (22; 303,333). Unit-cell parameters refined from the powder data with whole-pattern fitting are $a = 10.039(5) \text{ \AA}$, $b = 24.198(5) \text{ \AA}$, $c = 6.261(5) \text{ \AA}$, $\beta = 91.50(2)^\circ$, $V = 1520.4 \text{ \AA}^3$. The single-crystal data obtained using synchrotron monochromatic radiation ($\lambda = 0.7107 \text{ \AA}$) at 100 K shows the mineral is monoclinic, space group $C2/c$, $a = 10.021(4) \text{ \AA}$, $b = 24.137(5) \text{ \AA}$, $c = 6.226(3) \text{ \AA}$, $\beta = 91.54(2)^\circ$, $V = 1505 \text{ \AA}^3$, $Z = 2$. The crystal structure was refined to $R_{\text{obs}} = 0.043$ for all 1909 unique reflections. In the structure the heteropolyhedral layers parallel to (010) is based on [100] zigzag chains of corner-connected Al-centered octahedra that are linked along [001] via corner-sharing with PO_4 tetrahedra. The eightfold-coordinated Ca2 polyhedra form part of the layer structure, while the eightfold-coordinated Ca1-centred polyhedra and Mn-centered octahedra occupy sites on the surface of the layers. The $\text{Ca1O}_4(\text{H}_2\text{O})_4$ polyhedra share edges through the O of water molecules to form chains along [001]. Fanfaniite is related to calcioferriite, montgomeryite, kingsmountite, and zodacite having same general formula, $\text{Ca}_4A^{2+}B^{3+}(\text{PO}_4)_6(\text{OH})_4 \cdot 12\text{H}_2\text{O}$ and similar unit-cells (A^{2+} and $B^{3+} = \text{Mg}$ and Fe for calcioferriite, Mg and Al for montgomeryite, Fe^{2+} and Al for kingsmountite, and Mn and Fe for zodacite. Fanfaniite is the Mn^{2+} -dominant analogue of montgomeryite and could be considered as Mn^{2+} analogue of kingsmountite. However, a re-investigation of kingsmountite holotype shows lowering of the symmetry to triclinic results in splitting of the Ca sites into four independent sites, one of which is dominated by Mn. The new mineral name honors Luca Fanfani Italian geochemist, mineralogist and crystallographer who structurally characterized many phosphate minerals including montgomeryite. One holotype specimen and one cotype specimen from the Foote mine are deposited in the Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A. The Hagendorf-Süd cotype specimen is housed in the Museum Victoria, Melbourne, Australia. **D.B.**

References cited

- Grey, I.E., Mumme, W.G., Neville, S.M., Wilson, N.C., and Birch, W.D. (2010) Jahnsite-whiteite solid solutions and associated minerals in the phosphate pegmatite at Hagendorf-Süd, Bavaria, Germany. *Mineralogical Magazine*, 74, 969–978.
- Mücke, A. (1987) Sekundäre Phosphatminerale (Perloffit, Brasilianit, Mineralien der Kingsmountit-Gruppe) sowie Brochantit und die Zwieselit-Muschketoffit-Stilpnomelan-Pyrosomalith-Paragenese der 115-m-Sohle des Hagendorfer Pegmatits. *Aufschluss*, 38, 5–28.
- FERRIERITE-NH₄***
- N.V. Chukanov, I.V. Pekov, J. Sejkora, J. Plášil, D.I. Belakovskiy, and S.N. Britvin (2019) Ferrierite-NH₄, $(\text{NH}_4, \text{Mg}_{0.5})_5(\text{Al}_5\text{Si}_3\text{O}_{72}) \cdot 22\text{H}_2\text{O}$, a new zeolite mineral from Northern Bohemia, Czech Republic. *Canadian Mineralogist*, 57(1), 81–90.

Ferrierite-NH₄ (IMA 2017-099), ideally $(\text{NH}_4, \text{Mg}_{0.5})_5(\text{Al}_5\text{Si}_3\text{O}_{72}) \cdot 22\text{H}_2\text{O}$, orthorhombic, is a new zeolite-group mineral found as a relatively abundant phase in two open coal pits at Libouš (holotype) and Bílina, both located in the Miocene Most Basin, northern Bohemia, Czech Republic. At Libouš, ferrierite-NH₄ was collected from the base of the main coal seam, where it forms aggregates of elongated tabular crystals or fine fibrous aggregates in fractures in siderite nodules. Associated species are calcite, siderite, whewellite, quartz, opal, baryte, and clay minerals. Ferrierite-NH₄ was also discovered in the eastern margin of the Libouš open pit in the hanging wall of the main coal seam. There is a 1.5 m thick layer of carbonaceous shale above the coal seam, and it contains abundant small siderite concretions with radiating aggregates of the new mineral. At Bílina, ferrierite-NH₄ was found near the Bílina fault in fractures of carbonate concretions and in siderite and sandstone bands in the base of the main coal seam. Here it is associated with marcasite, pyrite, baryte, sphalerite, and supergene gypsum. At Libouš, the mineral forms white radiating aggregates up to 1.5 mm across that have silky luster. These aggregates consist of thin flattened prismatic crystals elongated along (001) and grow on pelosiderite rocks consisting of siderite, opal, kaolinite, goethite, and organic matter. Individual crystals are brittle to flexible, transparent and have vitreous luster. At Libouš, the new mineral also forms abundant white aggregates composed of flexible fibers 1 to 5 μm thick. In other occurrences in the Libouš and Bílina open pits, radiating aggregates of ferrierite-NH₄ up to 2 mm across are most common, but there are also random aggregates of thin fibers covering an area of several cm^2 . Cleavage is not observed. $D_{\text{calc}} = 2.154 \text{ g/cm}^3$. Ferrierite-NH₄ has intense bluish white fluorescence under the short- (254 nm) and long-wave (366 nm) UV light. Under microscope it is colorless, non-pleochroic, optically biaxial (+), $\alpha = 1.518(2)$, $\beta = 1.520(2)$, $\gamma = 1.522(2)$ ($\lambda = 589 \text{ nm}$), $2V_{\text{calc}} \approx 90^\circ$; $Z = \mathbf{c}$. The IR spectrum of ferrierite-NH₄ has the bands at (cm^{-1} ; s – strong band, w – weak band, sh – shoulder): 3610w, 3565sh, 3360w (O-H stretching of H₂O groups); 3250, 3220sh (N-H stretching of NH₄⁺); 1646 (H₂O groups bending); 1474 (NH₄⁺ bending); 1216s, 1076s, 1060sh (tetrahedral framework stretching); 791, 730, 707, 681, 647w, 564s, 530sh (mixed vibrations of the tetrahedral framework); 474s and 435s (lattice modes and libration H₂O modes). The average of five EDS electron probe analyses is [wt%, (range)]: Na₂O 0.24 (0–0.43), MgO 1.63 (1.52–1.74), Al_2O_3 10.48 (10.14–10.79), SiO₂ 69.44 (69.07–69.81), (NH₄)₂O 2.7(±0.2), H₂O_{calc} 14.8 ± 0.6, total 99.29. Hydrogen and nitrogen were measured by gas chromatography of the products of ignition at 1200° in an oxygen flow. The amount of H₂O was calculated by subtraction of H₂O formed because of oxidation of NH₄⁺ from the total measured water content from crystal structure. The empirical formula is $\text{H}_{0.35}[(\text{NH}_4)_{2.74}\text{Mg}_{1.07}\text{Na}_{0.21}](\text{Al}_{5.44}\text{Si}_{3.06}\text{O}_{72}) \cdot 22\text{H}_2\text{O}$ based on 36 (Si+Al) pfu. The strongest lines in the powder X-ray diffraction pattern are [$d \text{ \AA}$ (I %; hkl)]: 9.52 (97; 200), 6.95 (28; 101), 6.60 (19; 011), 3.988 (61; 321,031,420), 3.784 (19; 330), 3.547 (73; 112,040), 3.482 (100; 202), 3.143 (37; 312). The unit-cell parameters refined from the powder XRD data are $a = 19.10(1)$, $b = 14.15(1)$, $c = 7.489(3) \text{ \AA}$, V

= 2024 Å³. The single-crystal XRD data shows ferrierite-NH₄ is orthorhombic, *Immm*, *a* = 19.1444(18), *b* = 14.1633(13), *c* = 7.4905(5) Å, *V* = 2031.0 Å³, *Z* = 1. The crystal structure was not solved because of the poor quality of crystals but is isostructural with ferrierite-K and its synthetic NH₄ analogue based on properties and powder X-ray data similarity. The mineral named by analogy with other ferrierite-series zeolites: ferrierite-Na, ferrierite-K, and ferrierite-Mg. The holotype specimen of ferrierite-NH₄ is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **Yu.U.**

FEYNNMANITE*

A.R. Kampf, T.A. Olds, J. Plášil, J. Marty, and S.N. Perry (2019) Feynmanite, a new sodium uranyl sulfate mineral from Red Canyon, San Juan County, Utah, USA. *Mineralogical Magazine*, 83(2), 153–160.

Feynmanite, (IMA 2017-035), ideally Na(UO₂)(SO₄)(OH)·3.5H₂O, monoclinic, was discovered underground in the Blue Lizard and the Markey mines as a rare mineral in the secondary mineral assemblages and at both locations on pyrite-rich asphaltum matrix. At the Blue Lizard mine, it occurs in association with chinleite-(Y), gypsum, goethite, natrojarosite, natrozippeite, plášilite, and shumwayite. At the Markey mine, it occurs in association with chinleite-(Y), gypsum, natrojarosite, natrozippeite, plášilite, and wetherillite. Numerous other secondary minerals have been found at both mines. Feynmanite crystals are very prone to dehydration, forming fine-grained plášilite. The new mineral forms thin needles or blades up to 0.1 mm long, and the crystals grow in random “jackstraw” aggregates. The blades are flattened on {010} and elongate on [100]. They display {010}, {001}, {101}, and {101} forms; no twinning was observed. Feynmanite is pale greenish yellow with a white streak. It fluoresces in bright greenish white under the 405 nm laser. Individual crystals are transparent and have vitreous luster. It is brittle with irregular curved fracture, one perfect cleavage on {010} and Mohs hardness ~2. The density was not measured due to the tiny size of crystals; *D*_{calc} = 3.324 g/cm³. Feynmanite dissolves very slowly in water at room temperature and immediately in dilute HCl. It is optically biaxial (–), with *α* = 1.534(2), *β* = 1.561(2), *γ* = 1.571(2) (white light), 2*V* = 62(2)°; *X* = **b**, *Y* ≈ **a**, *Z* ≈ **c**. Dispersion is unnoticeable. Feynmanite is weakly pleochroic: *X* – colorless < *Y* – very pale green-yellow < *Z* – pale green-yellow. The Raman spectrum shows the bands (cm⁻¹; s – strong band, w – weak band, sh – shoulder): 1219w and 1189w [split triply degenerate *v*₃(SO₄)²⁻ antisymmetric stretching]; 1075m-s, 1042m-s, and 1006m-s [*v*₁(SO₄)²⁻ symmetric stretching]; 846s [*v*₁(UO₂)²⁺ symmetric stretching]; 911w [*v*₃(UO₂)²⁺ antisymmetric stretching]; 658w and 612w [split, triply degenerate *v*₂(δ)(SO₄)²⁻ bending]; 484 and 454 [split doubly degenerate *v*₂(δ)(SO₄)²⁻ bending]; 358w [either due to *v*(U–O_{equatorial}) stretching or Na–O stretches]; 249, 219, 194, and 176 [*v*₂(δ)U–O–U bending modes]; remaining bands at <150 cm⁻¹ are assigned to external lattice vibration modes. The IR spectrum contains bands at (cm⁻¹; s – strong band, w – weak band, sh – shoulder): 3381s, 3517s, 3220sh [stretching vibrations *v*(OH)], broad and low intensity bands between 2345–2070 [combination bands (δ H₂O and L H₂O)]; 1639m-s and 1628m-s [*v*₂(δ)-bending vibrations of structurally unique H₂O groups]; 1190, 1116, and 1048 [triply degenerate *v*₃(SO₄)²⁻ antisymmetric stretching]; 1011sh [*v*₁(SO₄)²⁻ symmetric stretching]; 909s [*v*₃(UO₂)²⁺ antisymmetric stretching]; 818s (δ U–OH out-of-plane bending mode); 669w [*v*₄(SO₄)²⁻ coinciding with either *γ* U–OH out-of-plane bending or librations of H₂O groups]. The average of three WDS electron probe analyses is [wt% (range)]: Na₂O 5.56 (5.13–6.43), FeO 0.13 (0.01–0.25), UO₃ 61.77 (58.75–64.05), SO₃ 17.19 (16.82–17.88), H₂O (by stoichiometry), 15.35, total 100.00. The empirical formula based on O = 10.5 pfu is (Na_{0.84}Fe_{0.01})(U_{1.01}O₂)(S_{1.01}O₄)(OH)·3.5H₂O. The strongest lines in the powder X-ray diffraction pattern of feynmanite are [*d* Å (*I*%; *hkl*)]: 8.37 (100; 010), 6.37 (33; 101,101), 5.07 (27; 111,111), 4.053 (46; 004,021), 3.578 (34; 120). The

crystal structure was solved by direct methods for a single crystal from the Markey mine and refined to *R*₁ = 3.71%. Feynmanite is monoclinic, *P2₁/n*, *a* = 6.927(3), *b* = 8.355(4), *c* = 16.210(7) Å, *β* = 90.543(4)°, *V* = 938.1(7) Å³, *Z* = 4. The crystal structure of feynmanite is based on edge-sharing pairs of pentagonal bipyramids that are linked by sharing corners with [SO₄] groups, forming a [(UO₂)₂(SO₄)₂(OH)]₂²⁻ sheet based on the phosphuranylite anion topology. The [(UO₂)₂(SO₄)₂(OH)]₂²⁻ sheet is topologically identical to those in deliensite, johannite and plášilite. The dehydration of feynmanite to plášilite results in interlayer collapse involving geometric reconfiguration of the sheets and the ordering of Na. The mineral name honors Richard Feynman, famous American physicist and a Nobel Prize winner in Physics. Four cotype specimens from Blue Lizard and Markey mines are deposited in the Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A. **Yu.U.**

HJALMARITE*

D. Holstam, F. Cámara, H. Skogby, and A. Karlsson (2019) Hjalmarite, a new Na–Mn member of the amphibole supergroup, from Mn skarn in the Långban deposit, Värmland, Sweden. *European Journal of Mineralogy*, 31(3), 565–574.

Hjalmarite (IMA 2017-070), ideally ^ANa^B(NaMn)^CMg₃^TSi₈O₂₂^W(OH)₂, is a new root-name member of the amphibole supergroup related to richterite via the homovalent substitution ^BCa²⁺ → ^BMn²⁺, corresponding to “root name 13” in the current amphibole supergroup nomenclature (Hawthorne et al. 2012). Hjalmarite was discovered in the famous Långban Fe–Mn–(Ba–As–Pb–Sb–Be–B) skarn deposit, Filipstad, Värmland, Sweden. A similar Mn-rich mineral (with higher CaO of 5.83 wt% and lower Na₂O of 4.02 wt%) from Långban was described under the name “astochit” by Sjögren (1891). Chosen mineral name honors of S.A. Hjalmar Sjögren (1856–1922), a Swedish geologist and mineralogist, a pioneer in the mineralogical investigations of the Långban-type deposits in the Bergslagen and curator at the Mineralogical Department, Swedish Museum of Natural History from 1901 to 1922. Hjalmarite occurs in dense Mn-rich skarn, as masses of irregularly arranged subhedral grains mainly with rhodonite and quartz. The skarn had been formed at the peak of the regional metamorphism, *T* ≥ 600 °C, at high SiO₂ activity and relatively low O fugacity. Other associated minerals are baryte (with Ba-rich hedyphane inclusions), richterite-like amphibole, serandite, pectolite, bustamite, and calcite. The new mineral forms grayish white vitreous short-prismatic grains 0.2–1 × 1–5 mm elongated by [001]. It does not fluoresce under UV light. The fracture is splintery, and cleavage is perfect on {110}. The indentation hardness VHN₁₀₀ = 782 (669–888) corresponding to 5–5½ on Mohs scale; *D*_{meas} = 3.0(1) and *D*_{calc} = 3.123 g/cm³. In thin sections hjalmarite is colorless, non-pleochroic. It is optically biaxial (–), *α* = 1.620(5), *β* = 1.630(5), *γ* = 1.640(5) (white light); 2*V*_{meas} = 60–70°, 2*V*_{calc} = 89.5°; *Y* = **b**, *Z* ^ **c** ~ 16°. The dispersion of optical axes is moderate, *r* < *v*. Polarized single-crystal FTIR spectra in the range 2000–8000 cm⁻¹ show distinct absorption bands at 3673 and 3731 cm⁻¹ polarized in a direction (O–H stretching of the OH dipole). Other spectra intervals are not shown. The averages of two areas (A and B) electron probe WDS analyses (4 points each) are [wt% A / wt% B (range B)]: SiO₂ 56.12 / 55.37 (55.33–55.46), Al₂O₃ 0.13 / 0.04 (0.04–0.05), Cr₂O₃ 0.02 / 0.01 (0–0.03), Fe₂O₃ 0.00/0.10 (0.07–0.14), MnO 12.67 / 14.04 (13.91–14.20), NiO 0.02 / 0.01 (0–0.02), MgO 19.12 / 17.84 (17.72–17.93), CaO 3.02 / 2.80 (2.74–2.83), SrO 0.00 / 0.06 (0.05–0.11), BaO 0.03 / 0.03 (0–0.04), Na₂O 6.00 / 6.61 (5.87–7.17), K₂O 1.10 / 0.86 (0.84–0.90), PbO 0.20 / 0.27 (0.23–0.43), F – / 0.18 (nuclear-reaction analyses), H₂O (by structure) 1.99 / 2.08, O=F₂ 0.10 / 0.07; total 100.29 / 100.23. All Mn is assumed as Mn²⁺ based on optical data. The contents of Li, B, and F by nuclear-reaction analysis are: Li 144 ± 12, B 33 ± 3 and F 1820 ± 200 µg/g. The empirical formula (considering crystal-structure data) is

(Na_{0.84}K_{0.16})_{Σ1}(Na_{1.01}Mn_{0.55}Ca_{0.43}Sr_{0.01})_{Σ2}(Mg_{3.83}Mn_{1.16}Al_{0.01})_{Σ5}(Si_{7.99}Al_{0.01})_{Σ8}O₂₂(OH)_{1.92}F_{0.08})_{Σ2}. The strongest peaks in the powder X-ray diffraction pattern are [*d* Å, (*I*%, *hkl*)]: 3.164 (100; 310), 2.837 (50; 330), 8.50 (44; 110), 3.302 (40; 240), 1.670 (34; 461), 1.448 (32; 661), 2.727 (30; 151), 2.183 (18; 261). Single-crystal XRD data collected at 298 and 180 K shows hjalmarite at ambient temperature is monoclinic, space group *C2/m*, *a* = 9.9113(3), *b* = 18.1361(4), *c* = 5.2831(5) Å, β = 103.658(5)°, and *V* = 922.80 Å³, *Z* = 4. The crystal structure refined to *R*₁ = 2.6% [*I* > 2σ(*I*)]. The *A* and *M*(4) sites split into *A*(*m*) (K⁺, Na⁺), *A*(2) (Na⁺), and *M*(4) (Mn²⁺) subsites, respectively. Among the octahedrally coordinated C group cations, Mn²⁺ orders strongly at the *M*(2) site. No significant violation of *C2/m* symmetry or change in the structure topology was detected at low temperature (*R*₁ = 2.1%). The holotype specimen, including a polished section, is deposited at the Department of Geosciences of Swedish Museum of Natural History, Stockholm, Sweden. **D.B.**

References cited

- Hawthorne, F.C., Oberti, R., Harlow, G.E., Maresch, W.V., Martin, R.F., Schumacher, J.C., and Welch, M.D. (2012) Nomenclature of the amphibole supergroup. *American Mineralogist*, 97, 2031–2048.
- Sjögren, H. (1891) Bidrag till Sveriges mineralogi. 2. Astochit, en ny led af amfibolgruppen. *Geologiska Föreningen I Stockholm Förhandlingar*, 13, 604–607.

KENNGOTTITE*

- J. Sejkora, I.E. Grey, and A.R. Kampf (2019) Kenngottite, Mn₃²⁺Fe₄³⁺(PO₄)₄(OH)₆(H₂O)₂: a new phosphate mineral from Krásno near Horní Slavkov, Czech Republic. *European Journal of Mineralogy*, 31(4), 629–636.

Kenngottite (IMA 2018-063), ideally Mn₃²⁺Fe₄³⁺(PO₄)₄(OH)₆(H₂O)₂, monoclinic, is a new mineral discovered at the 5th level of the Huber shaft, Krásno ore district near Horní Slavkov, Czech Republic (50°07'22"N; 12°48'2"E). The district is represented by greisen mineralization in several granite cupolas of the large Krušné hory (Erzgebirge) granite batholith underlying metamorphic rock (mainly gneisses). It is one of the most important areas of tin and tungsten mining in central Europe. Earlier "a probably new Fe–Mn phosphate" from Krásno was mentioned as an unnamed mineral phase UNK9 by Sejkora et al. (2006) with X-ray powder diffraction data and chemical composition close to those published for the unnamed Fe–Mn "dufrénite-like" mineral from Buranga, Rwanda, by von Knorring and Sahama (1982). Kenngottite occurs in phosphate accumulation with dominant fluorapatite and triplite aggregates from 10 cm to 1 m in size, located in coarse-grained white quartz of the Huber stock. Aggregates of dark Fe–Mn phosphates with predominant frondelite occur along contacts of these phosphate accumulations with white quartz and cavernous corroded portions carrying younger phosphates (iangreyite, strengite, and the chalcociderite–turquoise series). The new mineral is intergrown with phosphosiderite, fluorapatite, Mn-rich dufrénite, frondelite, rockbridgeite, morinite, beraunite, strengite, natrodufrénite, fluorite, and a K–Mn oxide. It forms brown opaque aggregates up to 3 mm across (composed of imperfect laths to fibrous crystals up to 0.5 mm elongated by [010] and flattened on {100}) in tiny cavities of hydrothermally altered black rockbridgeite-group minerals. Kenngottite has a light brown streak and a vitreous to pearly luster. No fluorescence under UV light was observed. The mineral is brittle with an uneven, stepped fracture and not directly observed cleavage (probably parallel to {100}). The Mohs hardness ~4–5 (by analogy with souzalite and gormanite). Density was not measured due to small size of crystals; *D*_{calc} = 3.40 g/cm³. Kenngottite is optically biaxial (–), α = 1.785(1), β = 1.790(5), γ = 1.810(2) (white light), 2*V*_{meas} = 50(10)°; 2*V*_{calc} = 53.6°. Orientation was not determined due to indistinct crystals shape. Dispersion of optical axes is extreme, *r* < *v*; anomalous interference colors were observed. The mineral is pleochroic: *X* (brown-yellow) < *Z* (olive-brown) < *Y* (blue-green). Raman spectra in the range 30–4200 cm^{–1} show main

bands at (cm^{–1}): 3570, 3374 (OH stretching), 1579 [*v*₂(δ) bending of H₂O], 1101, 1056 [*v*₃(PO₄) antisymmetric stretching], 994, 963 [*v*₁(PO₄) symmetric stretching], 691, 612, 575 [*v*₄(PO₄) bending], 451 [*v*₂(PO₄) bending], 373, 317, 288, 260, 235 (metal-oxygen stretching vibrations), 174, 144, 112, 84, 81, and 46 (lattice modes). The average of 12 electron probe WDS analysis [wt% (range)] is: Na₂O 0.03 (0–0.13), MnO 17.82 (14.42–20.74), CaO 0.31 (0.11–0.87), ZnO 0.32 (0.16–0.45), Fe₂O₃ 35.30 (31.67–38.89), Al₂O₃ 2.71 (1.79–3.83), P₂O₅ 30.80 (30.13–31.57), As₂O₃ 0.15 (0–0.44), SiO₂ 0.08 (0–0.52), H₂O [calculated based on 16 O + 8 (H₂O+OH) with charge balance by structure] 9.60, total 97.12. All iron is reported as Fe³⁺ based on the bond-valence calculations. Fluor was not detected. The reasons of low total is not discussed. The empirical formula based on 24 O pfu is (Mn_{2.29}Fe_{0.53}Ca_{0.05}Zn_{0.04}Na_{0.01})_{Σ2.92}(Fe_{3.51}Al_{0.49})_{Σ4.00}[(PO₄)_{3.96}(AsO₄)_{0.01}(SiO₄)_{0.01}]_{Σ3.98}(OH)_{6.42}(H₂O)_{1.66}. The strongest lines in the X-ray powder diffraction pattern are [*d* Å (*I*%, *hkl*)]: 4.87 (47; 20 $\bar{2}$,110), 3.458 (89; 40 $\bar{1}$,310), 3.209 (100; 203,311,11 $\bar{3}$,013,31 $\bar{2}$), 3.023 (31; 113,004); 2.623 (46; 114,204,020), 2.429 (49; 510,220,314); 1.9506 (28; 024,224), 1.5772 (34; 624). Unit-cell parameters refined from the powder data with whole-pattern fitting are: *a* = 13.919(9), *b* = 5.180(9), *c* = 12.159(10) Å, β = 98.905(14)°, *V* = 866.1 Å³. The single-crystal XRD data obtained from a fragment 0.09 × 0.04 × 0.02 mm shows kenngottite is monoclinic, space group *P2/a*, *a* = 13.909(10), *b* = 5.186(4), *c* = 12.159(9) Å, β = 98.88(1)°, *V* = 866.5 Å³, *Z* = 2. The crystal structure was refined to *wR*_{obs} = 0.088 for 350 *I* > 2σ(*I*) reflections. The structure contains trimeric clusters of face-shared octahedra (Mn–Fe–Mn) that are connected into chains along [001] by sharing edges with Mn-octahedra. The chains are corner-connected along [100] to linear corner-shared trimers of Fe-octahedra and along [010] via corner-connected PO₄ tetrahedra. Monoclinic kenngottite is structurally related to triclinic souzalite and gormanite. The mineral name honors Prof. Gustav Adolf Kennigott (1818–1897) of the University of Zürich (Switzerland) for his contributions to systematic mineralogy. Earlier the name kenngottite was used as a synonym of plumboan miargyrite or as a name for the amorphous variety of arsenolite. Both invalid names have not been used for more than 50 years. The holotype specimen is deposited in the Department of Mineralogy and Petrology of the National Museum in Prague, Czech Republic. **D.B.**

POTASSIC-RICHTERITE*

- D. Holtstam, F. Cámara, H. Skogby, A. Karlsson, and J. Langhof (2019) Description and recognition of potassic-richterite, an amphibole supergroup mineral from the Pajsberg ore field, Värmland, Sweden. *Mineralogy and Petrology*, 113(1), 7–16.

Potassic-richterite (IMA 2017-102), ideally ^AK^B(NaCa)^CMg₅^TSi₈O₂₂^W(OH)₂, monoclinic, is officially approved as a valid member of the amphibole supergroup based on study of the type material from Pajsberg Mn-Fe ore field, Filipstad, Värmland, Sweden. The existence of K-dominant richterite was known since the 19th and early 20th centuries mostly from the Långban Mn-Fe deposit, Sweden (Magnusson 1930), the type locality for richterite. The compositions of potassic-richterite, commonly referred as "potassium richterite" or "K-richterite," are also reported from ultrapotassic peridotite xenoliths (in kimberlite) and lamproites (Erlank and Finger 1970; Wagner and Velde 1986); from the metamorphosed Praborna manganese ore deposit, Val d'Aosta, Italy (Mottana and Griffin 1986). A Sr-bearing potassic-richterite from the Murun alkaline Massif, Yakutia, Russia) was also structurally characterized (Sokolova et al., 2000). In Pajsberg (most likely Stora Pajsberg mine—Långban-type Mn-Fe oxide deposit hosted by dolomitic marble) the mineral occurs in a Mn-rich skarn, closely associated with mainly phlogopite, jacobsonite, and tephroite. The potassic-richterite thought to be formed at peak metamorphism, under conditions of low SiO₂ and Al₂O₃ activities and relatively high oxygen fugacities. Potassic-richterite forms

straw yellow to grayish brown, vitreous, short-prismatic by [001] nearly anhedral crystals up to 4 mm long. The streak is white. No fluorescence under UV light was observed. Cleavage is perfect along {110}. It is brittle; indentation hardness $VHN_{100} = 806$ (610–946) corresponding to 5–6 of the Mohs scale. The density was not measured due to other minerals inclusions; $D_{\text{calc}} = 3.07$ g/cm³. In plane-polarized light the mineral is pale yellow (non-pleochroic). It is optically biaxial (–), $\alpha = 1.615(5)$, $\beta = 1.625(5)$, $\gamma = 1.635(5)$. A FTIR spectrum (on powder) in the range 600–4000 cm^{–1} shows absorption bands (cm^{–1}) at 1145, 1077, 1043, 970, 957, 922, 740, 703, and 677. Polarized single-crystal FTIR spectra show bands 3672 and 3736 (O–H stretching of the OH dipole). The Mössbauer data shows Fe³⁺ in tetrahedral coordination with amount of Fe²⁺, if present, estimated to be <2% of all Fe. The average of 6 electron probe WDS analysis is [wt% (range)]: SiO₂ 56.03 (55.31–56.44), Al₂O₃ 0.23 (0.20–0.29), TiO₂ 0.01 (0–0.04), Cr₂O₃ 0.03 (0.03), Fe₂O₃ 1.99 (1.65–2.11), MnO 4.48 (3.95–5.22), NiO 0.02 (0–0.08), MgO 20.36 (20.08–20.92), CaO 5.17 (5.04–5.52), SrO 0.04 (0–0.11), BaO 0.02 (0–0.05), Na₂O 5.24 (4.93–5.45), K₂O 3.36 (3.17–3.49), PbO 0.59 (0.48–0.77), F 0.40 (0.32–0.80), H₂O_{calc} 1.92 (1.74–1.95), O=F₂ 0.17 (0.14–0.34), total 99.74. Light elements contents were measured by nuclear-reaction analysis: Li 18 ± 4, B 104 ± 6, and F 6440 ± 480 ppm. The empirical formula based on O+OH+F = 24 apfu and considering Mössbauer and IR data is $(K_{0.61}Na_{0.30}Pb_{0.02})_{\Sigma 0.93}(Na_{1.14}Ca_{0.79}Mn_{0.07})_{\Sigma 2}(Mg_{4.31}Mn_{0.47}Fe_{0.20}^{2+})_{\Sigma 5}(Si_{7.95}Al_{0.04}Fe_{0.01}^{3+})_{\Sigma 8}O_{22}(OH_{1.82}F_{0.18})_{\Sigma 2}$ for a fragment used for collection of single-crystal X-ray diffraction data. The main X-ray powder-diffraction lines [d Å (%; hkl)] are: 9.05 (5; 020), 8.55 (36; 110), 3.40 (20; 131), 3.303 (56; 240), 3.181 (100; 310), 2.847 (50; 330), 2.714 (37; 151), 2.173 (25; 261). The unit-cell parameters, obtained from powder data are: of 22 reflections, are: $a = 10.006(2)$ Å, $b = 18.038(4)$ Å, $c = 5.279(1)$ Å, $\beta = 104.5(3)^\circ$, $V = 922.5$ Å³. A single-crystal X-ray data obtained on a $420 \times 80 \times 90$ µm crystal shows the mineral is monoclinic, space group $C2/m$, $a = 9.9977(3)$ Å, $b = 18.0409(4)$ Å, $c = 5.2794(2)$ Å, $\beta = 104.465(4)^\circ$, $V = 922.05$ Å³, $Z = 2$. The crystal structure was refined to $R_1 = 0.0363$ for $I > 2\sigma(I)$ reflections. The A and $M(4)$ sites split into $A(m)$ (K⁺), $A(2/m)$ (Na⁺), $A(2)$ (Pb²⁺), and $M(4')$ (Mn²⁺) subsites, respectively. The remaining Mn²⁺ is strongly ordered at the octahedrally coordinated $M(2)$ site, possibly together with most of Fe³⁺. The mineral name given according to current nomenclature of amphibole supergroup (Hawthorne et al. 2012). The holotype is an old specimen from the Swedish Museum of Natural History collected in 1850s. **D.B.**

References cited

- Erlank, A.J., and Finger, L.W. (1970) The occurrence of potassic-richterite in a mica nodule from the Wessleton kimberlite, South Africa. *Carnegie I Wash*, 68, 320–324.
- Hawthorne, F.C., Oberti, R., Harlow, G.E., Maresch, W.V., Martin, R.F., Schumacher, J.C., and Welch, M.D. (2012) Nomenclature of the amphibole supergroup. *American Mineralogist*, 97, 2031–2048.
- Magnusson, N.H. (1930) Långbans malmskratt. Sveriges geologiska undersökning. Series Ca. Avhandlingar och uppsatser 23, 111.
- Wagner, C., and Velde, D. (1986) The mineralogy of K-richterite-bearing lamproites. *American Mineralogist*, 71, 17–37.
- Ferrorockbridegite (IMA 2018-004), $(Fe^{2+}, Mn^{2+})_2(Fe^{3+})_3(PO_4)_3(OH)_4(H_2O)$, and ferrirockbridegite (IMA 2018-065), $(Fe_{0.67}^{3+}, \square_{0.33})_2(Fe^{3+})_3(PO_4)_3(OH)_4(H_2O)$, are two new orthorhombic minerals of the rockbridegite group, which has been officially established by the IMA Commission on New Minerals, Nomenclature and Classification. The general formula of the group is $A_2B_3(PO_4)_3(OH, H_2O)_5$, (A – the octahedrally coordinated $M2$ site, in which divalent cations are ordered, B – the octahedrally coordinated $M1+M3$ sites, which contain predominantly Fe³⁺, with trace Al). The different rockbridegite-group minerals are distinguished by the occupancy of the A site. The ideal formula for rockbridegite is $(Fe_{0.5}^{2+}Fe_{0.5}^{3+})_2Fe_3^{3+}(PO_4)_3(OH)_5$, that for frondelite is $(Mn_{0.5}^{2+}Fe_{0.5}^{3+})_2Fe_3^{3+}(PO_4)_3(OH)_5$ and that for plimerite is $Zn_2Fe_3^{3+}(PO_4)_3(OH)_4(H_2O)$. To preserve the identity of frondelite and rockbridegite within the structure-based formalism, the phase-composition diagram defined by occupation of the A site by Fe²⁺, Mn²⁺, and Fe³⁺ is divided into five compositional phase-fields rather than the usual three fields. In the latter case both minerals would be classed as “ferrirockbridegite” since the chemical analyses of frondelite and rockbridegite types, both have considerably more than 50% Fe³⁺ in the A site, which would lead to discreditation one of these well-entrenched species, valuable indicators of phosphate paragenetic environments. In the five-field diagram, the ideal rockbridegite and frondelite compositions correspond to mid-series compositions instead of end-member compositions. This scheme involves the eventual characterization of three new rockbridegite-group members with A site dominant by Fe²⁺ (ferrorockbridegite), Mn²⁺ (manganorockbridegite), and Fe³⁺ (ferrirockbridegite). The structure of rockbridegite-group minerals is built of two types of (100) layers. One contains double columns along [001] of face- and corner-sharing statistically half-occupied $M3$ octahedra that are interconnected along [010] via corners with PO₄ tetrahedra. The second type of layer contains the $M1$ - and $M2$ -octahedra, which form face-sharing trimers (“ h -clusters”). The trimers connect into chains along [010] by edge-sharing between the $M2$ -octahedra. The chains are interconnected along [001] by corner-sharing with PO₄ tetrahedra.
- Ferrorockbridegite** was discovered in the specimens collected at from the 76 m level of the Hagendorf-Süd pegmatite mine, Hagendorf, Hirschau, Oberpfalz, Bavaria, Germany (49°39'1" N, 12°27'35" E). It is one of secondary phosphates most likely formed from hydrothermal alteration of triphylite and/or zwieselite. The mineral occurs as densely packed intergrowths of lustrous, dark green to black blades (up to 2 mm × 10 µm, flattened on {010} and elongated on [001]), associated with oxidized schoonerite-group minerals, jahnsite, idiomorphic crystals of laueite and coatings of mitridatite. The density measured on two specimens was 3.21(1) and 3.33(1) g/cm³ while D_{calc} is 3.51 g/cm³. The lower measured density is attributed to the presence of sub-micrometer scale porosity confirmed by BSE images. No other macroscopical physical properties reported. Optically, ferrorockbridegite is biaxial (–), with $\alpha = 1.763(3)$, $\beta = 1.781(\text{calc})$, $\gamma = 1.797(3)$ (white light), $2V = 87(1)^\circ$ for one type specimen and $\alpha = 1.758(3)$, $\beta = 1.777(\text{calc})$, $\gamma = 1.797(3)$, and $2V = 89.8(5)$ (white light); $X = c$, $Y = a$, $Z = b$. The dispersion of optical axes is strong, based upon extinction colors; but the sense was not determined because the isogyres could not be observed. The pleochroism is X – blue green \approx Y – olive green $>$ Z – yellow brown. The IR spectrum shows peaks (cm^{–1}) at: 3585 (OH vibrations), 3250 (H₂O and strongly hydrogen-bonded hydroxyl ions), 1610 (H–O–H bending of H₂O), 1150, 1015, 960, 870 [(PO₄)^{3–} stretching]. Mössbauer spectrum gave a Fe²⁺/Fe³⁺ ratio as 26% to 74%. The thermal analysis shows the mass loss of 10.0 wt% to 600°. It is 1.5 wt% higher than H₂O content obtained from the crystal-structure due to the presence of non-structural water in micropores. The average of 30 EMPA (WDS) for specimen IGC90 [wt% (range)] / wet chemical analysis for the same specimen (wt%) / average of 7 analyses for sample IGC29 [wt% (SD)] are: ZnO 0.42 (0.07–0.84) / n.a. / 0.71(0.48), MnO 5.51 (4.48–6.79) / 6.29 (including ZnO if any) / 7.89(0.48), MgO 0.02 (0–0.13) / 0.11 / 0.0(0.07), CaO 0.40 (0.18–0.58) / 2.16 / 0.39(0.14), Fe_{total} as Fe₂O₃ 52.4 (49.1–54.5) / – / 48.8(1.4) [FeO

ROCKBRIDGEGITE-GROUP MINERALS

Ferrorockbridegite* and Ferrirockbridegite*

- I.E. Grey, A.R. Kampf, E. Keck, J.D. Cashion, C.M. Macrae, Y. Gozuka, V.K. Peterson, and F.L. Shanks (2019) The rockbridegite group approved and a new member, ferrorockbridegite, $(Fe^{2+}, Mn^{2+})_2(Fe^{3+})_3(PO_4)_3(OH)_4(H_2O)$, described from the Hagendorf Süd pegmatite, Oberpfalz, Bavaria. *European Journal of Mineralogy*, 31(2), 389–397.
- I.E. Grey, A.R. Kampf, E. Keck, J.D. Cashion, C.M. Macrae, Y. Gozuka, and F.L. Shanks (2019) Ferrirockbridegite, $(Fe_{0.67}^{3+}, \square_{0.33})_2(Fe^{3+})_3(PO_4)_3(OH)_4(H_2O)$, and the oxidation mechanism for rockbridegite-group minerals. *European Journal of Mineralogy*, 31(3), 585–594.

14.74 / 12.0 / 11.4; Fe₂O₃ 36.4 / 37.6 / 36.1 (EMPA apportioned by Mössbauer data), Al₂O₃ 0.11 (0–0.31) / 0.0 / 0.0, P₂O₅ 31.6 (29.1–35.7) / 31.9 / 30.9(0.4), H₂O 10.0 (TGA) / 9.6 / 10.0 (TGA), total 99.20 / 99.66 / 97.39. The low EMPA total for sample IGC29 is 17 due to the fine-scale porosity. The empirical formulae considering Mössbauer data and H₂O content from the structure analysis and based on 17 anions pfu are: Fe_{1.33}²⁺Mn_{0.52}²⁺Zn_{0.03}Ca_{0.05}Fe_{3.03}³⁺Al_{0.01}P_{2.97}H_{6.17}O₁₇ / Fe_{1.07}²⁺Mn_{0.57}²⁺Ca_{0.25}Mg_{0.02}Fe_{3.01}³⁺P_{2.87}H_{6.81}O₁₇ / Fe_{1.09}²⁺Mn_{0.77}²⁺Zn_{0.06}Ca_{0.05}Fe_{3.11}³⁺P_{2.99}H_{5.78}O₁₇. The strongest lines in the X-ray powder diffraction pattern are [*d* Å (*I*%; *hkl*)]: 6.987 (21; 200), 4.853 (26; 101), 3.615 (24; 240), 3.465 (33; 301), 3.424 (39; 410), 3.205 (100; 321), 1.603 (24; 642). The unit-cell parameters refined from the powder data are: *a* = 14.0016(5), *b* = 16.8593(5), *c* = 5.1831(1) Å, *V* = 1223.5 Å³ (sample IGC90) and *a* = 13.9880(4), *b* = 16.9026(5), *c* = 5.1816(1) Å, *V* = 1225.1 Å³ (sample IGC29); *Z* = 4. The unit-cell parameters refined from neutron powder diffraction data are *a* = 13.994(1), *b* = 16.840(1), *c* = 5.1835(4) Å, *V* = 1221.5 Å³ (IGC90). The single-crystal X-ray data confirms ferrirockbridgeite is orthorhombic, space group *Bbmm*, with *a* = 14.008(5), *b* = 16.808(5), *c* = 5.190(3) Å, *V* = 1222.0 Å³ [for IGC90 (synchrotron radiation λ = 0.7107 at 100 K)] and *a* = 13.995(1), *b* = 16.884(1), *c* = 5.1866(4) Å, *V* = 1225.5 Å³ [for IGC29 MoKα radiation λ = 0.7107 at 293 K]. The structure was refined to *R*_{obs} = 0.032 and 0.048, respectively, for 982 and 470 *I*>3σ(*I*) reflections. The two type specimens are housed at Museum Victoria, Melbourne, Australia. A small fragment removed from one of them is deposited in the Natural History Museum of Los Angeles County, California, U.S.A.

Ferrirockbridgeite is from the Palermo No. 1 pegmatite, North Groton, Grafton County, New Hampshire, U.S.A. (43°45.038'N 71°53.378'W). The holotype is the specimen #95086 of the Harvard University Mineralogical and Geological Museum analyzed and described by Frondel (1949) as being in the form of radial fibrous crusts and masses, derived from the alteration of triphylite. The millimeter-sized chips of the specimen #95086 used for this study comprised of compact intergrowths of reddish-brown blade-like crystals, flattened on {010} and elongated on [001]. Other macroscopic properties are not reported. The measured density is 3.33 g/cm³ while *D*_{calc} = 3.42 g/cm³. The difference is due to microporous nature of the mineral. Optically, ferrirockbridgeite is biaxial (–), α = 1.875(5), β = 1.890_(calc), γ = 1.900(5) (white light), 2*V* = 78(1)°; *X* = *c*, *Y* = *a*, *Z* = *b*. The optical axes dispersion is strong, *r* > *v*. The pleochroism is *X* – yellow brown < *Y* – olive brown < *Z* – dark olive green. The IR spectrum shows peaks (cm^{–1}) at: 3565, 3520 (OH vibrations), 3230 (H₂O groups), 1600 (H–O–H bending of H₂O), 1165, 1030, 930 [(PO₄)^{3–} stretching]. The TGA and MS curves show the loss of H₂O (8.7 wt%) up to 600 °C. Along with ferrirockbridgeite the other minerals of this group were studied including type specimens of rockbridgeite (HMM #80600 from South Mountain, Midvale, Rockbridge Co., Virginia, U.S.A.) and frondelite (NMNH #1059460 from Sapucaia, Minas Gerais, Brazil) and frondelite from Hagendorf-Süd pegmatite, Bavaria, Germany. The average of 8 WDS EMP analyses of ferrirockbridgeite (wt%) / wet chemical analysis of ferrirockbridgeite Frondel (1949) in wt% / average of 15 WDS EMP analyses of type rockbridgeite (wt%) / average of 9 WDS EMP analyses of type frondelite (wt%) / average of 47 WDS EMP analyses of frondelite (Hagendorf Süd IGC89) (wt%) / and 8 WDS EMPA of frondelite (Hagendorf Süd IGC14) (wt%): MnO 3.53 / 2.24 / 0.32 / 7.21 / 6.42 / 6.9; MgO 0.07 / 0 / 0.03 / 0.25 / 0.02 / 0.01; ZnO 0.33 / 0 / 0.0 / 0.91 / 0.29 / 2.4; CaO 0.47 / 0 / 0.16 / 0.05 / 0.28 / 0.24, Al₂O₃ 0 / 0 / 0.20 / 0.29 / 0.01 / 0.03, Fe_{total} as Fe₂O₃ 53.9 / – / 57.6 / 48.7 / 51.6 / 48.5 [apportioned according Mössbauer data: FeO 0.96 / 0.99 / 4.66 / 0.88 / 0.46 / 0.9; Fe₂O₃ 52.8 / 55.84 / 52.4 / 47.7 / 51.1 / 47.4], P₂O₅ 32.2 / 32.86 / 31.1 / 32.6 / 31.8 / 31.2, H₂O 8.7 (TGA) / 7.96 / 9.0 (TGA) / 7.5 / 8.9 / 8.0 (TGA), total 99.1 / 99.89 / 97.8 / 97.3 / 99.3 / 97.1. The empirical formulae based on 17 anions pfu coupled with Mössbauer and TGA data are respectively: Mn_{0.31}²⁺Fe_{0.08}²⁺Mg_{0.01}Zn_{0.03}Ca_{0.05}Fe_{3.18}³⁺P_{2.87}O₁₇H_{6.11} / Mn_{0.20}²⁺Fe_{0.09}²⁺Fe_{3.41}³⁺P_{2.92}O₁₇H_{5.58} / Mn_{0.03}²⁺Fe_{0.42}²⁺Ca_{0.02}Al_{0.02}Fe_{3.22}³⁺P_{2.82}O₁₇H_{6.27} / Mn_{0.66}²⁺Fe_{0.08}²⁺Mg_{0.04}Zn_{0.07}Ca_{0.01}Al_{0.04}Fe_{3.91}³⁺P_{3.00}O₁₇H_{5.44} / Mn_{0.58}²⁺Fe_{0.04}²⁺Zn_{0.02}

Fe_{4.07}³⁺P_{2.85}O₁₇H_{6.28} / Mn_{0.67}²⁺Fe_{0.08}²⁺Zn_{0.20}Ca_{0.03}Fe_{4.07}³⁺P_{3.00}O₁₇H_{6.05}. The strongest lines in the X-ray powder diffraction pattern are [*d* Å (*I*%; *hkl*)]: 6.994 (21; 200), 4.853 (26; 101), 3.615 (24; 240), 3.465 (33; 301), 3.424 (39; 410), 3.205 (100; 321), 1.603 (24; 642). Single-crystal X-ray data shows ferrirockbridgeite is orthorhombic, space group *Bbmm*, *a* = 13.853(1), *b* = 6.928(1), *c* = 5.1917(5) Å, *V* = 1217.5 Å³, *Z* = 4. The structure was refined to *R*_{obs} = 0.046 for 570 *I*>3σ(*I*) reflections. The structural formula of ferrirockbridgeite is given as ^{M2}(Mn_{0.31}²⁺Zn_{0.03}Mg_{0.01}Fe_{0.08}²⁺Ca_{0.05}Fe_{1.04}³⁺O_{0.53})₅₂^{M1}Fe_{1.00}^{M3}(Fe_{3.19}³⁺□_{1.81})₂₄(PO₄)₃(OH)_{4.55}(H₂O)_{0.45}. The structure refinements on ferrirockbridgeite and other rockbridgeite-group species, including type rockbridgeite and type frondelite, show that oxidation is accompanied by loss of Fe²⁺ from the *M2* site and suggest that the oxidized minerals have formed from more reduced precursors by a reaction [3Fe²⁺] → [2Fe³⁺ + □] + Fe²⁺ (removed) + 2e[–]. This mechanism involves diffusion of Fe²⁺ through the crystal structure to a surface, where it is released. A variable portion of the Fe²⁺ removed from the *M2* site becomes trapped at *M3* site vacancies. **D.B.**

References cited

Frondel, C. (1949) The dufenite problem. *American Mineralogist*, 34, 513–540.

RUDABÁNYAITE*

H. Effenberger, S. Szakáll, B. Fehér, T. Váczi, and N. Zajzon (2019) Rudabányaite, a new mineral with a [Ag₂Hg₂]⁴⁺ cluster cation from the Rudabánya ore deposit (Hungary). *European Journal of Mineralogy*, 31(3), 537–547.

Rudabányaite (IMA 2016-088), ideally [Ag₂Hg₂][AsO₄]Cl, cubic, was found in cavities of siliceous sphaerosiderite and limonite rocks at the Adolf mine area of the Rudabánya ore deposit, near Rudabánya town, ~35 km north of Miskolc, North-East Hungary, 48°23'5"N, 20°37'41"E. The ore deposit has an early metasomatic iron mineralization, a stratiform baryte–Cu–Zn–Pb sulfide mineralization, and a late-hydrothermal Sb–Hg–As–Ag mineralization. The latter was accompanied by significant silicification, and the formation of the sphaerosiderite and limonite rocks. A significant oxidation zone developed downwards to 40–60 m depth. The most common secondary minerals are malachite, cerussite, cuprite, cinnabar, jarosite, less frequently plumbojarosite, oxyplumboroméite, meta-cinnabar, eglestonite, and Ag amalgams. Rudabányaite closely associated with Ag halides (chlorargyrite, bromargyrite, iodargyrite) and Ag–Hg sulfo-halides (perroudite, capgaronnite, iltsite) and is probably resulted from the reaction of Ag-, Hg- and As-bearing sulfides or Ag amalgams with chlorine-bearing solutions. The new mineral forms small mostly xenomorphic transparent bright yellowish-orange to brownish-yellow adamantine crystals up to 0.6 mm and aggregates of a few millimeters across. Occasionally it shows {110} and {100} forms. The streak is lemon yellow. No fluorescence was observed. Rudabányaite is brittle with an uneven fracture and no cleavage. The Mohs hardness is 3–4. The density was not measured due to lack of material; *D*_{calc} = 8.04 g/cm³. The mineral is non-pleochroic, optically isotropic; dispersion is weak; *n*_{calc} = 2.33. The micro-Raman spectra in the range 0–1000 cm^{–1} show bands at 850–750 cm^{–1} [*v*₁ and *v*₃ symmetric and antisymmetric stretching of (AsO₄)^{3–}]; at 467–418 and 318–278 cm^{–1} [*v*₂ and *v*₄ (AsO₄)^{3–} bending modes respectively]; the bands below 200 cm^{–1} are assigned to external modes. The average of 5-point electron probe WDS analyses [wt% (range)] is Ag₂O 29.39 (28.91–29.86), Hg₂O 52.62 (52.28–53.08), As₂O₃ 13.69 (13.38–13.84), Cl 4.62 (4.21–4.79), SO₃ 0.19 (0.12–0.27), O=Cl₂ 1.04, total 99.47. The empirical formula based on 4 O pfu is (Ag_{2.06}Hg_{2.05})_{Σ4.11}(As_{0.97}S_{0.02})_{Σ0.99}O₄Cl_{1.06}. The strongest lines in the powder XRD pattern [*d* Å (*I*, *s* – strong, *m* – medium, *w* – weak)] are: 5.00 (*m*), 4.33 (*mw*), 2.931 (*s*), 2.882 (*w*), 2.611 (*s*), 2.255 (*mw*), 2.001 (*m*), 1.734 (*mw*). The unit-cell parameters refined from the powder data are *a* = 17.324(3) Å, *V* = 5199 Å³. The single-crystal X-ray study shows the mineral is cubic, space group *F*4̄3*c*, *a* = 17.360(3) Å, *V* = 5231.8 Å³, *Z* = 32. The crystal

structure was refined to $R_1 = 0.031$ for all 972 unique reflections. The crystal structure is characterized by two crystallographically different $[M_4]^{4+}$ cluster cations forming empty tetrahedra; $M = (\text{Ag}, \text{Hg})$ with a ratio $\text{Ag}:\text{Hg} \sim 1:1$. Such tetrahedra so far only known for two synthetic compounds $[\text{Ag}_2\text{Hg}_2]_3[\text{VO}_4]_4$ and $[\text{Ag}_2\text{Hg}_2]_2[\text{HgO}_2][\text{AsO}_4]_2$. The M atoms in all $[M_4]$ clusters are [6] coordinated by three M atoms and by three anions (two O and one Cl in rudabányaite). There is not any evidence for an order between the Ag and Hg atoms. Small amounts of the M atoms are displaced by ~ 0.5 Å. The barycentres of the $[M_4]^{4+}$ clusters and the As atom positions form a cubic primitive lattice with $a' = \frac{1}{2}a = 8.68$ Å; half of the voids are occupied by Cl atoms. Rudabányaite was named for its type locality, the Rudabánya mining town. The holotype specimen is deposited at the mineral collection of the Herman Ottó Museum, Miskolc, Hungary. **D.B.**

STRONTIOPERLOFFITE*

P. Elliott (2019) Strontioperloffite, $\text{SrMn}_2^{2+}\text{Fe}_3^{3+}(\text{PO}_4)_3(\text{OH})_3$, a new bjarebyite-group mineral from the Spring Creek mine, South Australia, Australia. *European Journal of Mineralogy*, 31(3), 559–555.

Strontioperloffite (IMA 2015-023), ideally $\text{SrMn}_2^{2+}\text{Fe}_3^{3+}(\text{PO}_4)_3(\text{OH})_3$, monoclinic, is a new bjarebyite-group mineral, strontian analog of perloffite. It was found at the dumps of the Spring Creek copper mine, ~ 10 km south of Wilmington, South Australia, Australia. The primary mineralization of this mine occurs in a heavily brecciated, hydrothermal vein containing native copper, cuprite and minor chalcocite, chalcocopyrite, covellite, and pyrite. The mine is well known for its diverse suite of secondary copper and phosphate minerals that occur in small cavities in quartz veins and have crystallized from low-temperature hydrothermal solutions. Tabular to bladed on $\{001\}$, brownish orange translucent vitreous crystals of strontioperloffite up to 0.4 mm were found in cavities in a matrix of quartz and minor goethite associating with copper, cuprite, mitridatite, and rhodochrosite. Minor crystal forms are $\{\bar{1}01\}$, $\{021\}$,

$\{\bar{1}31\}$. The mineral also occurs as hemispherical aggregates of crystals up to 0.5 mm. It has pale orange streak, and is brittle with an uneven fracture and one excellent cleavage on $\{100\}$. The Mohs hardness is 4.5. Density was not measured due to the lack of heavy liquids; $D_{\text{calc}} = 3.89$ g/cm³. The mineral is nonfluorescent. It is optically biaxial (-), $\alpha = 1.805(4)$, $\beta = 1.820(4)$, $\gamma = 1.829(4)$ (white light); $2V_{\text{calc}} = 75^\circ$. The IR spectrum in the range 4000–650 cm⁻¹ shows a broad band 3495–2740 centered ~ 3160 cm⁻¹ and a sharp band at 3565 cm⁻¹ (ν O–H stretching). Bands at 1030 cm⁻¹ with shoulders at 1198, 1165, 1030, and 945 cm⁻¹ and the weaker band at 1200 cm⁻¹ are assigned to PO_4 ν₃ antisymmetric stretching vibrations, and band at 665 cm⁻¹ – to PO_4 ν₄ vibrations. The average of 13 electron probe WDS analysis [wt% (range)] is: P₂O₅ 31.90 (31.30–33.31), As₂O₅ 0.10 (0.02–0.18), Fe₂O₃ 23.62 (23.42–24.17), FeO 1.55 (0.61–2.27) [Fe³⁺/Fe²⁺ proportion based on Fe³⁺+Al = 2.00 apfu], Al₂O₃ 0.17 (0.15–0.22), MnO 19.41 (19.09–19.79), CaO 0.38 (0.32–0.52), SrO 8.90 (8.05–9.61), BaO 8.65 (7.85–9.71), Na₂O 0.05 (0.03–0.10), H₂O (by structure) 4.08, total 98.81. No elements with $Z > 8$ were detected in amounts > 0.05 wt% oxide. The empirical formula based on 15 O pfu is $(\text{Sr}_{0.57}\text{Ba}_{0.38}\text{Na}_{0.01})_{\Sigma 0.96}(\text{Mn}_{1.83}\text{Fe}_{0.14}\text{Ca}_{0.05})_{\Sigma 2.02}(\text{Fe}_{1.98}\text{Al}_{0.02})_{\Sigma 2.00}(\text{P}_{3.00}\text{As}_{0.01})_{\Sigma 3.01}\text{O}_{11.98}(\text{OH})_{3.02}$. The strongest X-ray powder-diffraction lines [d Å ($P\%$; hkl)] are: 9.055 (32; 100), 5.122 (23; 120), 3.158 (100; 031, 22 $\bar{1}$), 3.106 (53; 040), 2.985 (20; 211), 2.938 (22; 140, 310), 2.892 (20; 131), 1.921 (53; 222, 350). The unit-cell parameters refined from the powder data are: $a = 9.202(3)$, $b = 12.442(3)$, $c = 5.008(1)$ Å, $\beta = 100.15(2)^\circ$, $V = 564.32$ Å³. The single-crystal X-ray data obtained on $0.035 \times 0.020 \times 0.008$ mm crystal fragment using synchrotron radiation with a wavelength of 0.71080 Å shows the mineral is monoclinic, $P2_1/m$, $a = 9.1830(18)$, $b = 12.349(3)$, $c = 5.0081(10)$ Å, $\beta = 100.23(3)^\circ$, $V = 558.91$ Å³, $Z = 2$. The crystal structure refined to $R_1 = 4.10\%$ for 1620 unique $F_o > 4\sigma(F_o)$ reflections. Strontioperloffite is isostructural with bjarebyite-group members with general formula $X\text{M}_1\text{M}_2(\text{PO}_4)_3(\text{OH})_3$ where $X = \text{Ba}, \text{Sr}$, $\text{M}_1 = \text{Fe}^{2+}, \text{Mn}^{2+}, \text{Mg}$ and $\text{M}_2 = \text{Al}, \text{Fe}^{3+}$. The holotype specimen is deposited in the South Australian Museum, Adelaide, South Australia. **D.B.**