New Mineral Names*·†

Dmitriy I. Belakovskiy[1], Fernando Cámara[2], and Yulia Uvarova[3]

[1]Fersman Mineralogical Museum, Russian Academy of Sciences, Leninskiy Prospekt 18 korp. 2, Moscow 119071, Russia
[2]Dipartimento di Scienze della Terra "Ardito Desio", Universitá di degli Studi di Milano, Via Mangiagalli, 34, 20133 Milano, Italy
[3]CSIRO Mineral Resources, ARRC, 26 Dick Perry Avenue, Kensington, Western Australia, 6151 Australia

In this issue

This New Mineral Names has entries for 16 new minerals, including, ariegilatite, aurihydrargyumite, carmeltazite, cerromojonite, dargaite, ewingite, fiemmeite horákite, nöggerathite-(Ce), paddlewheelite, parafiniukite, sharyginite, thalhammerite, thermaerogenite, tiberiobardiite, and verneite.

Ariegilatite*

E.V. Galuskin, B. Krüger, I.O. Galuskina, H. Krüger, Y. Vapnik, J.A. Wojdyla, and M. Murashko (2018) New mineral with modular structure derived from hatrurite from the pyrometamorphic rocks of the Hatrurim Complex: Ariegilatite, $BaCa_{12}(SiO_4)_4(PO4)_2F_2O$, from Negev Desert, Israel. Minerals, 8(3), 19.

Ariegilatite (IMA 2016-100), ideally $BaCa_{12}(SiO_4)_4(PO_4)_2F_2O$, trigonal, is a new member of the nabimusaite group* found in different outcrops of pyrometamorphic rocks of the Hatrurim Complex located in the territories of Israel, Palestine Autonomy, and Jordan. The first samples of ariegilatite were found in larnite pebble (as poikilitic crystals up to 0.25 mm with gehlenite, spinel, fluormayenite, fluorapatite, perovskite), in the northern part of the Daba-Siwaqa area, 80 km south of Amman, Jordan. While the description of the mineral is mostly based on samples collected in the Negev Desert near Arad, Israel (N31°13′E35°16′) ariegilatite was also found in flamite rocks (with fluormayenite-fluorkyuygenite, brownmillerite, fluorapatite, gehlenite, and jasmundite) at Ma'ale Adummim, Palestinean Autonomy. Ariegilatite is usually limited to re-crystallization zones of dark-gray fine-grained spurrite rocks, which differ from the surrounding rocks by discoloration, development of thin calcite veins and also by local appearance of large spurrite metacrysts (up to 1 cm in size), as well as the presence of sulfide mineralization. It is associated with spurrite, calcite, brownmillerite, shulamitite, CO_3-bearing fluorapatite, fluormayenite-fluorkyuygenite, aravaite, periclase, brucite, barytocalcite, baryte, garnets of elbrusite-kerimasite series, and unidentified Ca-Fe- and Rb-bearing K-Fe sulfides. Ariegilatite is often overgrown and replaced by stracherite. It forms strongly flattened crystals of disk-shaped form. Pseudo-aciculate morphology is observed in thin sections. Some highly fractured crystals of ariegilatite are up to 0.5 × 0.1 mm. The mineral is colorless, transparent, with white streaks and vitreous luster. It does not show pronounced cleavage on {001} as usual for other members of the group, fracture is irregular. It does not show any fluorescence. Due to the small size of the density was not measured; D_{calc} = 3.329 g/cm³. The mineral is optically uniaxial (–), ω = 1.650(2), ε = 1.647(2) (λ = 589 nm), non-pleochroic. The microindentation hardness VHN_{50} = 356 (331–378) kg/mm², corresponding to 4–4.5 of Mohs scale. The Raman spectrum exhibits the following strong bands (cm⁻¹): 129, 179, 229, and 309 (lattice mode, Ba-O, Ca-O vibrations); 403 [$v_2(SiO_4)^{4-}$]; 427 [$v_2(PO_4)^{2-}$]; 520 [$v_4(SiO_4)^{4-}$]; 569 and

591 [$v_4(PO_4)^{3-}$]; 834 and 874 [$v_1(SiO_4)^{4-}$]; 947 [$v_1(PO_4)^{3-}$]; 993 [$v_1SO_4)^{2-}$]; 1030 [$v_3(PO_4)^{3-}$]; 1066 [$v_1(CO_3)^{2-}$]. Raman spectroscopy data indicate that H_2O is absent in ariegilatite. The average of 22 WDS electron probe analyses [wt%, (range)] is: SO_3 0.17 (0.05–0.31), V_2O_5 0.1 (0–0.17), P_2O_5 9.83 (8.96–10.55), TiO_2 0.12 (0.05–0.25), SiO_2 19.87 (19.52–20.42), Al_2O_3 0.12 (0.07–0.18), BaO 12.26 (12.14–12.41), FeO 0.32 (0.24–0.46), MnO 0.29 (0.09–0.39), CaO 53.84 (53.19–54.40), MgO 0.14 (0.11–0.22), K_2O 0.04 (0–0.10), Na_2O 0.22 (0.16–0.36), F 3.17 (2.96–3.34), CO_2 0.57 (calculated on charge balance), $-O=F_2$ 1.33, total 99.72. The empirical formula based on 13 non-tetrahedral cations pfu is $(Ba_{0.98}K_{0.01}Na_{0.01})_{\Sigma1}(Ca_{11.77}Na_{0.08}Fe^{2+}_{0.06}Mn^{2+}_{0.05}Mg_{0.04})_{\Sigma12}[(Si_{3.95}Al_{0.03}Ti_{0.02})_{\Sigma4}O_{16}][(P_{1.70}C_{0.16}Si_{0.10}S^{6+}_{0.03}V_{0.01})_{\Sigma2}O_8]F_{2.04}O_{0.96}$. The strongest lines in the calculated X-ray powder diffraction pattern are [d_{calc} Å (I_{calc}%; hkl)]: 3.578 (51; $2\overline{1}0$), 3.437 (45; 1.0.10), 3.090 (100; $2\overline{2}1$), 2.822 (82; $2\overline{1}9$), 2.754 (62; 0.0.15), 2.743 (51; $2\overline{2}7$), 1.983 (47; $2.\overline{2}.16$), 1.789 (92; $4\overline{2}0$). Single-crystal X-ray studies on a crystal of 0.038 × 0.032 × 0.025 mm show the mineral is trigonal, space group $R\overline{3}m$, a = 7.1551(6), c = 41.303(3) Å, V = 1831.2 Å³, Z = 3. The crystal structure of ariegilatite was refined to R_1 = 0.0191 for 822 $I > 2\sigma(I)$ unique reflections. It exhibits a modular an intercalated antiperovskite structure derived from hatrurite (Ca_3SiO_5), and it is most easily described as a 1:1 stacking of the two modules: one triple antiperovskite module {$[F_2OCa_{12}](SiO_4)_4$}$^{4+}$ and {$Ba(PO_4)_2$}$^{4-}$ along [001]. In the module {$[F_2OCa_{12}](SiO_4)_4$}$^{4+}$, the sites F1 and O7 are coordinated by six Ca atoms in an octahedral arrangement forming three (001) layers. The module {$[F_2OCa_{12}](SiO_4)_4$}$^{4+}$ can be also described as consisting of columns formed by Ca-triplets Ca_3O_{14}, rotated relative to each other by 60°; Ca-triplets form four layers with $(SiO_4)^{4-}$ tetrahedra in structural cavities. The module {$Ba(PO_4)_2$}$^{4-}$ is characterized by ($P1O_4$) tetrahedra connected to six-coordinated Ba1. The name honors Arie Gilat (b. 1939), retired from the Geological Survey of Israel, where he was involved in geological mapping, tectonics and geochemical studies for more than 30 years. The holotype is deposited in the Fersman Mineralogical Museum, Moscow, Russia. **F.C.**

Comments: According new nomenclature recently approved by CNMNC IMA ariegilatite along with nabimusaite and dargaite (see abstract below) belongs to arctite group of arctite supergroup. Citation: R. Miyawaki, F. Hatert, M. Pasero, and S.J. Mills (2020) CNMNC Newsletter No. 54, Mineralogical Magazine, 84(2), 359–365.

Aurihydrargyrumite*

D. Nishio-Hamane, T. Tanaka, and T. Minakawa (2018) Aurihydrargyrumite, a natural Au_6Hg_5 phase from Japan. Minerals, 8(9), 415.

Aurihydrargyrumite (IMA 2017-003), Au_6Hg_5, hexagonal, is a new mineral, a natural amalgam, discovered in a placer in the middle of Oda River at Iyoki, Uchiko, Ehime Prefecture, Shikoku Island, Japan. Oda

---

River valley developed in Sanbagawa metamorphic sequence. The small quartz vein that included the gold- and mercury-bearing mineralization was found in the area being a possible source. Other minerals in placer include ilmenite, magnetite, chromite, zircon, scheelite, gold, iridium, osmium, and irarsite. Aurihydrargyrumite forms through the weathering of mercury-bearing placer gold by involvement of self-electrorefining. It occurs as a complete or partial silvery coating up to 2 μm thick on gold particles. The coatings consist of commonly anhedral and occasionally subhedral hexagonal-like crystals up to 2 μm formed by {001} and {100} or {110}. The mineral has metallic luster, silvery white streak, Mohs hardness ~2.5 and ductile and malleable tenacity. Other properties were not determined due to small size of the crystals; D_{calc} = 16.86 g/cm³. The averages of five electron probe EDS analyses obtained on each of: natural surface of aurihydrargyrumite layer/ *"gold-rich" zone underneath that layer*/ core of gold particles [wt% (range)] are Au 54.92 (54.26–55.76)/ *96.82 (95.47–98.73)*/ 88.20 (88.15–88.87), Ag 0.0/ *0.0*/ 9.90 (9.83–10.04), Hg 47.50 (46.54–48.91)/ *2.96 (1.41–4.60)*/ 1.69 (1.28–2.17), total 102.42/ *99.78*/ 99.79. The high total explained by irregular surface topography. The empirical formula of aurihydrargyrumite based on 11 Au+Hg, is $Au_{5.95}Hg_{5.05}$. The strongest lines in the powder X-ray diffraction pattern [d Å (I%; hkl)] are: 2.877 (29; 112), 2.597 (23; 202), 2.434 (42; 113), 2.337 (100; 104), 2.234 (87; 211), 1.401 (39; 314), 1.301 (41; 404), 1.225 (65; 217). The unit-cell parameters refined from the powder data are a = 6.996(1) Å, c = 10.154(2) Å, and V = 430.40 Å³, Z = 10. Aurihydrargyrumite is hexagonal, $P6_3/mcm$. The crystal structure of aurihydrargyrumite contains one Au site and two Hg sites. Each distinct site forms a sheet in the **ab** plane. Atoms of the Au sheets form triangular trimers arranged in a triangular net. The Hg atoms form a ditrigonally distorted Kagome net in the Hg1 sheets, but a honeycomb net in the Hg2 sheets. Two Au sheets and one Hg1 sheet form a compound Au–Hg1–Au layer and the next such layer is rotated 60° around the **c**-axis. The Hg2 sheets occur between these layers. Aurihydrargyrumite is identical to the synthetic Au_6Hg_5. Another hexagonal natural amalgam weishanite $(Au,Ag)_3Hg_2$ has unit-cell parameters identical to the synthetic phase Au_3Hg. The third natural amalgam $Au_{94-88}Hg_{6-12}$ referred as UM1992-08-E:AuHg (Smith and Nickel 2007) reported to be monoclinic (Desborough and Foord 1992). The mineral name reflects the Latin roots for its components: aurum (gold) and hydrargyrum (mercury). The type specimen has been deposited in the collections of the National Museum of Nature and Science, Japan. **D.B.**

References cited

Desborough, G.A., and Foord, E.E. (1992) A monoclinic, pseudo-orthorhombic Au-Hg mineral of potential economic significance in Pleistocene Snake River alluvial deposits of southeastern Idaho. Canadian Mineralogist, 30, 1033–1038.

Smith, D.G.W., and Nickel, E.H. (2007) A system of codification for unnamed minerals: Report of the sub-committee for unnamed minerals of the IMA Commission on New Minerals, Nomenclature and Classification. Canadian Mineralogist, 45, 983–1055.

Carmeltazite*

W.L. Griffin, S.E.M. Gain, L. Bindi, V. Toledo, F. Cámara, M. Saunders, and S.Y. O'Reilly (2018) Carmeltazite, $ZrAl_2Ti_4O_{11}$, a new mineral trapped in corundum from volcanic rocks of Mt Carmel, Northern Israel. Minerals, 8(12), 601.

Carmeltazite (IMA 2018-103), ideally $ZrAl_2Ti_4O_{11}$, orthorhombic, is a new mineral species discovered in pockets of trapped melt interstitial to, or included in, skeletal corundum crystals found in the pyroclastic ejecta in mafic to ultramafic upper Cretaceous volcanic rocks and in associated alluvial placers near Mt Carmel, Kishon River, near Haifa, northern Israel. The associated minerals include tistarite, corundum, anorthite, osbornite, spinel, unnamed *REE* phase in a matrix of Ca-Mg-Al-Si-O glass. The basaltic(?) silicate melts parental to this assemblage had previously been desilicated by the exsolution of immiscible Fe-Ti oxide melts

and Fe-Ti-Zr-silicide melts (found also as inclusions in carmeltazite), crystallization of moissanite and khamrabaevite at f_{O_2} = ΔIW-6 or less, and later (with lowering f_{O_2}), osbornite, khamrabaevite, and unnamed TiB_2, TiO, and TiN. Carmeltazite hosting corundum aggregates thought to have formed near the crust-mantle boundary (~30 km depth), in the presence of excess volatiles dominated by mantle-derived CH_4+H_2. This recently has been verified by the discovery of the first natural hydride in the same Israeli volcanic xenocrysts. Carmeltazite assemblage shows some analogies with those observed in calcium-aluminum inclusions (CAIs) in carbonaceous chondrites although crystallization conditions at Mt Carmel being similar to that of CAIs in terms of temperature and f_{O_2} appears to be higher by pressures, ca. 1 GPa. Carmeltazite forms black metallic crystals, up to 80 μm by a few micrometers thick, with a reddish streak. In reflected light, carmeltazite is weakly pleochroic from dark brown to dark green, weakly to moderately bireflectant with no internal reflections. It is anisotropic without characteristic rotation tints. Reflectance values for the COM wavelengths [R_{min}, R_{max} (%) λ nm] are: 21.8, 22.9 (471.1); 21.0, 21.6 (548.3), 19.9, 20.7 (586.6); and 18.5, 19.8 (652.3). Other physical properties were not determined due to small amount of available material; D_{calc} = 4.122 g/cm³ (for ideal formula). The average of eight spot electron probe WDS analyses [wt% (range)] is SiO_2 1.50 (1.24–1.70), ZrO_2 24.9 (23.7–27.9), HfO_2 0.53 (0.48–0.67), UO_2 0.16 (0–0.40), ThO_2 0.06 (0–0.13), Al_2O_3 18.8 (18.0–20.1), Cr_2O_3 0.02 (0–0.08), Ti_2O_3 50.6 (48.8–52.2), Sc_2O_3 0.76 (0.59–1.24), Y_2O_3 0.39 (0.30–0.51), MgO 1.89 (1.50–2.93), CaO 0.51 (0.29–1.45), total 100.12. The empirical formula based on 11 O pfu is $(Ti^{3+}_{3.60}Al_{1.89}Zr_{1.04}Mg_{0.24}Si_{0.13}Sc^{3+}_{0.06}Ca_{0.05}Y_{0.02}Hf_{0.01})_{\Sigma7.04}O_{11}$. The main X-ray powder diffraction lines [d Å (I%; hkl)] are: 5.78 (20; 201), 5.04 (65; 002,011), 4.09 (60; 211), 2.961 (100; 312), 2.885 (40; 411), 2.732 (30; 303), 2.597 (20; 221), 2.051 (25; 404), 2.047 (60; 422), 1.456 (30; 026). The unit-cell parameters refined from powder XRD data are a = 14.076(2), b = 5.8124(8), c = 10.0924(9) Å, V = 825.7 Å³. The single-crystal XRD data obtained on a crystal 0.060 × 0.075 × 0.080 mm shows carmeltazite is orthorhombic, space group *Pnma*, a = 14.0951(9), b = 5.8123 (4), c = 10.0848 (7) Å, V = 826.2 Å³, Z = 4. The crystal structure was refined to a final R_1 = 0.0216 for 1165 observed reflections with $F_o > 4\sigma(F_o)$ and is close to that of a defective spinel with stoichiometry M_7O_{11} instead M_9O_{12} in spinel. The stacking of oxygen layers is not a cubic-close-packing yielding a standard ABCABC sequence along [111] but is hexagonal sequence ABACBC along [100] with two central layers shifted changing coordination of some atoms. This structural topology is known for the synthetic compounds $Ba_2Ti_{9.25}Li_3O_{22}$, $SrLiCrTi_4O_{11}$, and $SrLiFeTi_4O_{11}$. The *M*1 site in carmeltazite has a pyramidal 1+4 coordination with occupation $(Al_{0.68}Mg_{0.22}Sc^{3+}_{0.04}Ca_{0.03}Y_{0.02}Hf_{0.01})$. The occupation of 4 octahedral sites is: $M2 - (Zr^{4+}_{0.85}Ti^{3+}_{0.15})$; $M3 - Ti^{3+}_{1.00}$; $M4 - (Ti^{3+}_{0.86}Al_{0.14})$; $M5 - (Ti^{3+}_{0.87}Al_{0.13})$; For tetrahedral site it is $(Al_{0.87}Si_{0.13})$. Considering the multiplicity of the sites, the empirical formula based on structure refinement is $(Ti^{3+}_{3.75}Al_{1.94}Zr_{0.85}Mg_{0.22}Si_{0.14}Sc^{3+}_{0.04}Ca_{0.03}Y_{0.02}Hf_{0.01})_{\Sigma7.00}O_{11}$. The name carmeltazite derives from Mt Carmel and from the dominant metals present in the mineral, i.e., titanium, aluminum, and zirconium ("TAZ"). The holotype specimen is deposited in the Museo di Storia Naturale, Università degli Studi di Firenze, Florence, Italy. **D.B.**

Cerromojonite*

H.-J. Förster, L. Bindi, G. Grundmann, and C.J. Stanley (2018) Cerromojonite, $CuPbBiSe_3$, from El Dragón (Bolivia): A new member of the bournonite group. Minerals, 8(10), 420.

Cerromojonite (IMA 2018-049), ideally $CuPbBiSe_3$, orthorhombic, is a new selenide of bournonite group, Se-analogue of součekite $CuPbBi(S,Se)_3$. It was discovered at the El Dragón mine, Department of Potosí, Bolivia, and named for Cerro Mojon, the highest mountain peak in the area. A multi-phase assemblage of primary and secondary selenides

occurs in a single vein of 0.5 to 2 cm thick in a shear zone cutting series of thinly stratified, pyrite-rich black shales, and reddish-gray, hematite-bearing siltstones. Phases similar to cerromojonite were previously described at El Dragón (phase "C" of Förster et al. 2016) and, as tiny inclusions intimately intergrown with berzelianite, in carbonate veins of the U–Se–polymetallic deposit Schlema–Alberoda, Erzgebirge, Germany (Dymkov et al. 1991). However, no structural data were provided. At El Dragón cerromojonite found in two different mineral assemblages deposited from low-T hydrothermal fluids with f_{Se}/f_S ratio >1. In the first one it occurs as grains up to 30 μm in the interstices of quijarroite/hansblockite intergrowths (forming an angular network-like intersertal texture), partly together with penroseite, klockmannite, watkinsonite, clausthalite, rarely petrovicite. These aggregates cemented by umangite and klockmannite and deposited at the surfaces of krut'aite–penroseite. In the second, cerromojonite occurs within lath-shaped or acicular aggregates up to 2 mm × 200 μm, interpreted as pseudomorphs after the above described intersertal aggregates. It forms elongated thin-tabular crystals (up to 200 × 40 μm), in subparallel intergrowths with watkinsonite or quijarroite, clausthalite, nickeltyrrellite, and not defined selenides, all cemented by klockmannite. The appearance of the cerromojonite grains resembles a spinifex texture, indicating fast crystallization. These aggregates are deposited in interstices in brecciated krut'aite–penroseite grains. All minerals of this association are altered by late klockmannite, fracture-filling chalcopyrite, covellite, goethite, petříčekite and krut'aite, and native selenium. Cerromojonite is black, opaque, with a metallic luster and black streak. It is brittle, with an irregular fracture, and no obvious cleavage and parting. Density and hardness were not measured due to small grain size; D_{calc} = 7.035 g/cm³. In reflected light, cerromojonite is weakly pleochroic gray to cream-white with no internal reflections. It is weakly anisotropic, with rotation tints in shades of brown and gray. Lamellar twinning on {110} is common. The reflectance values in air (R_1, R_2, nm) are (**COM** wavelengths are bolded): 47.0, 48.0, 400; 47.2, 48.6, 420; 47.5, 49.3, 440; 47.8, 50.0, 460; **48.8, 50.3, 470**; 48.1, 50.6, 480; 48.3, 51.1, 500; 48.3, 51.5, 520; 48.3, 51.7, 540; **48.2, 51.8, 546**; 48.1, 51.9, 560; 47.9, 52.0, 580; **47.8, 52.0, 589**; 47.7, 52.1, 600; 47.5, 52.1, 620; 47.3, 52.0, 640; **47.2, 52.0, 650**; 47.1, 51.9, 660; 46.9, 51.7, 680; 46.8, 51.6, 700. The average of 24 spot electron probe WDS analyses [wt% (range)] is: Cu 7.91 (7.40–8.16), Ag 2.35 (2.16–2.54), Hg 7.42 (7.19–7.60), Pb 16.39 (16.15–16.77), Fe 0.04 (0–0.18), Ni 0.02 (0–0.18), Bi 32.61 (32.19–32.91), Se 33.37 (32.93–33.81), total 100.11. No concentrations of Co, As, Sb, and S were detected. The empirical formula based on 6 apfu is $(Cu_{0.89}Hg_{0.11})_{\Sigma1.00}(Pb_{0.56}Ag_{0.16}Hg_{0.15}Bi_{0.11}Fe_{0.01})_{\Sigma0.99}Bi_{1.00}Se_{3.01}$. The strongest X-ray powder diffraction lines [d Å (I%; hkl)] are: 4.00 (20; 002), 3.86 (25; 120), 2.783 (100; 122), 2.727 (55; 212), 2.608 (40; 310), 1.999 (25; 004), 1.992 (20; 330), 1.788 (20; 412). The unit-cell values refined from the powder data are a = 8.2004(6), b = 8.7461(5), c = 8.0159 Å, V = 574.91 Å³. The single-crystal X-ray data obtained on the crystal fragment 0.040 × 0.055 × 0.060 mm shows cerromojonite is orthorhombic, space group $Pn2_1m$, a = 8.202(1), b = 8.741(1), c = 8.029(1) Å, V = 575.7 Å³, Z = 4. The crystal structure was refined to R_1 = 0.0256 for 701 F_o>4σ(F_o) reflections (0.0315 for all 1359 unique reflections). It is identical to those of other members of the bournonite group and consists of $^{[7,9]}$Pb-polyhedra, $^{[3+2,3+3]}$Bi-polyhedra, and CuSe₄ tetrahedra, which share corners and edges to form a three-dimensional framework; CuSe₄ tetrahedra share corners to form chains parallel to [001]. The site populations were determined giving crystallochemical empirical formula $[Cu_{0.88}Hg_{0.12}]Bi[Pb_{0.56}Ag_{0.16}Hg_{0.14}Bi_{0.110.04}]Se_3$ in good agreement with observed bond distances and chemical data. The X-rayed crystal is preserved at the Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Italy. The polished section (holotype) is housed in the Natural History Museum, London. Another polished section (cotype) is deposited in the Mineralogical State Collection Munich (Mineralogische Staatssammlung München, Museum "Reich der Kristalle"), Germany. **D.B.**

References cited

Dymkov, Y.M., Ryzhov, B.I., Begizov, V.I., Dubakina, L.S., Zav'yalov, E.N., Ryabeva, V.G., and Tsvetkova, M.V. (1991) Mgriite, bismuth petrovicite and associated selenides from carbonate veins of the Erzgebirge. Novye Dannye o Mineralakh, 37, 81–101. (In Russian.)

Förster, H.-J., Bindi, L., and Stanley, C.J. (2016) Grundmannite, CuBiSe₂, the Se-analogue of emplectite: A new mineral from the El Dragón mine, Potosí, Bolivia. European Journal of Mineralogy, 28, 467–477.

Dargaite*

I.O. Galuskina, F. Gfeller, E.V. Galuskin, T. Armbruster, Y. Vapnik, M. Dulski, M. Gardocki, L. Jeżak, and M. Murashko (2019) New minerals with modular structure derived from hatrurite from the pyrometamorphic rocks. Part IV: Dargaite, BaCa₁₂(SiO₄)₄(SO₄)₂O₃, from Nahal Darga, Palestinian Autonomy. Mineralogical Magazine, 83(1), 81–88.

Dargaite (IMA 2015-068), ideally $BaCa_{12}(SiO_4)_4(SO_4)_2O_3$, trigonal, is a new member of the arctite group. It was originally found along with isostructural nabimusaite in pyrometamorphic larnite rocks at the Jabel Harmun, Palestinian Autonomy (Galuskin et al. 2015). The discovery of larger grains (up to 30–40 μm in aggregates up to 100–150 μm) in larnite pebbles within larnite pseudoconglomerates at the Hahal Darga, Judean Mts, West Bank, Palestinian Autonomy (31°36.5′N, 35°22.7′E) allowed complete description of dargaite, which was named for its locality. Beside dargaite six new minerals of the arctite supergroup with modular intercalated antiperovskite structures derived from hatrurite $Ca_3(SiO_4)O$ have been recently discovered in pyrometamorphic rocks of the Hatrurim Complex ("Mottled zone") distributed along the Dead Sea Rift in the territories of Israel, Palestinian Autonomy, and Jordan. Namely (arctite group): nabimusaite $KCa_{12}(SiO_4)_4(SO_4)_2O_2F$, ariegilatite $BaCa_{12}(SiO_4)_4(PO_4)_2OF_2$ (see abstract above), and (zadovite group): zadovite $BaCa_6[(SiO_4)(PO_4)](PO_4)_2F$, aradite $BaCa_6[(SiO_4)(VO_4)](VO_4)_2F$, gazeevite $BaCa_6(SiO_4)_2(SO_4)_2O$, stracherite $BaCa_6(SiO_4)_2[(PO_4)(CO_3)]F$. Dargaite was also found in larnite rocks of the Hatrurim Complex at Ma'ale Adumim, Palestinian Autonomy and in altered carbonate xenolith (as very rare grains ~30 μm with larnite, spurrite, fluorellestadite, gazeevite, hydrocalumite, and chlormayenite) from the lava bed of the Shadi-Khokh volcano, Southern Ossetia. The formation of dargaite is related to the local pyrometamorphic by-products (gases, fluids, and melts) transforming earlier mineral associations at ~900 °C. In the holotype specimen larnite, fluorellestadite–fluorapatite, brownmillerite, fluormayenite–fluorkyuygenite, and ye'elimite are the main minerals; ternesite, shulamitite and periclase are noted rarely. Dargaite, nabimusaite and gazeevite occur in linear zones with higher porosity within larnite rocks. Pores are filled with ettringite and Ca-hydrosilicates, less commonly with gibbsite, brucite, baryte, katoite, and calciolangbeinite. Dargaite is colorless, transparent with a white streak and a vitreous luster. It exhibits pronounced parting and imperfect cleavage on {001}. The micro-indentation hardness VHN = 423 (380–492) kg/mm² corresponds to ~4.5–5.5 of the Mohs scale. Density was not measured due to abundant tiny inclusions of larnite and ye'elimite; D_{calc} = 3.235 g/cm³. Dargaite is non-pleochroic, optically uniaxial (–), ω = 1.643(3), ε = 1.639(3) (589 nm). Raman spectra of the holotype and dargaite from Ma'ale Adumim and Shadil-Khokh correspond to those of Ba-bearing nabimusaite and contain main bands at (cm⁻¹): 70, 122, 129, 263, and 323 (lattice mode, Ba–O, Ca–O vibrations); 401 [$v_2(SiO_4)^{4-}$]; 464 [$v_2(SO_4)^{2-}$]; 523 [$v_4(SiO_4)^{4-}$]; 563 [$v_4(PO_4)^{3-}$]; 641, 644 [$v_4(SO_4)^{2-}$]; 829, 869 [v_1 of two types of $(SiO_4)^{4-}$]; 947 [$v_1(PO_4)^{3-}$](absent for dargaite from Shadil-Khokh with low P content); 991 [$v_1(SO_4)^{2-}$]; 1078–1080 [$v_1(CO_3)^{2-}$]; 1116 [$v_3(SO_4)^{2-}$]; ~2270, 2476, 3474, 3630 (overtones or combinational bands). The averages of electron probe WDS analysis of dargaite from Nahal Darga (22)/ *Ma'ale Adumim (16)*/ Shadil-Khokh (3) are [wt% (range)]: Na₂O 0.12 (0.08–0.15)/ *0.25 (0.18–0.28)*/ 0.04; K₂O 0.94 (0.85–1.04)/ *1.11 (0.54–1.35)*/ 0.73; MgO 0.14 (0.10–0.18)/ *0.09 (0.06–0.11)*/ 0.06; CaO

55.73 (55.17–56.73)/ *57.19 (56.44–58.02)*/ 56.30; SrO n.d./ *n.d.*/0.20; BaO 9.21 (8.35–9.93)/ *8.19 (7.49–9.78)*/ 10.12; Al_2O_3 0.45 (0.34–0.56)/ *0.90 (0.73–1.20)*/ 0.32; Fe_2O_3 n.d./ *0.20 (0–0.36)*/ 0.30; SiO_2 18.26 (17.74–18.76)/ *18.74 (18.28–19.39)*/ 19.30; TiO_2 0.18 (0.13–0.25)/ *0.13 (0.08–0.19)*/ 0.47; P_2O_5 2.90 (2.70–3.36)/ *2.56 (1.71–4.33)*/ 0.30; SO_3 11.25 (9.15–11.48)/ *11.12 (9.23–11.78)*/ 12.21; F 0.72 (0.64–0.86)/ *1.32 (0.97–1.53)*/ 0.66; –O=F_2 0.30/ *0.45*/ 0.28; CO_2 (calculated) 0.12/ *0.11*/ 0.41; Total 99.71/ *101.34*/ 101.14. The empirical formulae based on 19 cations pfu are accordingly: $^A(Ba_{0.72}K_{0.24}Na_{0.04})_{\Sigma1.00}{}^B(Ca_{11.95}Mg_{0.04}Na_{0.01})_{\Sigma12.00}$ $^{T1}([SiO_4]_{3.65}[PO_4]_{0.21}[AlO_4]_{0.11}[Ti^{4+}O_4]_{0.03})_{\Sigma4.00}{}^{T2}([SO_4]_{1.69}[PO_4]_{0.28}[CO_3]_{0.03})_{\Sigma2.00}$ $^{W1}(O_{0.54}F_{0.46})_{\Sigma1.00}{}^{W2}O_2$/ $^A(Ba_{0.63}K_{0.28}Na_{0.10})_{\Sigma1.01}{}^B(Ca_{11.97}Mg_{0.03})_{\Sigma12.00}{}^{T1}([SiO_4]_{3.66}$ $[PO_4]_{0.08}[AlO_4]_{0.21}[Fe^{3+}O_4]_{0.03}[Ti^{4+}O_4]_{0.02})_{\Sigma4.00}{}^{T2}([SO_4]_{1.63}[PO_4]_{0.34}$ $[CO_3]_{0.03})_{\Sigma2.00}{}^{W1}(F_{0.81}O_{0.19})_{\Sigma1.00}{}^{W2}O_2$/ $^A(Ba_{0.79}K_{0.19}Sr_{0.02}Na_{<0.01})_{\Sigma1.00}$ $^B(Ca_{11.97}Mg_{0.02}Na_{0.01})_{\Sigma12.00}{}^{T1}([SiO_4]_{3.81}[AlO_4]_{0.08}[Ti^{4+}O_4]_{0.07}[Fe^{3+}O_4]_{0.05})_{\Sigma4.00}$ $^{T2}([SO_4]_{1.82}[CO_3]_{0.11}[PO_4]_{0.05}[SiO_4]_{0.02})_{\Sigma2.00}{}^{W1}(O_{0.59}F_{0.41})_{\Sigma1.00}{}^{W2}O_2$. (* see Comment.) The strongest lines in the calculated X-ray powder diffraction pattern are [d_{calc} Å (I_{calc}%; *hkl*)]: 3.103 (100; $2\bar{2}1$), 2.753 (95; 027), 2.750 (88; 0.0.15), 2.665 (63; $02\bar{8}$), 2.141 (43; $2.\bar{2}.\overline{14}$), 1.797 ($2\bar{4}0$), 1.539 (58; $3.\bar{3}.18$). Single-crystal XRD data obtained on a crystal of ~0.03 × 0.03 × 0.02 mm shows dargaite is trigonal, space group $R\bar{3}m$, a = 7.1874(4), c = 41.292(3) Å, V = 1847.32 Å^3, Z = 3. The crystal structure was refined to R_1 = 0.0376 for 396 I>2σ(I) unique reflections. The structure is formed by three-layered antiperovskite modules $\{O_3Ca_{12}(SiO_4)_4\}^{2+}$ interstratified with $Ba(SO_4)_2^{2-}$ layers along [001]. The former consists of columns of three face-sharing antiperovskite [OCa_6] octahedra extended along [001] and interconnected through SiO_4 tetrahedra while in the latter SO_4 tetrahedra connected to six-coordinated Ba. Dargaite belongs to the arctite structural type with the structural formula $AB1_6B2_6[(T1O_4)_2(T2O_4)_2]$ $(T3O_4)_2W1_2W2$. The main isomorphic scheme in the nabimusaite–dargaite series is $^AK^+ + {}^WF^- \rightarrow {}^ABa^{2+} + {}^WO^{2-}$, in the dargaite–ariegilatite series: $^T(SO_4)^{2-} + {}^WO^{2-} \rightarrow {}^T(PO_4)^{3-} + {}^WF^-$, and in the nabimusaite–ariegilatite series: $^AK^T(SO_4)_2^{3-} + {}^WO^{2-} \rightarrow {}^ABa^T(PO_4)_2^{4-} + {}^WF^-$. Isomorphic substitutions in the tetrahedral layer $A(TO_4)_2$ of this series are balanced by the O/F ratio variation within the antiperovskite modules. According a new structure model for dargaite and nabimusaite, F enters to the $O7Ca_6$ octahedra of external antiperovskite layers (site $W1$). Type material has been deposited in the Fersman Mineralogical Museum Russian Academy of Sciences, Moscow, Russia. **D.B.**

Comment: The empirical formulae above are calculated based on the structure model with F assigned to central antiperovskite layer. Considering a new model with F at the external antiperovskite layers the corresponding parts of empirical formulae should be written as $^{W1}(O_{1.54}F_{0.46})_{\Sigma2.00}{}^{W2}O$/ $^{W1}(O_{1.19}F_{0.81})_{\Sigma2.00}{}^{W2}O$/$^{W1}(O_{1.59}F_{0.41})_{\Sigma2.00}{}^{W2}O$, accordingly.

References cited

Galuskin, E.V., Gfeller, F., Armbruster, T., Galuskina, I.O., Vapnik, Ye., Murashko, M., Wodyka, R., and Dzierżanowski, P. (2015) New minerals with modular structure derived from hatrurite from the pyrometamorphic Hatrurim Complex, Part I: Nabimusaite, $KCa_{12}(SiO_4)_4(SO_4)_2O_2F$, from larnite rock of the Jabel Harmun, Palestinian Autonomy, Israel. Mineralogical Magazine, 79, 1061–1072.

EWINGITE*

T.A. Olds, J. Plášil, A.R. Kampf, A. Simonetti, L.R. Sadergaski, Yu-S. Chen, and P.C. Burns (2017) Ewingite: Earth's most complex mineral. Geology, 45(11), 1007–1010.

Ewingite (IMA 2016-012), $Mg_8Ca_8(UO_2)_{24}(CO_3)_{30}O_4(OH)_{12}(H_2O)_{138}$, tetragonal, is a new uranyl carbonate mineral considered to be the most structurally complex mineral known. It was discovered on a damp wall in the abandoned Plavno mine in the Jáchymov ore district, western Bohemia, Czech Republic. The uranium was mined in this area over 100 years. Ewingite is a secondary mineral resulted from postmining oxidation of primary uraninite in wet environment similar to other uranyl carbonates which may form on uranium mine tailings, nuclear waste in repositories or nuclear reactor meltdown products. Ewingite forms aggregates of equant golden-yellow crystals up to 0.2 mm on altered uraninite, with other uranyl carbonate minerals, including liebigite, metazellerite and unnamed Ca-Cu uranyl carbonate. Ewingite crystals are transparent, with a vitreous luster a pale-yellow streak. No twinning was observed. The mineral is non-fluorescent under UV radiation. It is brittle with uneven fracture and no discernable cleavage. The Mohs hardness is estimated as ~2. The density was not measured due to the limited availability of material; D_{calc} = 2.543 g/cm^3 (2.525 for an ideal formula). The mineral is very weakly anisotropic (practically isotropic), optically uniaxial, neutral, ω = ε = 1.537 (white light). The Raman spectrum bands are (cm^{-1}, b – broad, s – strong, w – weak, sh – shoulder): 1379, 1344, 1250 [$v_3(CO_3)^{2-}$ antisymmetric stretching]; 1095, 1107sh, 1087sh [split $v_1(CO_3)^{2-}$ symmetric stretching]; 832s [$v_1(UO_2)^{2+}$ symmetric stretching]; 761, 751sh, 687, 668, 636 [$v_4(\delta)(CO_3)^{2-}$ in-plane bending]; weak 340, 329, 317, 243, 203 [$v_2(\delta)$ $(UO_2)^{2+}$ bending]; <200 (lattice modes). FTIR spectrum shows: ~3200b, 3500sh, 3350sh (v O–H stretching of H_2O); 1630w [$v_2(\delta)$ H_2O bending]; 1494, 1505sh, 1332, 1440sh [$v_3(CO_3)^{2-}$ antisymmetric stretching]; 1108w [split $v_1(CO_3)^{2-}$ symmetric stretching]; 918s [$v_3(UO_2)^{2+}$ antisymmetric stretching]; 771 [$v_4(\delta)(CO_3)^{2-}$ in-plane bending]. Obtained microprobe data were not reliable due to difficulty of preparation and vacuum behavior of highly hydrated crystals. The concentrations of U, Mg, Mn, and Ca were determined by means of HR-ICP-MS as a ratio relative to uranium. The mean U/cation ratio values are: Mg 3.042 (2.857–3.158); Ca 3.122 (2.915–3.507); Mn 70.240 (61.731–79.446); U 1.000. Direct determinations of H_2O and CO_2 content were not done due to the paucity of material. The presence of $(CO_3)^{2-}$ and H_2O was confirmed by Raman and FTIR spectroscopy. The empirical formula calculated on the basis of 24 U, 292 O, and 30 CO_3 pfu (from crystal structure constrains) with charge balanced by adding hydrogen is: $(Mg_{7.89}Ca_{7.69}Mn_{0.34})_{\Sigma15.92}(UO_2)_{24}$ $(CO_3)_{30}O_4(OH)_{11.84}(H_2O)_{138.16}$. Oxides wt% calculated from the mean apfu values are: MgO 2.75, CaO 3.73, MnO 0.21, UO_3 59.41, CO_2 11.43, H_2O 22.47; total 100%. The strongest reflections in the X-ray powder diffraction pattern are [d Å (I%; *hkl*)]: 17.8 (19; 200),14.3 (31; 202), 10.1 (74; 312,204), 8.28 (100; 402,314), 6.61 (24; 512,424,316), 6.03 (30; 008), 5.69 (36; multiple), 4.774 (29; 606). The unit-cell parameters refined from the powder data with whole pattern fitting are a = 35.624(10), c = 48.449(13) Å, V = 61485 Å^3. The single-crystal X-ray diffraction data obtained using synchrotron radiation on a crystal 66 × 44 × 11 μm shows ewingite is tetragonal, space group $I4_1/acd$, a = 35.142(2), c = 47.974(3) Å, V = 59245 Å^3, Z = 8. The crystal structure of ewingite (refined to R_1 = 15.15% for 1394 I_{obs}>4σ(I) reflections) contains nanometer-scale anionic uranyl carbonate cages constructed by combination of three fundamental building units (FBU). FBU-1 is a triplet of UO_7 pentagonal bipyramids with a single O atom bonded to all three uranyl polyhedra, and bipyramids each sharing two of their equatorial edges with two other bipyramids. In FBU-2 uranyl ion is coordinated by three carbonate triangles in the equatorial edges of UO_8 hexagonal bipyramid. In FBU-3 uranyl ion is coordinated by 2 carbonate triangles and 2 H_2O groups in the equatorial region of a hexagonal bipyramid. Linkages between the FBUs within the cage are through carbonate groups. Each cage requires 24 uranyl polyhedra with 6 Ca, 2 Mg cations, and H_2O groups inside the cages. The uranyl carbonate cages are linked to other cages by bonds to Ca and Mg cations, and H bonds of H_2O groups. The interstitial components typically exhibit partial occupancy and disorder. There are 8 symmetrically equivalent cages in the unit cell. The discovery of ewingite suggests that nanoscale uranyl carbonate cages could be aqueous species in some systems, and these may affect the geochemical behavior of uranium. The complexity of crystal structure is count as the information content of the unit cell. The value for ewingite is 12 684.86 bits per unit cell (most high among minerals so far) as determined by the single-crystal XRD analysis which does not provide locations of some of the disordered H_2O groups or any of the H atoms in the structure. The total information content is ~23 000 bits/unit cell when all unit cell constituents are accounted. The mineral name honors of Rodney C. Ewing (b. 1946) mineralogist and material scientist focused

on the properties of nuclear materials at Stanford University, California, U.S.A. The holotype specimen is deposited in the Natural History Museum of Los Angeles County, U.S.A. **D.B.**

Fiemmeite*

F. Demartin, I. Campostrini, P. Ferretti, and I. Rocchetti (2018) Fiemmeite $Cu_2(C_2O_4)(OH)_2 \cdot 2H_2O$, a new mineral from Val di Fiemme, Trentino, Italy. Minerals, 8(6), 248

Fiemmeite (IMA 2017-115), ideally $Cu_2(C_2O_4)(OH)_2 \cdot 2H_2O$, monoclinic, was discovered NE of the Passo di San Lugano, Val di Fiemme, Carano, Trento, Italy (46.312° N, 11.406° E) and was named for its type locality. It occurs in coalified wood trunks at the base of the Val Gardena Sandstone (upper Permian) which were permeated by mineralizing solutions containing Cu, U, As, Pb and Zn. The mineralization is referable as "sandstone-uranium type" roll front deposits. The oxalate anions have originated from diagenesis of the plant remains included in sandstones. Fiemmeite is associated with baryte, olivenite, middlebackite, moolooite, brochantite, cuprite, devilline, malachite, azurite, zeunerite/metazeunerite, tennantite, chalcocite, galena. The mineral forms aggregate up to 1 mm across of sky-blue platelet crystals up to ~50 µm. The streak is pale blue, and the luster is from vitreous to waxy. It is brittle with uneven fracture and almost perfect cleavage parallel to {010} or {001}. Hardness was not determined; $D_{meas} = 2.78(1)$ g/cm³ and $D_{calc} = 2.802$ g/cm³. Fiemmeite is highly birefringent with minimum and maximum refractive indexes 1.54 and 1.90. No other optical properties obtained; $n_{calc} = 1.64$. The Raman spectrum shows bands (cm⁻¹): 3471, 3438 (consistent with the range of hydrogen bond lengths found 2.655–2.903 Å); 1683, 1705 (v_a C=O); 1457 (v_s C–O + v_s C–C); 903, 853 (v_s C–O + δ O–C=C); 466, 517, 543 (v Cu–O + v C–C); 298 (out-of-plane bends and to lattice modes). The average chemical composition (number of analysis not specified) [wt% (range)] is Cu 44.00 (43.79–44.24), Zn 0.09 (0.06–0.12) (Cu and Zn by electron probe EDS analyses); O 44.40, C 8.34, H 2.10; total 98.93. The values for O, C, and H are calculated for theoretical empirical formula based on 8 anions: $Cu_{2.00}Zn_{<0.01}(C_2O_4)(OH)_2 \cdot 2H_2O$. Crystals rapidly decompose under an electron beam even using low voltage current and a wide beam. The presence of H_2O and C_2O_3 was confirmed by crystal structure analysis and Raman spectroscopy. No other significant element quantities were detected. The strongest reflections in the X-ray powder diffraction pattern are: [d Å (I; hkl)] 9.71 (55; 002), 7.02 (28; 012), 5.079 (100; 020), 4.501 (50; 022), 3.072 (58; 112), 2.891 (20; 113), 2.730 (15; 026), 2.686 (25; 114). The unit-cell parameters refined from powder XRD are $a = 3.4345(5)$, $b = 10.159(2)$, $c = 19.412(3)$ Å, $β = 90.83(1)$, $V = 677.5$ Å³. The single-crystal X-ray data shows fiemmeite is monoclinic, space group: $P2_1/c$, $a = 3.4245(6)$, $b = 10.141(2)$, $c = 19.397(3)$ Å, $β = 90.71(1)°$, $V = 673.6$ Å³, $Z = 4$. The crystal structure was refined to $R_1 = 0.0386$ for 1942 observed [$I>2σ(I)$] reflections with all the hydrogen atoms located from a Difference-Fourier map. The asymmetric unit contains two independent Cu^{2+} cations that display a distorted square-bipyramidal (4+2) coordination, one oxalate anion, two hydroxyl anions, and two water molecules. The coordination polyhedra of the two copper atoms share common edges to form polymeric rows with composition $[Cu_2(C_2O_4)(OH)_2 \cdot 2H_2O]_n$ running along [100]. These rows are held together by hydrogen bonds between the oxalate oxygens not involved in the coordination to copper, the hydrogen atoms of the water molecules and the hydroxyl anions. A portion of that kind polymeric rows is reported in the structure of middlebackite $Cu_2C_2O_4(OH)_2$ where these rows are interconnected to form channels where the hydrogen atoms of hydroxyl groups are located. Holotype of fiemmeite is deposited in the MUSE, Museo delle Scienze di Trento, Trento, Italy. **D.B.**

Horákite

J. Plášil, A.R. Kampf, J. Sejkora, J. Čejka, R. Škoda, and J. Tvrdý (2018) Horákite, a new hydrated bismuth uranyl–arsenate–phosphate mineral

from Jáchymov (Czech Republic) with a unique uranyl-anion topology. Journal of Geosciences, 63, 265–276.

Horákite (IMA 2017-033), ideally $(Bi_7O_7OH)[(UO_2)_4(PO_4)_2(AsO_4)_2(OH)_2] \cdot 3.5H_2O$, monoclinic, is a new uranyl mineral discovered on old private collection specimen from Jáchymov (St. Joachimsthal), Czech Republic (most likely from the Geister vein at Rovnost mine). It is the first uranyl mineral containing both phosphate and arsenate as essential components. Horákite occurs in mylonitized mica-schist containing thin quartz veinlets. It is a supergene alteration mineral associating with phosphuranylite (overgrowing older metatorbernite–metazeunerite) in vugs of the quartz gangue with relics of tennantite and fine-grained uraninite. Horákite forms greenish-yellow to pale yellow transparent to translucent prismatic to bladed crystals elongated on [001] clustering in aggregates up to 1 mm across. The mineral has a light-yellow streak and a vitreous luster. The cleavage is perfect on {100}. The Mohs hardness is ~2. Density was not measured; $D_{calc} = 6.358$ g/cm³. Horákite is non-pleochroic, optically biaxial (+), with α ≈ 1.81, β ≈ 1.84, γ ≈ 1.88 (white light); $2V = 78(1)°$, $2V_{calc} = 83°$; $X = \mathbf{b}$, $Z ≈ \mathbf{c}$. No dispersion observed. The main bands of Raman spectrum (cm⁻¹; w – weak, s – strong, sh – shoulder, b – broad) are: 3580 wb with a shoulder at 3410 (v O–H stretchings of hydrogen-bonded OH⁻ and H_2O); series of weak bands at 1103, 1081, 1069, 1055, 1039 [triply degenerate v_3 antisymmetric stretching of $(PO_4)^{3-}$ polyhedra]; 1030–930w [v_1 symmetric stretching of $(PO_4)^{3-}$]; 879 and 864 [$v_3(UO_2)^{2+}$ vibrations]; 850sh, 801s [$v_1(UO_2)^{2+}$ symmetric stretching along with δ–UOH (in-plane) bending modes and the triply degenerate v_3 antisymmetric stretching vibration of AsO_4 tetrahedra]; 774 (v_1 symmetric stretching of AsO_4); 640–520w (triply degenerate v_4 bending of PO_4 tetrahedra and Bi–O stretching); 510–360 (doubly degenerate v_2 bending vibrations, triply degenerate v_3 bending of AsO_4, Bi–O stretching and Bi–O–Bi bending vibrations); 380–280 (doubly degenerate v_2 bending of AsO_4 and Bi–O stretching); 271sh, 251, 228sh [doubly degenerate v_2 bending vibrations of $(UO_2)^{2+}$ groups]; 189, 163, 147, 123, 105, 74, and 48 [external lattice vibration modes and $(UO_2)^{2+}$ translations and rotations]. No Raman band was observed where the v_2 (δ) H–O–H bending vibrations should occur. The average of 21 spot electron probe WDS analysis is [wt% (range)]: PbO 0.99 (0–1.75), Bi_2O_3 50.22 (49.00–51.33), UO_3 35.58 (33.47–37.66), SiO_2 0.85 (0.60–1.27), P_2O_5 4.47 (4.09–5.91), As_2O_5 5.21 (4.28–5.91), H_2O (by structure constrains) 2.77, total 100.09. The empirical formula based on 37.5 O apfu is $(Bi_{7.01}Pb_{0.14})O_7OH[(U_{1.01}O_2)_4(P_{1.03}O_4)_2(As_{0.74}Si_{0.23}O_4)_2(OH)_2] \cdot 3.5H_2O$. The strongest X-ray powder-diffraction lines are [d Å (I; hkl)]: 11.77 (100; 110), 6.21 (23; $\overline{2}$02), 5.55 (23; 310,$\overline{1}$12), 4.19 (27; $\overline{3}$31), 3.54 (61; 510,$\overline{4}$23), 3.29 (20; 331), 3.14 (58; 241,023), 3.02 (98; 150,113,$\overline{5}$33, multiple). The single-crystal X-ray data obtained on a crystal of 0.020 × 0.012 × 0.010 mm show horákite is monoclinic, $C2/c$, $a = 21.374(2)$, $b = 15.451(3)$, $c = 12.168(2)$ Å, $β = 122.26(1)°$, $V = 3398.1$ Å³, $Z = 4$. The crystal structure refined to $R = 0.0595$ for 1774 unique observed [$I_{obs}>3σ(I)$] reflections. This novel sheet structure contains 2 U sites, 4 Bi sites, 2 T sites jointly occupied by P and As ($T1$ site dominantly occupied by As^{5+} while $T2$ is nearly fully occupied by P^{5+}), and 20 O sites (of which 3 are OH groups and 4 H_2O groups). It consists of topologically unique $[(UO_2)_4(PO_4)_2(AsO_4)_2(OH)_2]$ sheets (horákite topology), and an interstitial $\{(Bi_7O_7OH)(H_2O)_{3.5}\}$ complex. Sheets result from the polymerization of UO_7 pentagonal bipyramids by sharing edges to form tetrameric units; tetrahedrally coordinated sites are linked to the UO_7 both monodentately ($T1$ to $U1$) and bidentately ($T2$ to $U2$). The name honors František Horák (1882–1919), the mining engineer, a chief of the radium factory in St. Joachimsthal (Jáchymov) from 1916 to 1918, and his grandson, Vladimír Horák (b. 1964), an amateur mineralogist focused on the mining history of the Jáchymov ore district. The holotype specimen is deposited in the Natural History Museum of Los Angeles County, California, U.S.A. **D.B.**

Nöggerathite-(Ce)*

N.V. Chukanov, N.V. Zubkova, S.N. Britvin, I.V. Pekov, M.F. Vigasina, C. Schäfer, B. Ternes, W. Schüller, Y.S. Polekhovsky, V.N. Ermolaeva, and D.Yu. Pushcharovsky (2018) Nöggerathite-(Ce), $(Ce,Ca)_2Zr_2(Nb,Ti)$ $(Ti,Nb)_2Fe^{2+}O_{14}$, a new zirconolite-related mineral from the Eifel Volcanic Region, Germany. Minerals, 8(10), 449.

Nöggerathite-(Ce) (IMA 2017-107), $(Ce,Ca)_2Zr_2(Nb,Ti)$ $(Ti,Nb)_2Fe^{2+}O_{14}$, orthorhombic, is a new mineral discovered at the In den Dellen (Zieglowski) pumice quarry, near Mendig, Laach Lake (Laacher See) paleovolcano, Eifel region, Rhineland-Palatinate, Germany. The mineral found in cavities of sanidinite volcanic ejectum with sanidine, dark mica, magnetite, baddeleyite, nosean, and a chevkinite-group mineral. Nöggerathite-(Ce) forms brown to very dark reddish brown, almost black, translucent to transparent prismatic often twinned crystals up to $0.1 \times 0.1 \times 1.0$ mm, elongated by [001] isolated or combined in random aggregates. The crystal forms are: {100}, {010}, {110}, {120}, {111}, and minor {001}. Twinning plane is (130). The mineral has adamantine luster and brownish red streak. It is brittle with uneven fractures and no cleavage. The micro-indentation hardness $VHN_{20} = 615$ kg/mm², corresponding to 5½ of a Mohs scale. The density was not measured; $D_{calc} = 5.332$ g/cm³. In reflected light, nöggerathite-(Ce) is light gray, with reddish brown internal reflections, weakly anisotropic. Pleochroism is not reported. The reflectance values (R_1, R_2, nm) **COM** wavelengths are bolded: 17.3, 16.8, 400; 16.8, 16.4, 420; 16.4, 16.0, 440; 16.0, 15.5, 460; **15.8, 15.3, 470**; 15.6, 15.2, 480; 15.3, 15.0, 500; 15.3, 14.8, 520; 15.0, 14.7, 540; **15.0, 14.7, 546**; 15.0, 14.6, 560; 14.9, 14.6, 580; **14.9, 14.5, 589**; 14.8, 14.5, 600; 14.8, 14.5, 620; 14.8, 14.4, 640; **14.8, 14.4, 650**; 14.8, 14.4, 660; 14.7, 14.4, 680; 14.7, 14.3, 700. The calculated mean refractive index is 2.267. The Raman spectrum shows bands in the ranges (cm⁻¹): 400–800 [(Ti,Nb,Zr)–O-stretchings]; 100–400 [(REE,Ca)–O-stretching and O–(Ti,Nb,Zr)–O bending vibrations]. Broad features above 900 cm⁻¹ correspond to luminescence due to high amounts of REE. The bands corresponding to hydrogen groups and CO_3^{2-} anions are absent. The Raman spectrum is similar to that of laachite $Ca_2Zr_2Nb_2TiFeO_{14}$ in which the bands of (REE,Ca)–O- and (Ti,Nb,Zr)–O-stretching vibrations are shifted towards higher and lower values, respectively. The averages of unspecified number of WDS electron probe analysis for holotype/ cotype specimens [wt% (range)] are: CaO 5.45 (5.27–5.55)/ 5.29 (5.12–5.39), MnO 4.19 (4.07–4.32)/ 4.16 (4.06–4.34), FeO 7.63 (7.46–7.79)/ 6.62 (6.23–6.83), Al_2O_3 0.27 (0.18–0.38)/ 0.59 (0.48–0.78), Y_2O_3 0.00/ 0.90 (0.61–0.99), La_2O_3 3.17 (3.05–3.28)/ 3.64 (3.47–3.84), Ce_2O_3 11.48 (11.27–11.73)/ 11.22 (10.95–11.69), Pr_2O_3 1.04 (0.89–1.24)/ 0.92 (0.90–0.97), Nd_2O_3 2.18 (2.10–2.34)/ 2.46 (2.28–2.81), ThO_2 2.32 (2.11–2.50)/ 1.98 (1.79–2.17), TiO_2 17.78 (17.45–18.12)/ 18.69 (18.49–18.90), ZrO_2 27.01 (26.82–27.26)/ 27.69 (27.51–27.86), Nb_2O_5 17.04 (16.72–17.37)/ 15.77 (15.53–15.99); total 99.59/ 99.82. Other elements with $Z > 8$ were not detected. Iron and manganese are considered as Fe^{2+} and Mn^{2+} based on structural data and by analogy with laachite, respectively. The empirical formulae based on 14 O pfu are: $(Ce_{0.59}La_{0.17}Nd_{0.11}Pr_{0.05})_{\Sigma0.92}Ca_{0.82}Th_{0.07}Mn_{0.50}Fe_{0.90}Al_{0.05}Zr_{1.86}Ti_{1.88}Nb_{1.07}O_{14}$ (holotype), and $(Ce_{0.57}La_{0.19}Nd_{0.12}Pr_{0.05}Y_{0.06})_{\Sigma0.99}Ca_{0.79}Th_{0.06}Mn_{0.49}Fe_{0.77}Al_{0.10}$ $Zr_{1.89}Ti_{1.96}Nb_{1.00}O_{14}$ (cotype). The strongest lines of the powder X-ray diffraction pattern [d Å (I%; hkl)] are: 2.963 (91; 202), 2.903 (100; 042), 2.540 (39; 004), 1.823 (15; 400), 1.796 (51; 244), 1.543 (20; 442), 1.519 (16; 282). The unit-cell parameters refined from the powder data are $a = 7.296(1)$, $b = 14.147(2)$, $c = 10.161(1)$ Å, $V = 1048.9$ Å³. The single-crystal X-ray data obtained from the crystal $0.01 \times 0.01 \times 0.10$ mm shows nöggerathite-(Ce) is orthorhombic, space group $Cmca$, $a = 7.2985(3)$, $b = 14.1454(4)$, $c = 10.1607(4)$ Å, $V = 1048.99$ Å³, $Z = 4$. The crystal structure was solved by direct methods and refined to $R = 0.0198$ for 574 unique $I > 2\sigma(I)$ reflections. The structure shows an alternation of two types of bent polyhedral layers: an octahedral layer and a layer

of cations with 7- and 8-fold coordination. The octahedral layer is built by vertex-sharing $M(3)O_6$ and $M(4)O_6$ octahedra forming three- and six-membered rings, whereas $M(5)$ and $M(6)$ sites are located in the centers of six-membered rings. The adjacent sites $M(5)$ and $M(6)$, with coordination numbers 4 and 5, respectively, are statistically occupied by Fe^{2+} as the major cation. The $M(1)$ site is a distorted cube which shares edges with neighboring $M(1)$ cubes to form rows along the **a** axis. Similar rows are formed by sevenfold $M(2)$ mono-capped octahedra. Adjacent rows of eightfold and sevenfold polyhedra are linked with each other via common edges forming a dense layer. The crystal-chemical formula of nöggerathite-(Ce) is: $^{M(1)VIII}(LREE_{0.88}Ca_{0.80}Mn_{0.24}Th_{0.08})^{M(2)VII}(Zr_{1.88}Mn_{0.12})$ $^{M(3)VI}(Nb_{1.22}Ti_{0.78})^{M(4)VI}(Ti_{1.48}Nb_{0.48}Al_{0.04})^{M(5)IV}(Fe_{0.48}Mn_{0.08})^{M(6)V}(Fe_{0.40}Mn_{0.04})_2O_{14}$. Nöggerathite-(Ce) is an analogue of zirconolite-3O, $CaZrTi_2O_7$, with Nb dominant over Ti in one of two octahedral sites and REE dominant over Ca in the eightfold-coordinated site. The name honors Johann Jacob Nöggerath (1788–1877), German mineralogist and geologist, a professor of mineralogy and geology at the University of Bonn. Among his publications is a geological description of the Laacher See paleovolcanic region. The type material is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **D.B.**

Paddlewheelite*

T.A. Olds, J. Plášil, A.R. Kampf, F. Dal Bo, and P.C. Burns (2018) Paddlewheelite, a new uranyl carbonate from the Jáchymov District, Bohemia, Czech Republic. Minerals, 8(11), 511.

Paddlewheelite (IMA 2017-098), $MgCa_5Cu_2[(UO_2)(CO_3)_3]_4 \cdot 33H_2O$, monoclinic, is a new uranyl carbonate mineral discovered at the bifurcation of the Prokop vein on the 5th level of the Svornost abandoned underground mine, Jáchymov District, Bohemia, Czech Republic. The mine is one of the major ore clusters in the area representing classical hydrothermal Ag-Co-Ni-Bi-As±U (five-element vein type) ore deposits. The new mineral is one of the products of post-mining oxidation. Its crystallization requires concomitant dissolution of uraninite, calcite, dolomite, chalcopyrite, and andersonite. Paddlewheelite occurs with calcite, dolomite, and chalcopyrite in the area of Prokop vein rich in andersonite. Other closely associated minerals include coffinitized uraninite, quartz, hematite, and goethite (var. "sammetblende"). The mineral forms cleavage coating and wedged tabular crystals flattened by {100} up to ~400 μm with not apparent twinning. The crystals are blue green, transparent with sub-adamantine luster and very pale blue green streak. Paddlewheelite does not fluoresce in UV light. It is brittle with Mohs hardness ~2 and at least one perfect cleavage on {100}. Due to limited availability of crystals the density was not measured; $D_{calc} = 2.435$ g/cm³ (2.497 for an ideal formula). Paddlewheelite are immediately soluble with effervescence in dilute HCl at room temperature. In plane-polarized transmitted light, the mineral is pleochroic with $X \approx Y$ (blue green) $>> Z$ (pale yellow). It is optically biaxial (+), $\alpha = 1.520(2)$, $\beta = 1.527(2)$, $\gamma = 1.540(2)$ (white light), $2V = 72°(1)$, $Z // \mathbf{b}$, $X = \mathbf{a}$, $Y = \mathbf{c}$. Dispersion of optical axis is weak $r < v$. FTIR spectra of paddlewheelite show features at (cm⁻¹; w – weak, s – strong): multicomponent band spanning from ~3500 to ~2800 (3515, 3377, 3200, 3026, 2850) is related to vO–H stretching of H_2O; 1632w [$v_2(\delta)$-bending vibration of H_2O]; 1591w, 1544w, 1498s, 1459w, 1410s, 1379w, 1351s, 1289w [splitted v_3 $(CO_3)^{2-}$ antisymmetric stretching]; 1115w [v_1 $(CO_3)^{2-}$ symmetric stretching]; 931.5vs [$v_3(UO_2)^{2+}$ antisymmetric stretching and probably obscured $v_2(\delta)$ $(CO_3)^{2-}$]; 771w [coincidence of either v_1 $(UO_2)^{2+}$ or v_4 (δ) $(CO_3)^{2-}$ in-plane bending vibration]. The average of six electron probe WDS analysis [wt% (range)/ wt% normalized to 100% total)] is: CaO 12.47 (11.71–13.38)/ 10.74, CuO 2.65 (1.64–3.26)/ 2.28, FeO 0.01 (0–0.04)/ 0.01, MgO 1.7 (1.16–1.93)/ 1.47, SiO_2 0.42 (0–0.93)/ 0.36, UO_3 49.38 (48.22–50.69)/ 42.97, CO_2 (based on structure) 22.8/ 19.84, H_2O (based on structure) 25.66/ 22.33; total 115.09/ 100.00. Crystals were heavily dehydrated and fractured in the vacuum, leading to high U totals. Strong depleting of Cu during the analysis was

due to high beam current used (15 kV, 30 nA, 5 μm beam diameter). No other elements with $Z > 8$ were detected. The presence of H_2O and CO_3^{2-} confirmed by FTIR. The empirical formula based on 77 O, 4 U, and 12 CO_3 pfu is $Mg_{0.98}Ca_{5.16}Cu_{0.77}Si_{0.16}(UO_2)_4(CO_3)_{12}(H_2O)_{33}$. Attempt to use LA-ICP-MS was not successful giving the average empirical cation formula $Mg_{0.40}Ca_{3.20}Cu_{1.26}U_{4.00}$. The strongest lines in the powder X-ray diffraction pattern are [d Å (I%; hkl)]: 11.12 (100; 111), 9.69 (22; 002), 8.63 (18; 020), 7.33 (46; $\overline{2}$02), 6.42 (30; 022, $\overline{2}$21), 5,54 (37; 222), 4.823 (33; 004,$\overline{4}$02), 4.642 (38; 313), 4.215 (34; 024), 3.717 (33; 115,$\overline{3}$33). Unit-cell parameters refined from the powder data with whole pattern fitting are a = 22.061(4), b = 17.128(3), c = 19.368(3) Å, β = 90.476°(2), V = 7318 Å^3. The single-crystal X-ray data obtained on a crystal 5 × 40 × 50 μm show paddlewheelite is monoclinic, space group Pc, a = 22.052(4), b = 17.118(3), c = 19.354(3) Å, β = 90.474°(2), V = 7306 Å^3, Z = 4. The crystal structure was refined to R_1 = 0.0706 for 17 626 I>2σ(I) reflections. The paddlewheelite crystal structure contains several first known instances for uranyl minerals, including isolated square pyramidal CuO_5 polyhedra "axles" and cubic CaO_8 "gearboxes". These two unique polyhedra bind to hexagonal bipyramidal uranyl tricarbonate $(UO_2)(CO_3)_3^{4-}$ units (UTC), forming clusters resembling the paddlewheel of a steamboat which is reflected in the mineral name. Four UTC "paddles" bind to the bases of two Cu square pyramids by sharing corners with carbonate triangles, forming the "axle" of each "paddlewheel" centered by the cubic calcium "gearbox" which shares two O atoms from edges of each of four UTC units forming a "paddlewheel" quadruplet cluster. The apical O atom of each CuO_5 square pyramid shares the corner with CO_3 group of adjacent UTC paddle. Two UTC "paddles" from each "wheel" form the planarity of the sheet, and 7-coordinated polyhedra of Ca sites connect "paddlewheels" together into an open-topology type sheet. Octahedrally coordinated Mg cations are within pores between "paddlewheels" in the sheet above, such that one Mg cation coordinates to one paddlewheel unit. Two unique sheets of "paddlewheels" at x = ½ and x = 0 are nearly identical except slight difference in rotation of the "paddlewheels". There is no direct contact between "paddlewheels" of different sheets, which are connected only by hydrogen bonds. Interstitial space between sheets is filled by 11 disordered H_2O groups and 22 H_2O groups bound to Ca and Mg cations. Each Ca site has a variable number (3 to 6) of coordinating H_2O groups, while each Mg binds to 5 H_2O groups. Thus, an idealized formula of paddlewheelite can be written as $Mg(H_2O)_5Ca_5(H_2O)_{17}Cu_2[(UO_2)(CO_3)_3]_4 \cdot 11H_2O$. The structure has some similarities to other uranyl carbonate minerals with paddle-like motifs: braunerite, línekite, albrechtschraufite, and andersonite. Paddlewheelite is the second-most structurally complex uranyl carbonate mineral known after ewingite $Mg_8Ca_8(UO_2)_{24}(CO_3)_{30}O_4(OH)_{12}(H_2O)_{138}$ and it is chemically related to the insufficiently described mineral voglite $Ca_2Cu(UO_2)(CO_3)_4 \cdot 6H_2O$ with unknown crystal structure. The holotype specimen is deposited in the Natural History Museum of Los Angeles County, U.S.A. **D.B.**

Parafiniukite*

A. Pieczka, C. Biagioni, B. Gołębiowska, P. Jeleń, M. Pasero, and M. Sitarz (2018) Parafiniukite, $Ca_2Mn_3(PO_4)_3Cl$, a new member of the apatite supergroup from the Szklary Pegmatite, Lower Silesia, Poland: description and crystal structure. Minerals, 8(11), 485.

Parafiniukite (IMA 2018-047), ideally $Ca_2Mn_3(PO_4)_3Cl$, monoclinic, is a new mineral of the apatite supergroup (Pasero et al. 2012) from the Szklary LCT pegmatite (50°39.068′ N, 16°49.932′ E), ~6 km N of the Ząbkowice Śląskie town, ~60 km south of Wrocław, Lower Silesia, Poland. The Szklary pegmatite is formed by NNE-SSW elongated lens or a boudin ~4 × 1 m large in planar section, which was in primary intrusive contact with an altered aplitic gneiss, up to 2 m thick, and both rocks were surrounded by tectonized serpentinite. The pegmatite represents the beryl–columbite–phosphate subtype of the rare element

(REL)–Li pegmatite class sensu Černý and Ercit (2005). Parafiniukite is found disseminated in the intermediate and central zone of the pegmatite, closely associated with small aggregates of beusite, up to ~1 cm in size, which underwent intense alteration into a secondary assemblage of Mn-oxides and smectites, where pieczkaite and rarer parafiniukite usually survived only as small relicts, not exceeding 250 μm in size. The mineral is transparent with dark olive-green color sometimes masked by the Mn-oxides. It has a vitreous luster, and it is brittle with irregular, uneven fracture. No forms and twinning were observed. Due to the occurring nature of the mineral, streak, hardness, density as well as main optical properties were not determined; D_{calc} = 3.614 g/cm^3; n_{calc} = 1.731. Mohs hardness is estimated as 4–5 (by analogy with pieczkaite). Raman spectra show bands (cm^{-1}) at (s = strong; m = medium; w = weak): ~955s, 1019m, and 1105w [stretching vibrations of the $(PO_4)^{3-}$ groups]; ~615w, 593m, 575m, and 425m [bending vibrations of $(PO_4)^{3-}$ groups]; weaker peaks below ~300 (deformations of the Ca and Mn polyhedra); ~3485 (O–H stretching). The average of 10 electron probe WDS analyses [wt% (range)] is: P_2O_5 39.20 (38.98–39.44), MgO 0.19 (0.12–0.27), CaO 24.14 (23.66–24.64), MnO 31.19 (30.04–31.78), FeO 2.95 (2.72–3.15), Na_2O 0.05 (0.01–0.07), F 0.39 (0.29–0.46), Cl 3.13 (3.00–3.29), H_2O [calculated according to stoichiometry, to have 1 (OH+F+Cl) pfu] 0.68 (0.61–0.71), –O=(F_2+Cl_2) 0.87, total 101.05. The empirical formula is $(Mn_{2.39}Ca_{2.34}Fe_{0.22}Mg_{0.03}Na_{0.01})_{\Sigma 4.99}$ $P_{3.00}O_{12}[Cl_{0.48}(OH)_{0.41}F_{0.11}]$ based on 12 O and 1 (F,Cl,OH) pfu. The strongest lines in the calculated powder X-ray diffraction pattern are [d_{calc} Å (I_{calc}%; hkl)]: 3.239 (39; 002), 2.801 (55, 211), 2.801 (76; 121), 2.740 (100; 300), 2.675 (50; 112), 2.544 (69; 202), 1.914 (31; 222), and 1.864 (22; 132). The cell parameters obtained from single-crystal diffraction data collected on a 0.07 × 0.04 × 0.03 mm crystal are a = 9.4900(6), c = 6.4777(5) Å, V =505.22(5) Å^3, hexagonal, $P6_3/m$, Z = 2. The crystal structure was refined to R = 4.63% on 320 reflections with $F_o > 4σ(F_o)$ and R_{all} = 6.76% on 422 reflections. It is topologically similar to those of the other members of the apatite supergroup. The $M(1)$ and $M(2)$ sites are Ca- and Mn-dominant, respectively, whereas Cl is the dominant X anion. The $M(2)$ site has a sevenfold coordination and a mixed (Mn,Ca) occupancy (idealized as $Mn_{0.63}Ca_{0.37}$). The preferential ordering of Mn at the $M(2)$ site is favored by the occurrence of Cl anion at the X site, whereas Mn tends to be ordered at $M(1)$ when X = F. Parafiniukite corresponds to the end-member composition $Ca_2Mn_3(PO_4)_3Cl$ hypothesized by Tait et al. (2015), and following Pasero et al. (2010) is a new member of the Hedyphane Group in the Apatite Supergroup. The name of the mineral is after Jan Parafiniuk (b. 1954), professor of mineralogy at the Institute of Geochemistry, Mineralogy and Petrology of the University of Warsaw, Poland. The parafiniukite holotype is deposited in the Mineralogical Museum of the University of Wrocław, Institute of Geological Sciences, Poland. **F.C.**

References cited

Černý, P., and Ercit, T.S. (2005) The classification of granitic pegmatites revisited. Canadian Mineralogist, 43, 2005–2026.

Pasero, M., Kampf, A.R., Ferraris, C., Pekov, I.V., Rakovan, J., and White, T.J. (2010) Nomenclature of the apatite supergroup minerals. European Journal of Mineralogy, 22, 163–179.

Tait, K., Ball, N.A., and Hawthorne, F.C. (2015) Pieczkaite, ideally $Mn_5(PO_4)_3Cl$, a new apatite-supergroup mineral from Cross Lake, Manitoba, Canada: Description and crystal structure. American Mineralogist, 100, 1047–1052.

Sharyginite*

R. Juroszek, H. Krüger, I. Galuskina, B. Krüger, L. Jeżak, B. Ternes, J. Wojdyla, T. Krzykawski, L. Pautov, and E. Galuskin (2018) Sharyginite, $Ca_3TiFe_2O_8$, a new mineral from the Bellerberg Volcano, Germany. Minerals 8(7), 308.

Sharyginite (IMA 2017-014), ideally $Ca_3TiFe_2O_8$, orthorhombic, a new member of the anion deficient perovskite group, was discovered in thermally metamorphosed limestone xenoliths in alkali basalt of the

Bellerberg volcano lava field Caspar quarry, Eifel, Rhineland-Palatinate, Germany (50°21′6″ N, 7°14′2″ E). This phase was previously documented as a member of the pseudobinary perovskite-brownmillerite series in ye'elimite-larnite pyrometamorphic rocks of the Hatrurim Complex (Sharygin et al. 2008) and in high-temperature skarns in carbonate xenoliths within ignimbrite of the Upper Chegem volcanic structure of the North Caucasus, Kabardino-Balkaria, Russia (Galuskin et al. 2008). It also was recognized in Ca-rich xenoliths in Klöch Basalt quarry, Bad Radkersburg, Styria, Austria (Niedermayr et al. 2011) and in metacarbonate rocks from burned dumps of the Donetsk (Sharygin et al. 2011) and Chelyabinsk coal basins (Sharygin 2012). It was previously identified in xenoliths from the Eifel region (Sharygin and Wirth 2012), but, due to the small size of the crystals was not studied completely. In the holotype specimen, sharyginite is widespread in the contact zone of Ca-rich xenolith with alkali basalt where it is closely associated with fluorellestadite, cuspidine, brownmillerite, rondorfite, larnite, and chlormayenite-wadalite. Rankinite, magnesioferrite, perovskite, and fluorite are less common in this zone. Sharyginite suggested to be formed after perovskite at high-temperature conditions >1000 °C. It occurs as flattened by {010} crystals up to 200 μm. Other forms are {100}, {001} and, rarely rhombic pyramid. The mineral is dark brown, opaque with a brown streak, sub-metallic luster, good cleavage on {010} and imperfect on {001} and {100}. It is brittle with uneven fracture and no parting. The micro indentation hardness VHN_{25} = 635 (621–649) kg/mm^2 corresponding to ~ 5½–6 of Mohs scale. Density was not measured due to abundant inclusions; D_{calc} = 3.943 g/cm^3. In reflected light, sharyginite is light gray with rare yellowish-brown internal reflections. It is weakly pleochroic from gray to very light gray and weakly anisotropic. The reflectance values in air [R_{max}/R_{min}, nm] with **COM** wavelength bolded are: 18.7/17.6, 400; 18.3/17.4, 420; 17.0/16.0, 440; 16.4/15.6, 460; **16.1/15.5, 470**; 15.9/15.4, 480; 15.5/14.9, 500; 15.2/14.5, 520; 15.0/14.3, 540; **14.9/14.2, 546**; 14.8/14.2, 560; 14.7/14.1, 580; **14.6/14.1, 589**; 14.6/14.1, 600; 14.6/14.0, 620; 14.6/14.0, 640; **14.5/13.9, 650**; 14.4/13.7, 660; 14.3/13.5, 680; 14.1/13.4, 700. The bands of the Raman spectrum (cm^{-1}): 114, 145, 190, 248, 307, 389, 486, 560, 710, 752, 785 and 1415, 1475 (overtone); 710s [symmetric stretching of $v_1(Fe^{3+}O_4)$ tetrahedra] with two shoulders at 752 [$v_1(AlO_4)$] and 785 [$v_3(Fe^{3+}O_4)$]; 486 and 560 [(Fe^{3+}O$_4$) bending]. Bands below 400 cm^{-1} are attributed to the polyhedral CaO$_8$ and octahedral (Fe^{3+},Ti)O$_6$ vibrations. No bands in the OH region were observed. The spectrum is similar to that of shulamitite Ca$_3$TiFeAlO$_8$, with the main distinction in the position of the main band. The averages of 9/ *19*/ 4 electron probe WDS analysis of sharyginite from Belleberg (holotype)/ *Jabel Harmun (Hatrurim complex) Palestinian Autonomy*/ Upper Chegem Caldera, North Caucasus, Russia, are [wt% (range): MnO$_2$ 2.27 (1.04–3.22)/ *n.d.*/ n.d.; SiO$_2$ 0.58 (0.40–0.80)/ *1.19 (1.07–1.43)*/ 0.17 (0.07–0.32); SnO$_2$ n.d./ *n.d.*/ 0.37 (0.15–0.61); TiO$_2$ 17.04 (16.29–19.34)/ *17.97 (16.65–18.76)*/ 17.38 (16.97–17.76); ZrO$_2$ 0.27 (0.07–0.57)/ *0.43 (0.25–0.62)*/ 0.39 (0.16–0.67); Al$_2$O$_3$ 2.49 (2.22–3.89)/ *3.83 (3.62–4.13)*/ 1.86 (1.36–2.29); Cr$_2$O$_3$ 0.20 (0.07–0.42)/ *0.25 (0–0.47)*/ n.d.; Fe$_2$O$_3$ 34.87 (32.81–35.85)/ *32.80 (31.70–34.54)*/ 37.43 (36.40–38.72); CaO 41.59 (40.99–42.09)/ *42.19 (41.64–42.60)*/ 40.71 (40.53–40.85); MgO 0.13 (0.08–0.24)/ *0.08 (0.06–0.11)*/ 0.05 (0.04–0.06); MnO n.d./ *n.d.*/ 0.09 (0.01–0.13); SrO n.d./ *0.18 (0.08–0.32)*/ n.d.; total 99.44/ *98.91*/ 98.45. No other elements with Z > 8 were detected. The empirical formula of holotype calculated based on 8 O pfu is Ca$_{3.00}$(Fe$_{1.00}^{3+}$Ti$_{0.86}^{4+}$Mn$_{0.11}^{4+}$Zr$_{0.01}$Cr$_{0.01}^{3+}$Mg$_{0.01}$)$_{\Sigma2.00}$(Fe$_{0.76}^{3+}$Al$_{0.20}$Si$_{0.04}$)$_{\Sigma1.00}$O$_8$. The holotype sharyginite is represented by a complex solid-solution, with the end members: 64% of sharyginite, 20% of shulamitite, and 11% of Mn-analogue of sharyginite. Other components like Ca$_3$(Zr^{4+}Fe^{3+})Fe^{3+}O$_8$, Ca$_3$(Fe^{3+}Fe^{3+})SiO$_8$, Ca$_3$(Cr^{3+}Fe^{3+})SiO$_8$, and Ca$_3$(MgTi)SiO$_8$, are minor with contents less than 1–2%. The strongest lines in the X-ray powder diffraction pattern [d Å (I%; hkl)] are: 2.763 (32; 002), 2.712 (27; 200), 2.679 (100; 131), 1.936 (36; 202), 1.857 (19; 060), 1.580 (18; 133), 1.559 (12; 331); 1.341 (11; 262). Unit-cell parameters refined from the powder data are a = 5.4262(4),

b = 11.1468(7), c = 5.5308(3) Å, V = 334.5(3) Å^3. The single-crystal X-ray data obtained from the crystal 60 × 40 × 40 μm shows sharyginite is orthorhombic, space group $P2_1ma$, a = 5.423(2) Å, b = 11.150(8) Å, c = 5.528(2) Å, V = 334.3 Å^3, Z = 2. The crystal structure refined to R = 0.024 for all 951 unique reflections. It is closely related to that of shulamitite (the details are discussed) and consists of double layers of corner-sharing (Ti,Fe^{3+})O$_6$ octahedra, which are separated by single layers of (Fe^{3+}O$_4$) tetrahedra which form zweier single-chains. These chains are characteristic for sharyginite, shulamitite and the structurally related brownmillerite. One octahedral site hosted by ½ Ti and ½ Fe^{3+} with minor Al. The tetrahedral site occupied by ¾ Fe^{3+} and ¼ Al. The independent calcium cations located between the two octahedral layers (*Ca*2) and between octahedral and tetrahedral layers (*Ca*1). The name honors Victor Victorovich Sharygin (b.1964) of the Sobolev Institute of Geology and Mineralogy, Novosibirsk, Russia, for his contributions to petrology of alkaline and pyrometamorphic rocks. He also found and published preliminary data on this mineral. Type material was deposited in the Fersman Mineralogical Museum RAS, Moscow, Russia. **D.B.**

References cited

Galuskin, E.V., Gazeev, V.M., Armbruster, T., Zadov, A.E., Galuskina, I.O., Pertsev, N.N., Dzierżanowski, P., Kadiyski, M., Gurbanov, A.G., Wrzalik, R., and Winiarski, A. (2008) Lakargiite CaZrO$_3$: A new mineral of the perovskite group from the North Caucasus, Kabardino-Balkaria, Russia. American Mineralogist, 93, 1903–1910.

Niedermayr, G., Auer, C., Bernhard, F., Brandstätter, F., Gröbner, J., Hammer, V.M.F., Knobloch, G., Koch, G., Kolitchs, U., Konzett, J., Leikauf, B., Loffler, E., Postl, W., Prasnik, H., Prayer, A., Pristacz, H., Sabor, M., Seemann, R., Stehlik, H., Thinschmidt, A., and Walter, F. (2011) Neue Mineralfunde aus Österreich LX. Carinthia II, 201, 135–186.

Sharygin, V.V. (2011) Lakargiite and minerals of the perovskite brownmillerite series in metacarbonate rocks from Donetsk burned dumps. Scientific works of Donetsk National Technical University, Mining and Geological Series, Donetsk National Technical University, Donetsk, Ukraine, 15, 114–125.

——— (2012) Minerals of the Ca$_3$TiFeAlO$_8$–Ca$_3$TiFeFeO$_8$ series in natural and technogenic pyrometamorphic systems. In the Mineralogy of Technogenesis, Institute of Mineralogy, Uralian Branch of Russian Academy of Sciences: Miass, Russia, 29–49.

Sharygin, V.V., and Wirth, R. (2012) Shulamitite and its Fe-analog in metacarbonate xenoliths from alkali basalts, E. Eifel, Germany. In Proceedings of the 29th International Conference Ore Potential of Alkaline, Kimberlite and Carbonatite Magmatism, "Alkaline magmatism of the Earth", Sudak-Moscow, Ukraine-Russia, 14–22 September 2012.

Sharygin, V.V., Sokol, E.V., and Vapnik, Y. (2008) Minerals of the pseudobinary perovskite-brownmillerite series from combustion metamorphic larnite rocks of the Hatrurim Formation (Israel). Russian Geology and Geophysics, 49, 709–726.

THALHAMMERITE*

A. Vymazalová, F. Laufek, S.F. Sluzhenikin, V.V. Kozlov, C.J. Stanley, J. Plášil, F. Zaccarini, G. Garuti, and R. Bakker (2018) Thalhammerite, Pd$_9$Ag$_2$Bi$_2$S$_4$, a new mineral from the Talnakh and Oktyabrsk Deposits, Noril'sk Region, Russia. Minerals, 8(8), 339.

Thalhammerite (IMA 2017-111), Pd$_9$Ag$_2$Bi$_2$S$_4$, tetragonal, is a new mineral discovered in the same specimen (polished section) which is also holotype for kravtsovite, PdAg$_2$S, and vymazalováite, Pd$_3$Bi$_2$S$_2$. The specimen originated from vein-disseminated galena-pyrite-chalcopyrite ore hosted by diopside-hydrogrossular metasomatites developed in diopside-monticellite skarns below the lower exocontact of the Talnakh intrusion at the eastern part of Komsomolsky mine (69°30′20″ N; 88°27′17″ E). Here thalhammerite is also associated with cooperite, braggite, vysotskite, stibiopalladinite, telargpalite, sobolevskite, kotulskite, sopcheite, insizwaite, Au-Ag alloys, and Ag-bearing sulphides, selenides, sulphoselenides, and tellurosulphoselenides. The mineral was also observed in vein-disseminated millerite-bornite-chalcopyrite ore (Talnakh and Oktyabrsk deposits) hosted by pyroxene-hornfels at the lower exocontact of the Kharaelakh intrusion at western part of the Komsomolsky mine, Noril'sk region, Russia. In the latter association

it found with kotulskite, telargpalite, laflammeite, and Au-Ag alloys. Thalhammerite was also observed in intergrowths with sobolevskite, in PGE ores from the Fedorov-Pana Layered Intrusive, Russia. Thalhammerite forms tiny inclusions (a few micrometers to ~40–50 μm) intergrown in galena, chalcopyrite, and bornite. It is opaque with a metallic luster and is brittle; D_{calc} = 9.72 g/cm^3. In plane-polarized light, thalhammerite is light yellow with weak bireflectance, weak pleochroism, in shades of slightly yellowish brown, weak anisotropy and with no internal reflections. The reflectance values in air [R_1/R_2 %, nm], **COM wavelengths are bolded** are: 41.9/43.0, 400; 40.6/41.8, 420; 41.1/42.3, 440; 41.7/42.8, 460; **41.9/43.0, 470**; 42.2/43.3, 480; 42.7/43.9, 500; 43.2/44.4, 520; 43.7/44.9, 540; **43.9/45.1, 546**; 44.2/45.4, 560; 44.7/45.9, 580; **44.9/46.1, 589**; 45.2/46.3, 600; 45.6/46.8, 620; 46.1/47.3, 640; **46.3/47.5, 650**; 46.5/47.8, 660; 47.0/48.3, 680; 47.4/48.9, 700. The reflectance values for synthetic analog are similar being slightly higher for each wavelength for 0.6–1.8%. The Raman spectra of thalhammerite and synthetic $Pd_9Ag_2Bi_2S_4$ are practically identical and show four main absorption bands at 122, 309, 362, and 483 cm^{-1}. The averaged electron probe WDS analysis 3 spots for holotype/ *5 spots for synthetic thalhammerite* (wt%): Pd 52.61/ *55.10*, Bi 22.21/ *24.99*, Pb 3.92/ –, Ag 14.37/ *12.75*, S 7.69/ *7.46*, Se 0.10/ –; total 100.90/ *100.30*. The empirical formulae based on 17 apfu are $Pd_{8.46}Ag_{2.28}(Bi_{1.82}Pb_{0.32})_{\Sigma2.14}(S_{4.10}Se_{0.02})_{\Sigma4.12}$/ *$Pd_{8.91}Ag_{2.03}Bi_{2.06}S_{4.00}$*. Due to the small size of thalhammerite grains the X-ray data were obtained only for its synthetic analogue. The structural identity between the synthetic $Pd_9Ag_2Bi_2S_4$ and the natural material was confirmed by EBSD, Raman spectroscopy and optical properties. The strongest lines in the X-ray powder diffraction pattern [d Å (I%; hkl)] are: 3.343 (24; 211), 2.839 (46; 220), 2.569 (21; 301), 2.412 (100; 222), 2.325 (61; 123), 2.287 (48; 004), 2.220 (29; 132), 2.007 (40; 400), 1.748 (23; 332), 1.509 (30; 404). The single-crystal X-ray data shows the synthetic thalhammerite is tetragonal, space group $I4/mmm$, a = 8.0266(2), c = 9.1531(2) Å, V = 589.70 Å^3, Z = 2. The crystal structure refined to R = 0.0310 for 221 unique observed [$I>3(\sigma)$] reflections is considered as only a substructure. The Rietveld refinement shows a few very weak unindexed peaks and peak splitting, which cannot be fitted using the tetragonal model. Attempts to refine the structure from single-crystal data in orthorhombic subgroups of $I4/mmm$ (i.e., $Fmmm$, $Immm$) led to negligible lowering of R-factors (0.0293) with a rapid increase of the refined parameters. No low-symmetry models could describe all peak splitting in powder diffraction patterns of synthetic thalhammerite. The tetragonal substructure contains three Pd, one Ag, Bi, and S sites. All sites, except the Pd(2) (0.88 occupancy), were found to be fully occupied. The Pd(1) position has perfectly planar square coordination of S atoms and further completed by two Ag atoms perpendicular to [Pd(1)S$_4$] square. The Pd(2) and Pd(3) sites form complex polyhedron being coordinated by two S atoms, two Bi, two Ag, and other Pd atoms. Ag site is surrounded by nine Pd atoms forming a mono-capped tetragonal antiprismatic coordination. The Bi atom is coordinated by eight Pd atoms to form a bi-capped trigonal prism. Thalhammerite has no exact structural analogues. The mineral honors Associate Professor Oskar Thalhammer (b.1956) of the University of Leoben, Austria for his contributions to the ore mineralogy and mineral deposits of PGE. The holotype is deposited at the Department of Earth Sciences of the Natural History Museum, London, U.K. **D.B.**

Thermaerogenite*

I.V. Pekov, F.D. Sandalov, N.N. Koshlyakova, M.F. Vigasina, Y.S. Polekhovsky, S.N. Britvin, E.G. Sidorov, and A.G. Turchkova (2018) Copper in natural oxide spinels: the new mineral thermaerogenite $CuAl_2O_4$, cuprospinel and Cu-enriched varieties of other spinel-group members from fumaroles of the Tolbachik Volcano, Kamchatka, Russia. Minerals, 8(11), 498.

Thermaerogenite (IMA 2018-021), ideally $CuAl_2O_4$, cubic, is a new member of the spinel supergroup (Bosi et al. 2019). It was found in the Arsenatnaya fumarole at the Second scoria cone of the Northern Breakthrough of the Great Tolbachik Fissure Eruption, Tolbachik volcano, Kamchatka Peninsula, Far-Eastern Region, Russia (55°41′ N 160°14′ E, 1200 m.a.s.l.), one of the hottest fumaroles at the Second scoria cone with a temperature measured in 2012–2018 which varied from 360 to 490 °C, depending on the depth. Thermaerogenite is found with other spinel supergroup members (spinel, gahnite, magnesioferrite, franklinite, and cuprospinel) and with tenorite, hematite, orthoclase (As-bearing variety), fluorophlogopite, langbeinite, calciolangbeinite, aphthitalite-type sulfates, anhydrite, krasheninnikovite, vanthoffite, fluoborite, sylvite, halite, pseudobrookite, rutile, corundum, and various arsenates (urusovite, johillerite, ericlaxmanite, kozyrevskite, popovite, lammerite, lammerite, tilasite, svabite, nickenichite, bradaczekite, dmisokolovite, shchurovskyite, etc.). Cu-bearing spinels are among the latest minerals of this assemblage: they occur in cavities and overgrow earlier oxides (hematite, tenorite) as well as silicates, arsenates and "saline" sulfates. Thermaerogenite is semitransparent to transparent, with a yellowish streak and strong vitreous luster. Thermaerogenite forms brown, yellow-brown, red-brown, brown-yellow, or brown red octahedral crystals up to 0.02 mm across, sometimes skeletal, typically combined in open-work clusters up to 1 mm across. Areas "sprinkled" by crystals of the new mineral are up to 0.5 cm × 0.5 cm. Major form are {111}, with narrow {110} faces observed on some crystals. Thermaerogenite is brittle, with conchoidal fracture (observed under the scanning electron microscope); cleavage or parting is not observed. Mohs hardness is ca. 7. D_{calc} = 4.870 g/cm^3. In reflected light, thermaerogenite is gray, optically isotropic, with yellowish internal reflections. The reflectance values in air [R % (nm)] (**COM wavelengths bolded**) are: 16.4 (400), 16.0 (420), 15.7 (440), 15.4 (460), **15.2 (470)**, 15.1 (480), 14.8 (500), 14.5 (520), 14.2 (540), **14.2 (546)**, 14.0 (560), 13.7 (580), **13.6 (589)**, 13.4 (600), 13.2 (620), 13.0 (640), **12.9 (650)**, 12.8 (660), 12.5 (680), 12.3 (700). The Raman spectrum of thermaerogenite contains four distinct bands (cm^{-1}, s = strong): 762s (A_{1g} mode, stretching vibrations of O-Al in tetrahedral coordination), 590 [F_{2g}(2) or F_{2g}(3) mode involving divalent cations, (Cu,Zn)–O], 284 [F_{2g}(1) mode], and 125s (lattice modes). The average of 4 WDS electron probe analyses [wt%, (range)] is: CuO 25.01 (23.64–26.86), ZnO 17.45 (14.46–18.71), Al$_2$O$_3$ 39.43 (34.59–45.43), Cr$_2$O$_3$ 0.27 (0.17–0.33), Fe$_2$O$_3$ 17.96 (11.47–22.21), total 100.12. The empirical formula based on 4 O pfu is $(Cu_{0.62}Zn_{0.42})_{\Sigma1.04}(Al_{1.52}Fe^{3+}_{0.44}Cr_{0.01})_{\Sigma1.97}O_4$. The strongest X-ray powder diffraction lines are [d Å (I%; hkl)]: 2.873 (65; 220), 2.451 (100; 311), 2.033 (10; 400), 1.660 (16; 422), 1.565 (28; 511), and 1.438 (30; 440). Unit-cell parameters refined from the powder data are a = 8.131(1) Å, V = 537.6 Å^3, Z = 8. The parameters of the cubic unit cell of thermaerogenite refined from a single-crystal are a = 8.093(9) Å, V = 530.1 Å^3, and space group $Fd\bar{3}m$; the crystal structure of the new mineral was not studied due to the low quality of single-crystal diffraction patterns caused by the imperfectness of all tested crystals. Thermaerogenite forms a continuous isomorphous series with gahnite and at Arsenatnaya fumarole at Tolbachik is associated to Cu-richest natural spinel-type oxide so far described with composition $(Cu_{0.83}Zn_{0.10}Mg_{0.04}Ni_{0.02})_{\Sigma1.00}(Fe^{3+}_{1.73}Al_{0.22}Mn^{3+}_{0.05}Ti_{0.01})_{\Sigma2.01}O_4$. The mineral name thermaerogenite is constructed based on the combination of Greek words θερμός, "hot", αέριον, "gas", γενής that means "born by". Thus, in whole it means *born by hot gas*, that reflects the fumarolic origin of the mineral. The type specimen of thermaerogenite is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **F.C.**

References cited

Bosi, F., Biagioni, C., and Pasero, M. (2019) Nomenclature and classification of the spinel supergroup. European Journal of Mineralogy, 31(1), 183–192.

TIBERIOBARDIITE*

C. Biagioni, M. Pasero, and F. Zaccarini (2018) Tiberiobardiite, $Cu_9Al(SiO_3OH)_2(OH)_{12}(H_2O)_6(SO_4)_{1.5}\cdot10H_2O$, a new mineral related to chalcophyllite from the Cretaio Cu prospect, Massa Marittima, Grosseto (Tuscany, Italy): occurrence and crystal structure. Minerals, 8(4), 152.

Tiberiobardiite (IMA 2016-96), ideally $Cu_9Al(SiO_3OH)_2(OH)_{12}(H_2O)_6$ $(SO_4)_{1.5}\cdot10H_2O$, trigonal, is a new mineral discovered in the Cretaio Cu prospect , Massa Marittima, Grosseto, Tuscany, Italy. The ore deposit is a small concentration of Cu sulfides (bornite, chalcocite, and covellite) and hematite, scattered as stockwork veins within highly deformed gabbro. Primary sulfides are strongly altered into antlerite, brochantite, chalcanthite, chalcoalumite, connellite, langite, libethenite, malachite, posnjakite, serpierite/devilline, and spangolite. Tiberiobardiite is found associated with brochantite as supergene alteration of Cu ore minerals in an oxidizing and hydrous low-T environment. Tiberiobardiite occurs as thin, tabular {001} crystals up to 200 × 5 μm, with a pseudo-hexagonal outline. The mineral is green, with a pale green streak; it is transparent with vitreous luster. Tiberiobardiite is brittle, with a perfect {001} cleavage and irregular fracture. Hardness and density and optical properties were not measured; D_{calc} = 2.528 g/cm³; n_{calc} = 1.568. Raman spectrum show peaks evident in the 300–1200 range (cm⁻¹): at 124, 203, and 261 (possibly lattice modes); at 394, 440, 487, 544, and 589 {bending modes of the $[SiO_3(OH)]$ and (SO_4) groups}; at 965 ($[SiO_3(OH)]$ and (SO_4) groups) and 1097 weak [likely (SO_4) antisymmetric stretching]; a strong and broad band was observed that can be deconvoluted into 3218, 3418, and 3555 bands (O–H stretching vibrations). The average of 5 WDS electron probe analyses [wt%, (range)] is: SO_3 10.37 (9.67–10.94), P_2O_5 3.41 (3.02–3.80), As_2O_5 0.05 (0.00–0.17), SiO_2 8.13 (7.29–9.03), Al_2O_3 5.54 (4.93–6.47), Fe_2O_3 0.74 (0.61–0.83), CuO 62.05 (57.44–65.20), ZnO 0.03 (0–0.10), total 90.32. The empirical formula based on 42 O pfu is $(Cu_{8.69}^{2+}Al_{0.21}Fe_{0.10}^{3+})_{\Sigma9.00}Al_{1.00}(Si_{1.51}P_{0.54})_{\Sigma2.05}S_{1.44}O_{12.53}$ $(OH)_{13.47}\cdot16H_2O$. The strongest X-ray Gandolfi camera diffraction lines are [d Å (relative visual intensity; s = strong; m = medium; mw = medium-weak; w = weak; vw = very weak; hkl)]: 9.4 (s; 003), 4.67 (s; 006,113,11$\bar{3}$), 2.576 (m; 223,22$\bar{3}$), 2.330 (m; 22$\bar{6}$,226), and 2.041 (mw; 229,22$\bar{9}$). The cell parameters obtained from single-crystal diffraction data collected on a 0.180 × 0.050 × 0.005 mm crystal are a = 10.6860(4), c = 28.3239(10) Å, V =2801.0 Å³, trigonal, $R\bar{3}$, Z = 3. The crystal structure was refined to R = 6.02% on 1747 reflections with F_o > 4σ(F_o) and R_{all} = 7.99% on 2809 reflections. The crystal structure of tiberiobardiite is composed by five independent cation positions ($Cu1$, $Cu2$, Al, Si, and S) and nine anion sites in the asymmetric unit. It can be described as formed by {001} heteropolyhedral layers, composed by $Cu\varphi_6$ polyhedra (φ = O, OH, H_2O), $Al(OH)_6$ octahedra, and $(Si,P)O_3(OH,O)$ tetrahedra, alternating with interlayers hosting (SO_4) and H_2O groups. The Si-centered tetrahedra (occupied by Si and P) are alternatively disposed above and below the sheet, which has a simplified chemical composition $\{Cu_9Al[(Si_{0.75}P_{0.25})O_5(OH_{0.75}O_{0.25})]_2$ $(OH)_{12}(H_2O)_6\}^{3+}$. The two independent Cu sites ($Cu1$ and $Cu2$) display a sixfold coordination, showing the typical distorted (4+2) octahedral coordination related to the Jahn-Teller effect of Cu^{2+}. Together with chalcophyllite $[Cu_9Al(AsO_4)_2(OH)_{12}(H_2O)_6(SO_4)_{1.5}\cdot10H_2O]$ from the chalcophyllite group. These species are related to barrotite, $\{Cu_9Al[SiO_3(OH)]_2(OH)_{12}(H_2O)_6\}\{(SO_4)[AsO_3(OH)]_{0.5}\}\cdot2H_2O$, but the crystal structure of barrotite being not solved, the actual relationships with the chalcophyllite group minerals are unknown. The mineral is named in honor of the mineral collector Tiberio Bardi (b.1960), for his contribution to the study of Tuscan mineralogy. The holotype specimen is deposited in the Museo di Storia Naturale of the University of Pisa, Calci (Pisa), Italy. **F.C.**

VERNEITE*

T. Balić-Žunić, A. Garavelli, D. Pinto, and D. Mitolo (2018) Verneite, $Na_2Ca_3Al_2F_{14}$, a new aluminum fluoride mineral from Icelandic and Vesuvius Fumaroles. Minerals, 8(12), 553.

Verneite (IMA 2016-112), ideally $Na_2Ca_3Al_2F_{14}$, cubic, is a new mineral discovered in fumarolic sublimates collected at Eldfell (in 1988) and Hekla (in 1992) volcanoes in Iceland and in the specimen from Vesuvius volcano, Italy, collected in 1925 and catalogued in the Museum of Earth Sciences at Bari University as "avogadrite or malladrite." The mineral is also found in fumaroles at Fimmvörduhals, Iceland, after the eruption in 2010. Verneite occurs in medium- to low-temperature fumaroles (170° C at the time of sampling), as white-yellowish to brown crusts and massive aggregates up to several millimeters in size, sometimes also in transparent, colorless to pale yellowish crystals. In Hekla verneite found in mixtures with ralstonite and hematite, jacobssonite, and unidentified "mineral HB." Other associated minerals are leonardsenite, heklaite, malladrite, opal, and fluorite. In Eldfell verneite forms {110} crystals up to 20 μm associated with jakobssonite, "mineral HB," anhydrite, leonardsenite, ralstonite, jarosite, and meniaylovite. In the Vesuvius specimen, crystals up to 10 μm formed by combination of {100}, {110}, and {111} are associated with ralstonite, hieratite, knasibfite, matteuccite, avogadrite, and malladrite. No fluorescence in UV light was observed on the investigated samples. No other physical properties were determined due to a small crystal size and admixtures; D_{calc} = 2.974 g/cm³ and n_{calc} = 1.357. The chemical composition was analyzed by SEM-EDS on the grains sputtered on a carbon film. No weight percentage data is presented. The empirical formulae based on 7 cations pfu are given as $Na_{2.01}Ca_{2.82}Al_{2.17}F_{14.02}$ (Eldfell)/ $(Na_{1.47}K_{0.09})_{\Sigma1.56}Ca_{3.25}Al_{2.19}F_{14.33}$ (Vesuvius). [wt% derived from these formulae are, respectively: Na 9.54/ *6.77*, K 0/ *0.71*, Ca 23.35/ *26.11*, Al 12.09/ *11.84*, F 55.02/ *54.57*]. The powder XRD data were obtained on a sample from Hekla, containing verneite, ralstonite, hematite, jakobssonite, and a minor amount of the "mineral HB." The main lines of powder XRD spectra assigned to verneite are [d Å (*I*%; hkl)]: 7.24 (17; 011), 5.11 (17; 002), 4.18 (76; 211), 3.62 (55; 022), 3.23 (68; 031), 2.95 (100; 222), 2.73 (38; 321), 2.414 (40; 411), 2.288 (40; 402); 2.184 (78; 332), 2.009 (98; 341,431), 1.871 (75; 251), 1.811 (84; 044), 1.663 (66; 611,532,352); 1.582 (28; 451), 1.545 (46; 622), 1.512 (31; 361). The Rietveld refinement confirmed verneite is cubic, space group $I2_13$, a = 10.264(1) Å, V = 1081.4 Å³, Z = 4. The crystal structure of its synthetic analogue described (Courbion and Ferrey 1988) as a three-dimensional network of $[FCa_3Na]^{6+}$ tetrahedra, linked by Ca^{2+} ions with inserted $[AlF_6]^{3-}$ octahedra and an independent fluoride F_3 ion, linked to three Ca^{2+} and one Na^+ ions. Based on these data another view on the crystal structure, considering cation coordination is presented as a three-dimensional mesh of sinuous chains of CaF_8 coordination bis-disphenoids interlaced with similarly sinuous chains of NaF_7-caped octahedra forming together the intersecting layers parallel to three equivalent crystallographic planes of {100} with AlF_6 octahedra imbedded in its interstitions. The characteristics of Ca coordination in fluorides, as well as their relations to other ternary Na–Ca–Al fluorides are discussed. Verneite is named after Jules Verne (1828–1905), famous French science fiction writer, for the promotion of the science. His novel *Voyage au center de la Terre* (1864), describes a journey through Earth's underground started through a crater of Iceland volcano Snæfell and finished by ejecting the travelers with the eruption of a volcano Stromboli in South Italy. The holotype and the cotype are kept in the Icelandic Institute of Natural History, Garðabær, Iceland. The Vesuvius sample is in the collection of the Department of Earth and Geo-Environmental Sciences, University of Bari, Italy. **D.B.**

References cited

Courbion, G., and Ferrey, G. (1988) $Na_2Ca_3Al_2F_{14}$: A new example of a structure with "independent F^-"—A new method of comparison between fluorides and oxides of different formula. Journal of Solid State Chemistry, 76, 426–431.