

New Mineral Names*†

DMITRIY I. BELAKOVSKIY¹, FERNANDO CÁMARA², AND YULIA UVAROVA³¹Fersman Mineralogical Museum, Russian Academy of Sciences, Leninskiy Prospekt 18 korp. 2, Moscow 119071, Russia²Dipartimento di Scienze della Terra “Ardito Desio”, Università degli Studi di Milano, Via Mangiagalli, 34, 20133 Milano, Italy³CSIRO Mineral Resources, ARRC, 26 Dick Perry Avenue, Kensington, Western Australia 6151, Australia

IN THIS ISSUE

This New Mineral Names has entries for 14 new species, including amamoorite, ammoniomathesusite, aravaite, arsenowagnerite, fluorarrojadite-(BaNa), fluorcarmoite-(BaNa), folvikite, gadolinite-(Nd), goryainovite, kruijenite, natrowalentaite, nollmotzite, qatranaitite, and triazolite.

AMAMOORITE*

R. Townend, I.E. Grey, W.G. Mummie, A.R. Kampf, M.P. Roberts, R.W. Gable, and R. Dale (2019) Amamoorite, $\text{CaMn}_2^2+\text{Mn}^{3+}(\text{Si}_2\text{O}_7)\text{O}(\text{OH})$, a new ilvaite-related mineral from the Mary Valley, southeastern Queensland. Australian Journal of Mineralogy, 20(2), 7–14.

Amamoorite (IMA 2018-105), ideally $\text{CaMn}_2^2+\text{Mn}^{3+}(\text{Si}_2\text{O}_7)\text{O}(\text{OH})$, monoclinic, is a new ilvaite-related mineral from the manganese deposits at Mary Valley, near Gympie in southeastern Queensland. It was discovered during petrographic examination of drill core samples from Amamoor mine, in the Lower Palaeozoic Mary Valley manganese deposits, located about 15 km southwest of Gympie in southeastern Queensland, Australia. Manganese ores occur in a series of metasedimentary rocks, mafic to intermediate lavas, volcanoclastic rocks and breccias. The richest zone in drill core was 3.2 m at 59.8 wt% MnO. Amamoorite is closely associated with braunite and hausmannite, with possible inclusions manganovesuvianite. Other minerals identified in the ore zone are quartz, calcite, baryte, garnet, lizardite, bustamite, magnetite, and a manganese-bearing chlorite. Amamoorite is shiny black and occurs as irregular grains up to a few hundred micrometers in size. It has a brown streak and vitreous luster. Cleavage is fair on {100} and {001}. Mohs hardness is ~6. $D_{\text{calc}} = 3.88 \text{ g/cm}^3$. Amamoorite is strongly pleochroic: X very dark brown > Y yellow brown >> Z dark brown. It is optically biaxial (+), $\alpha = 1.795(\text{calc})$, $\beta = 1.805(5)$, $\gamma = 1.820(5)$ (white light), $2V_{\text{meas}} = 80(1)^\circ$; $X \perp$ cleavage plates ($a?$), $Y \perp$ longitudinal cleavage ($c?$), $Z = b$. Dispersion was not observed. The average of six electron probe WDS analysis [wt% (range)] is: SiO₂ 30.3 (30.1–30.8), Al₂O₃ 0.10 (0.06–0.12), FeO 0.35 (0.18–0.49), MgO 0.46 (0.40–0.53), Mn (total) as MnO 49.5 (48.7–50.4), (from structure: MnO 33.0, Mn₂O₃ 18.4), CaO 14.04 (13.92–14.12), H₂O (from structure) 2.2, total 98.85. The empirical formula based on 9 (O+OH) pfu is $\text{Ca}_{1.02}\text{Mn}_{1.89}^{2+}\text{Mg}_{0.05}\text{Fe}_{0.02}^{2+}\text{Mn}_{0.95}^{3+}\text{Al}_{0.01}\text{Si}_{2.05}\text{O}_9\text{H}_{0.99}$. The strongest lines in powder XRD pattern [d Å (P %; hkl)] are: 7.349 (76; 110), 2.893 (100; 401, 130), 2.827 (48; 401), 2.754 (50; 112), 2.725 (50; 112), 2.699 (66; 230), 2.463 (32; 231, 022), 2.387 (31; 312, 421), 2.157 (33, 412), 2.100 (35; 412). The unit-cell parameters refined from the powder data are $a = 13.086(1)$, $b = 8.8836(6)$, $c = 5.9021(4)$ Å, $\beta = 91.661(5)^\circ$, $V = 685.8 \text{ \AA}^3$. The single-crystal XRD data shows amamoorite is monoclinic, space group $P2_1/a$, $a = 13.0981(1)$, $b = 8.8897(2)$, $c = 5.9029(5)$ Å, $\beta = 91.697(2)^\circ$, $V = 687.03 \text{ \AA}^3$, $Z = 4$. The crystal structure was refined to $R_1 = 0.038$ for 1258 observed $I > 3\sigma(I)$ reflections. The structure is built by two octahedra wide ribbons of edge-shared octahedra, centered on $M11$, $M12$, and $M2$ sites, which are aligned along [001]. The ribbons are intercon-

nected along [100] and [010] by corner-sharing of the octahedra with Si₂O₇ groups. Sevenfold-coordinated Ca atoms occupy channels along [001]. Trivalent manganese is ordered at the $M11$ site, differently of manganilvaite and ilvaite, for which the trivalent cation occupies the $M12$ site. amamoorite is closely related to manganilvaite, $\text{CaFe}^{2+}\text{Fe}^{3+}(\text{Mn}, \text{Fe}^{2+})(\text{Si}_2\text{O}_7)\text{O}(\text{OH})$, the major difference being that manganilvaite has manganese ordered only at the $M2$ site, whereas amamoorite has manganese dominant in all three M sites. The name is for the type locality. Holotype material is deposited in the Western Australian Museum, Perth. A portion of the holotype specimen is deposited in the Natural History Museum of Los Angeles County, California, U.S.A. F.C.

AMMONIOMATHESUSITE*

A.R. Kampf, J. Plášil, B.P. Nash, and J. Marty (2019) Ammoniomathesusite, a new uranyl sulfate–vanadate mineral from the Burro mine, San Miguel County, Colorado, USA. Mineralogical Magazine, 83(1), 115–121.

Ammoniomathesusite (IMA 2017-077), ideally $(\text{NH}_4)_5(\text{UO}_2)_4(\text{SO}_4)_4(\text{VO}_3) \cdot 4\text{H}_2\text{O}$, tetragonal, is a new mineral, named as ammonium analogue of K-dominant mathesusite. It was discovered in the abandoned Burro mine near the southern end of the Uravan Mineral Belt, Colorado Plateau, San Miguel County, Utah, U.S.A. (38°24'2" N, 108°53'23" W). The mine exploited one of roll-front deposits in the Jurassic sandstone. The U and V ore mineralization was deposited where solutions rich in U and V encountered strongly reducing environment, often around accumulations of carbonaceous plants. Ammoniomathesusite is a product of postmining oxidation of the earlier-formed montroseite–corvusite assemblages with pyrite and chalcocopyrite. The NH_4^+ presumably derives from organic matter. The new mineral is rare and occurs on asphaltum/quartz matrix in association with ammoniozippeite, gypsum, jarosite, and natrozippeite. Other secondary minerals in the mine include andersonite, ansermetite, barnesite, brochantite, burroite, calciodelrioite, calcite, chalcocopyrite, grantsite, gunterite, hewettite, huemulite, hughesite, hydrocerussite, kokinosite, lasalite, lindgrenite, magnesiopascoite, martyite, metamunirite, metarossite, metaschoepite, munirite, navajoite, orthoserpierite, pascoite, rossite, schindlerite, schröckingerite, serpierite, sherwoodite, strelkinite, tyuyamunite, uranopilite, volborthite, wernerbaurite, zippeite and number of potentially new minerals. Ammoniomathesusite forms sprays or bow-tie-like intergrowths of prismatic {110} crystals up to ~0.3 mm long with flat {001} terminations, sometimes modified by {111}. No twinning was observed. Crystals are yellow to greenish yellow, transparent, vitreous, with a very pale-yellow streak. The mineral fluoresces bright yellow-green under a 405 nm laser. It is brittle with stepped fracture, Mohs hardness of 2½. Cleavage is perfect on {110} and good on {001}. The density was not measured due to the mineral decomposition in

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

Clerici solution; $D_{\text{calc}} = 3.672 \text{ g/cm}^3$. The mineral is decomposing in H_2O at room temperature. Ammoniomathesiusite is distinctly pleochroic $O - \text{green-yellow} > E - \text{colorless}$. It is optically uniaxial ($-$), $\omega = 1.653(2)$ and $\varepsilon = 1.609(2)$ (white light). The Raman spectrum recorded from 2000 to 100 cm^{-1} shows bands (cm^{-1} , $s - \text{strong}$, $w - \text{weak}$, $b - \text{broad}$, $sh - \text{shoulder}$) at: 1200w (overtone or combination), 1110w, 1090w, 1057b, 1065sh (split triply degenerate ν_3 antisymmetric stretching of the SO_4 tetrahedra), two component band at 1010 (ν_1 symmetric stretching of the SO_4 tetrahedra), 977 [symmetric ν_1 ($V-O$) stretching], 904w, 894w (ν_3 antisymmetric stretching of UO_2^{2+}), 834s (ν_1 symmetric $U-O$ stretching vibration of UO_2^{2+}), 764w (H_2O libration mode), 688b 650w, 590b, 550b ($V-O_{\text{eq}}$ vibrations), 625, 615 [ν_4 (δ) triply degenerated antisymmetric stretching of the SO_4 tetrahedra], 482, 459 [split ν_2 (δ) doubly degenerate bending of the SO_4 tetrahedra], 373w ($\nu_{\text{Rotational}}$ of NH_4), 244b [split ν_2 (δ) UO_2^{2+} doubly degenerate bending], 294w, 277w, 227, 199, 178, 157 (lattice modes). The average of electron probe WDS analyses (seven points on six crystals) is [wt% (range)/ normalized to 100%]: $(\text{NH}_4)_2\text{O}$ 7.35 (6.38–7.89)/ 7.06; V_2O_5 5.38 (5.02–5.84)/ 5.17; UO_3 67.95 (67.40–69.04)/ 65.26; SO_3 19.02 (19.02–20.07)/ 18.27; H_2O (based on structure with $O=33$) 4.42/ 4.25; total 104.12/ 100.00. The data normalized to 100 wt% because of high total due to the crystals did not take a good polish, loss of weakly held H_2O under vacuum and a minor beam damage. The empirical formula based on 33 O pfu is $[(\text{NH}_4)_{4.75}(\text{UO}_2)_4(\text{SO}_4)_4(\text{VO}_3)_4(\text{H}_2\text{O})_7]$. Low N content (4.92 N apfu by structure refinement) is due to loss under vacuum. The strongest powder X-ray diffraction lines are [$d \text{ \AA}$ ($\% ; hkl$): 10.57 (46; 110), 7.10 (62; 001), 6.41 (100; 101), 4.71 (27; 310), 3.575 (25; 321), 3.460 (26; 102), 3.340 (35; 240), 3.226 (44; 141)]. The unit-cell parameters refined from the powder data with whole pattern fitting are $a = 14.9519(14)$, $c = 7.1083(8) \text{ \AA}$, $V = 1589.1 \text{ \AA}^3$. The single-crystal X-ray data shows ammoniomathesiusite is tetragonal, space group $P4/n$, $a = 14.9405(9)$, $c = 7.1020(5) \text{ \AA}$, $V = 1585.3 \text{ \AA}^3$, $Z = 2$. The structure of ammoniomathesiusite refined to $R_1 = 0.0218$ for $3427 I > 2\sigma(I)$ reflections. The clusters of four corner-sharing UO_2 pentagonal bipyramids with a square void at the center occupied by VO_3 square pyramid are linked through corner-sharing SO_4 tetrahedra, each of those shares a third vertex with UO_2 bipyramid in another cluster, to form a corrugated heteropolyhedral sheet $[(\text{UO}_2)_4(\text{SO}_4)_4(\text{VO}_3)]^{2-}$ stacked perpendicular to c . The NH_4^+ cations are located between the sheets, along with the H_2O groups. The structure is identical to that of mathesiusite, with NH_4^+ in place of K^+ . The holotype and three cotypes are deposited in the Natural History Museum of Los Angeles County, California, U.S.A. **D.B.**

ARAVAITE*

- B. Krüger, H. Krüger, E.V. Galuskin, I.O. Galuskina, Y. Vapnik, V. Olieric, and A. Pauluhnd (2018) Aravaite, $\text{Ba}_2\text{Ca}_{18}(\text{SiO}_4)_6(\text{PO}_4)_3(\text{CO}_3)\text{F}_3\text{O}$: modular structure and disorder of a new mineral with single and triple antiperovskite layers. *Acta Crystallographica*, B74, 492–501.
- E. Galuskin, I. Galuskina, B. Krüger, H. Krüger, Ye. Vapnik, A. Krz̄at̄ala, D. Środek, and G. Zieliński (2020) Nomenclature and classification of the arctite supergroup. Aravaite, $\text{Ba}_2\text{Ca}_{18}(\text{SiO}_4)_6(\text{PO}_4)_3(\text{CO}_3)\text{F}_3\text{O}$, a new arctite supergroup mineral from Negev desert, Israel. *Canadian Mineralogist* (Elena Sokolova thematic issue), in press.

Aravaite (IMA 2018-078), $\text{Ba}_2\text{Ca}_{18}(\text{SiO}_4)_6(\text{PO}_4)_3(\text{CO}_3)\text{F}_3\text{O}$, trigonal, is a new mineral of the arctite supergroup (Galuskin et al. 2018), which was discovered in pyrometamorphic spurrite rocks of the Hatrurim Complex in the Negev Desert near Arad, Israel ($31^\circ 13'58'' \text{ N}$, $35^\circ 16'2'' \text{ E}$). These pyrometamorphic rocks are represented by spurrite marbles, larnite pseudoconglomerates, gehlenite hornfels and different paralavas, occurring widely along the rift zone of the Dead Sea. Associated minerals are spurrite, calcite, brownmillerite, shulamite, CO_2 -bearing fluorapatite, brucite, fluormayenite–fluorkuygenite, periclase, barytocalcite, and baryte. Aravaite crystallizes after ariegilatite and is often overgrown later by stracherite. Flattened crystals of aravaite up to $0.5 \times 0.1 \text{ mm}$ were detected as epitaxial intergrowth with stracherite or/and ariegilatite crystals. No twinning observed.

In backscattered electron mode aravaite appears brighter than ariegilatite and darker than stracherite. Aravaite is colorless with a vitreous luster, white streak, and imperfect cleavage on $\{0001\}$. No parting was observed. It is brittle with irregular or flat fracture. The microindentation hardness is $\text{VHN}_{0.05} = 486$ (444–534) kg/mm^2 , corresponding to ≈ 5 of Mohs scale. The density was not measured due to crystals are highly fractured; $D_{\text{calc}} = 3.327 \text{ g/cm}^3$. In plane-polarized light aravaite is colorless, non-pleochroic. It is optically uniaxial ($-$), $\omega = 1.658(2)$, $\varepsilon = 1.654(2)$ ($\lambda = 589 \text{ nm}$). The Raman spectrum of aravaite is like the spectra of ariegilatite and stracherite, and has bands 829, 852, and 877 (cm^{-1}) corresponding to ν_1 of $(\text{SiO}_4)^+$ groups: the first and third bands have analogues in the spectrum of ariegilatite and the second band (852 cm^{-1}) corresponds to the 859 cm^{-1} band in the stracherite spectrum. Bands related to ν_1 of $(\text{PO}_4)^{3-}$, $(\text{SO}_4)^{2-}$, and $(\text{CO}_3)^{2-}$ groups are also evident at 944, 992, and 1065 cm^{-1} , respectively. Other weaker bands are present at (cm^{-1}) 702, 622, 599, 576, 517, 444, 430, 405, 313, 242, 216, 155, and 118. The averaged 41 point WDS electron probe analyses of aravaite gave [wt%, (range)]: SO_3 0.98 (0.57–1.18), V_2O_5 0.21 (0.06–0.43), P_2O_5 9.37 (8.59–10.29), TiO_2 0.13 (0.06–0.26), SiO_2 18.61 (18.07–19.22), Al_2O_3 0.10 (0.05–0.18), BaO 14.63 (13.58–15.60), MnO 0.17 (0–0.34), CaO 50.88 (49.65–52.43), MgO 0.10 (0.04–0.56), K_2O 0.04 (0–0.07), Na_2O 0.46 (0.18–0.93), CO_2 2.30 (by charge balance), F 3.30 (3.00–3.62), $-O=F$ 1.39, total 99.90. The empirical formula based on 30 cations pfu of aravaite is $(\text{Ca}_{17.77}\text{Na}_{0.17}\text{Mg}_{0.05}\text{Mn}_{0.05}^{2+}\text{Zr}_{18.00})[(\text{SiO}_4)_{6.05}(\text{PO}_4)_{2.58}(\text{CO}_3)_{1.02}(\text{SO}_4)_{0.24}(\text{AlO}_4)_{0.04}(\text{TiO}_4)_{0.03}(\text{VO}_4)_{0.04}]_{\Sigma 10.00}(\text{F}_{3.23}\text{O}_{0.77})_{\Sigma 4.00}$. The strongest lines of the powder X-ray diffraction pattern are [$d \text{ \AA}$ ($\% ; hkl$): 3.566 (60; 110), 3.075 (89; 022), 2.776 (86; 1.1.15), 2.764 (57; 0.0.24), 2.157 (39; 0.2.22), 1.967 (50; 0.3.10.0.2.26), 1.783 (100; 220,221,222), 1.498 (49; multiple)]. Single-crystal X-ray diffraction data was obtained at the X06DA beamline at the Swiss Light Source (Paul Scherrer Institute, Villigen, Switzerland). One-dimensional diffuse intensities along c^* were visible in the diffraction pattern. The average structure of aravaite was solved using direct methods and refined to $R_1 = 8.2\%$ for 1145 observed reflections with $F^2 > 2\sigma(F^2)$. The new mineral is trigonal, $R\bar{3}m$, $a = 7.12550(11)$, $c = 66.2902(13) \text{ \AA}$, $V = 2914.81 \text{ \AA}^3$, $Z = 3$. The structure of aravaite can be described as a stacking of three different modules along $[001]$: T-layers $[\text{Ba}(\text{PO}_4)_{1.5}(\text{CO}_3)_{0.5}]^{3-}$, triple antiperovskite (tAP) layers $[(\text{F}_2\text{OCa}_2)(\text{SiO}_4)_1]^{4+}$ and single antiperovskite (sAP) layers $[(\text{FCa}_6)(\text{SiO}_4)_2]^{3+}$. The modules are stacked in the sequence of T–sAP–T–tAP–... Along c the sum of all modules equals the sum of one unit cell of stracherite [three T-layers and three sAP layers] plus one unit cell of ariegilatite [three T-layers and three tAP layers]. The mineral named for its type location close to Arava (Hebrew: desolate and dry area) Valley located south of the Dead Sea basin. Type material is deposited in the Fersman Mineralogical Museum, Russian Academy of Sciences, Moscow, Russia. **F.C.**

References cited

- Galuskin, E.V., Krüger, B., Galuskina, I.O., Krüger, H., Vapnik, Y., Wojdyła, J.A., and Murashko, M. (2018) New mineral with modular structure derived from hatrurite from the pyrometamorphic rocks of the Hatrurim Complex: Ariegilatite, $\text{BaCa}_{12}(\text{SiO}_4)_4(\text{PO}_4)_2\text{F}_2\text{O}$, from Negev Desert, Israel. *Minerals*, 8, 109.

ARSENOWAGNERITE*

- I.V. Pekov, N.V. Zubkova, A.A. Agakhanov, V.O. Yapakurt, N.V. Chukanov, D.I. Belakovskiy, E.G. Sidorov, and D.Yu. Pushcharovskiy (2018) New arsenate minerals from the Arsenatnaya fumarole, Tolbachik volcano, Kamchatka, Russia. VIII. Arsenowagnerite, $\text{Mg}_2(\text{AsO}_4)\text{F}$. *Mineralogical Magazine*, 82(4), 877–888.

Arsenowagnerite (IMA 2014-100), ideally $\text{Mg}_2(\text{AsO}_4)\text{F}$, monoclinic, is a new mineral, the arsenate analogue of wagnerite, discovered in the Arsenatnaya fumarole, Second scoria cone of the Northern Breakthrough of the Great Tolbachik Fissure Eruption, Kamchatka. It was found in the complex sulfate–arsenate aggregates overgrowing basalt scoria at depths between 2 and 3 m being more abundant at 2.5–3 m. Temperatures at the time of collecting in July 2014 were 360–450 °C. Arsenowagnerite is suggested to be formed at temperatures lower than 450 °C as a result of

the interaction between fumarolic gas (an obvious source of As, O, and F) and basalt scoria, the most probable source of Mg which has low volatility at temperatures at least of 500 °C. The associated minerals are johillerite, tilasite, anhydrite, hematite, fluorophlogopite, cassiterite, calciojohillerite, apthitalite, nickenichite, svabite, berzeliite, apthitalite, metathénardite, krashennikovite, and fluorborite. Arsenowagnerite occurs as crude tabular crystals and euhedral grains up to 0.3 mm or distorted skeletal, typically case-like crystals up to 1 mm and open-work aggregates forming crusts up to 1.5 cm × 3 cm in area and up to 1 mm thick that cover coarse spherulites mainly consisting of johillerite, tilasite, and anhydrite. Small (up to 0.02 mm) grains of arsenowagnerite are also found inside the anhydrite-tilasite-johillerite spherulites where they form intimate intergrowths with these three minerals and occasionally with hematite. Well-shaped equant or tabular crystals up to 0.5 mm are rare. Crystals commonly contain numerous inclusions of other minerals and particles of basalt scoria. Arsenowagnerite also forms aggregates that cover hematite and fluorophlogopite crystal crusts or directly overgrow basalt scoria. Arsenowagnerite is transparent light to lemon-yellow, sometimes greenish yellow or colorless with a vitreous luster and a white streak. Under UV radiation it shows weak orange-red fluorescence in short-wave (245 nm) and does not fluoresce under long-wave (330 nm). The mineral is brittle, has uneven fracture and one direction of distinct cleavage on {001} (by analogy with structurally related wagnerite and sarkinite). The Mohs hardness is ~5. The density was not measured because of the cavernous nature of crystals and the presence of multiple inclusions; $D_{\text{calc}} = 3.698 \text{ g/cm}^3$. In plane-polarized light arsenowagnerite is colorless, non-pleochroic. It is optically biaxial (+), $\alpha = 1.614(2)$, $\beta = 1.615(2)$, $\gamma = 1.640(2)$ (589 nm), $2V_{\text{meas}} = 25(5)^\circ$, $2V_{\text{calc}} = 23^\circ$. Dispersion of optical axes was not observed. The IR spectrum shows bands at (cm^{-1} ; s – strong band, sh – shoulder): 900sh, 874s, 861s, 840sh, 820sh (stretching of AsO_4^{3-} groups); 561, 525sh, 507s, 491s, 470s, 443, 417 (bending of AsO_4^{3-} groups combined with Mg–O stretching), 375 (lattice mode, possibly involving Mg–F stretching). Weak shoulders at 1090 and 1140 cm^{-1} correspond to trace amounts of the sulfate anion. Numerous bands in the ranges from 800 to 900 and from 400 to 600 cm^{-1} are due to the presence of numerous non-equivalent sites of AsO_4^{3-} groups and Mg^{2+} cations in the crystal structure of arsenowagnerite. Bands corresponding to O–H, C–O, and B–O bonds are absent. The averaged 6 point WDS electron probe analyses of arsenowagnerite is [wt% (range)]: MgO 38.72 (38.04–39.28), CaO 0.23 (0.12–0.38), MnO 0.32 (0.08–0.61), CuO 0.60 (0.23–0.85), ZnO 0.05 (0–0.14), Fe_2O_3 0.11 (0.07–0.22), TiO_2 0.03 (0–0.06), SiO_2 0.08 (0.04–0.09), P_2O_5 0.18 (0–0.40), V_2O_5 0.03 (0–0.07), As_2O_5 54.96 (54.27–56.29), SO_3 0.10 (0–0.44), F 8.91 (8.61–9.20), $-\text{O}=\text{F}_2$ 3.75, total 100.57. The empirical formula is $(\text{Mg}_{1.98}\text{Cu}_{0.02}\text{Mn}_{0.01}\text{Ca}_{0.01}\text{Sr}_{0.02}\text{As}_{0.99}\text{P}_{0.01})_{\Sigma 1.00}\text{O}_{4.05}\text{F}_{0.97}$ based on 5 (O+F) atoms pfu. All iron is considered as Fe^{3+} because of the extremely oxidizing conditions of mineral formation. The strongest lines of the powder X-ray diffraction pattern are [d Å (I %; hkl): 5.80 (41; 002), 5.31 (35; 120), 3.916 (37; 221), 3.339 (98; 221,023), 3.155 (65; 202), 3.043 (100; $\bar{1}41$), 2.940 (72; $\bar{2}04$), 2.879 (34; $\bar{3}22$) and 2.787 (51; 320, $\bar{1}24$). The crystal structure of arsenowagnerite was solved by direct methods and refined to $R_1 = 4.85\%$. The new mineral is monoclinic, $P2_1/c$, $a = 9.8638(3)$, $b = 12.9830(3)$, $c = 12.3284(3)$ Å, $\beta = 109.291(3)^\circ$, $V = 1490.15 \text{ \AA}^3$, $Z = 16$. The crystal structure of arsenowagnerite is based on a complex three-dimensional framework formed by almost regular $[\text{AsO}_4]$ tetrahedra, distorted $[\text{MgO}_4\text{F}_2]$ octahedra, and distorted $[\text{MgO}_4\text{F}]$ trigonal bipyramids that share either edges or vertices. It belongs to the triplite-triploidite supergroup and to the wagnerite-*Ma2bc* structure type. Arsenowagnerite is named as the arsenate analogue of wagnerite $\text{Mg}_2(\text{PO}_4)\text{F}$. It can be also considered as a magnesium and fluorine analogue of sarkinite $\text{Mn}_2^+(\text{AsO}_4)\text{OH}$. The holotype specimen is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **Yu.U.**

FLUORARROJADITE-(BaNa)*

M. Števkó, J. Sejkora, P. Uher, F. Cámara, R. Škoda, and T. Vaculovič (2018) Fluorarrojadite-(BaNa), $\text{BaNa}_4\text{CaFe}_{13}\text{Al}(\text{PO}_4)_{11}(\text{PO}_3\text{OH})\text{F}_2$,

a new member of the arrojadite group from Gemerská Poloma, Slovakia. Mineralogical Magazine, 82(4), 863–876.

Fluorarrojadite-(BaNa) (IMA 2016-075), ideally $(\text{Ba}\square)\text{Na}_2\text{Ca}(\text{Na}\square)\text{Fe}_{13}\text{Al}(\text{PO}_4)_{11}(\text{PO}_3\text{OH})\text{F}_2$, monoclinic, is a new arrojadite group member discovered at the dump of Elisabeth adit exploited talc-magnesite deposit near Gemerská Poloma village, Rožňava Co., Košice Region, Slovakia ($48^\circ45'04.06'' \text{ N}$, $20^\circ29'39.27'' \text{ E}$). The matched compositions were previously noted in samples of fluoarrojadite-(BaFe) from the Sidibou-Kricha pegmatite in Morocco (Chopin et al. 2006) and as a product of the triphylite hydrothermal alteration (enriched with Mn^{2+}) from the Nanping No. 31 granitic pegmatite in Fujian Province, China (Rao et al. 2014). In Gemerská Poloma the fluorarrojadite-(BaNa) occurs in hydrothermal quartz veins up to 8 cm thick and up to 3 m long intersecting highly fractionated, topaz-zinnwaldite S-type Gemic leucogranite. It is associated with common and macroscopic fluorapatite and triplite, rare microscopic viitaniemiite and potentially new mineral “fluordickinsonite-(BaNa)”, and minor amounts of albite, orthoclase, muscovite, fluorite, Mn-siderite, rhodochrosite, arsenopyrite, pyrite, bismuthinite, kobellite, tintoite, giesSENite, and native bismuth. Fluorarrojadite-(BaNa) forms yellowish-brown to greenish-yellow very fine-grained irregular aggregates up to $4 \times 2 \text{ cm}$, consisting of individual anhedral grains up to 0.01 mm. It has pale yellow streak and a vitreous to greasy luster. No cleavage was observed. The mineral is brittle with irregular fracture, Mohs hardness $\sim 4\frac{1}{2}$ to 5; $D_{\text{meas}} = 3.61(2)$ and $D_{\text{calc}} = 3.650 \text{ g/cm}^3$. In plane-polarized light fluorarrojadite-(BaNa) does not show any apparent pleochroism (color not given). It is optically biaxial (+). Other optical properties were not determined due to small grain size; $n_{\text{calc}} = 1.674$. The Raman spectrum of collected in the range $3580\text{--}50 \text{ cm}^{-1}$ is similar to those of arrojadite-(KFe), arrojadite-(KNa), and arrojadite-(NaFe). The most intensive bands (cm^{-1}) are: 1020, 985, 959, 939, 916, and 839 [ν_1 symmetric stretching of $(\text{PO}_4)^{3-}$ and $(\text{PO}_3\text{OH})^{2-}$ groups]; 1151, 1113, and 1076 (ν_3 antisymmetric stretching of the same groups); 507, 481, 461, 439, 414 and 643, 602, 580, 575, 551, 532 (respectively ν_2 and ν_4 bending vibrations of the same groups); 3551, 3523 (OH stretching). The average of 5 points electron probe WDS analyses coupled with LA-ICP-MS* for trace elements [wt% (range)] is: K_2O 0.76 (0.70–0.86), Na_2O 5.72 (5.52–5.84), Li_2O 0.26, BaO 4.91 (4.02–5.73), SrO 0.98 (0.70–1.36), CaO 1.93 (1.85–2.01), PbO 0.23 (0.12–0.38), MgO 0.23 (0.21–0.24), ZnO 0.22 (0.19–0.24), MnO 17.08 (16.86–17.32), FeO 25.51 (25.21–26.15), Al_2O_3 2.43 (2.31–2.50), Sc_2O_3 0.26, Ga_2O_3 0.08, TiO_2 0.07 (0.05–0.10), P_2O_5 39.75 (39.21–40.26), F 1.36 (1.30–1.46), H_2O (calculated based on $\text{F}+\text{OH}+\text{Na}_3 = 3$), $-\text{O}=\text{F}_2$ 0.57, total 101.67. The empirical formula based on 47 O and (OH+F) = 3 apfu and considering data on the structure is $^{41}(\text{Ba}_{0.65}\text{K}_{0.33})_{\Sigma 1.00}^{42}\text{Na}_{0.35}^{81}(\text{Na}_{0.54}\text{Fe}_{0.46})_{\Sigma 1.00}^{82}\text{Na}_{0.54}^{83}\text{Ca}_{0.74}\text{Sr}_{0.20}\text{Pb}_{0.02}\text{Ba}_{0.04})_{\Sigma 1.00}\text{Na}_2^{84}\text{Na}_{0.46}^{85}(\text{Fe}_{7.16}\text{Mn}_{5.17}\text{Li}_{0.37}\text{Mg}_{0.12}\text{Sc}_{0.08}\text{Zn}_{0.06}\text{Ga}_{0.02}\text{Ti}_{0.02})_{\Sigma 13.00}\text{Al}_{1.02}(\text{PO}_4)_{11}\text{PO}_{3.46}(\text{OH})_{0.54}^{86}(\text{F}_{1.54}\text{OH}_{0.46})$. Some minute crystals showed compositions with $\text{Mn} > \text{Fe}$ classifiable as not yet approved “fluordickinsonite-(BaNa)”. The strongest lines in the powder XRD pattern are [d Å, (I %; hkl): 4.577 (14; 114), 3.412 (21; 116), 3.224 (37; 206), 3.040 (100; 424), 2.850 (22; 332), 2.714 (56; 226), 2.556 (33; 028,424), 2.512 (23; 040)]. The unit-cell parameters refined from the powder data show fluorarrojadite-(BaNa) is monoclinic, space group *Cc*, $a = 16.563(1) \text{ \AA}$, $b = 10.0476(6) \text{ \AA}$, $c = 24.669(1) \text{ \AA}$, $\beta = 105.452(4)^\circ$, $V = 3957.5 \text{ \AA}^3$, $Z = 4$. Single-crystal X-ray data was not obtained due to the lack of suitable crystal. The Rietveld refinement (although highly questionable considering >90 independent sites in the structure) was conducted based on the model for arrojadite-(SrFe), allowing to refine cation occupancies at *A1*, *A2*, *B1*, *Na3*, and *Ca* sites (Ba vs. K and Na; Na vs. Fe and Na; and Na and Ca vs. Sr, respectively) with wR_p after background subtraction -0.0911 , $R(F^2) = 0.1475$ when the chemistry at the *M1* and *M3* sites was allowed to vary, but was fixed in all the other *M* sites. The new mineral is named according to the nomenclature of arrojadite-group minerals with a general formula $\text{A}_2\text{B}_2\text{CaNa}_{2-x}\text{M}_{13}\text{Al}(\text{PO}_4)_{11}(\text{PO}_3\text{OH}_{1-x})\text{W}_2$ [(Chopin et al. 2006), see the details below in the abstract for fluorcarmoite-(BaNa)] since Fe^{2+} is dominant at the *M* sites (root-name arrojadite), two suffixes as Ba dominant at

the *A1* and *Na* at the *B1* sites. A prefix “fluor” is added since F is dominant at the *W* site. One fragment of the holotype specimen is deposited in the Department of Mineralogy and Petrology, National Museum in Prague, Czech Republic. The second one is housed in the Department of Mineralogy and Petrology, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic. **D.B.**

References cited

- Chopin, C., Oberti, R., and Cámara, F. (2006) The arrojadite enigma: II. Compositional space, new members and nomenclature of the group. *American Mineralogist*, 91, 1260–1270.
- Rao, C., Wang, R.C., Hatert, F., and Baijot, M. (2014) Hydrothermal transformations of triphylite from the Nanping No. 31 pegmatite dyke, southeastern China. *European Journal of Mineralogy*, 26, 179–188.

FLUORCARMOITE-(BaNa)*

- F. Cámara, E. Bittarello, M.E. Ciriotti, F. Nestola, F. Radica, F. Massimi, and R. Bracco (2019) Fluorcarmoite-(BaNa), the first Mg-dominant mineral of the arrojadite group. *European Journal of Mineralogy*, 31(4), 823–836.

Fluorcarmoite-(BaNa) (IMA 2015-062) ideally $^{41}\text{Ba}^{42}\square^{11}\text{Na}^{101.2}\text{Na}_2\text{Na}_3\square^{3}\text{Ca}^{\text{Mg}}\text{Mg}_{13}\text{Al}(\text{PO}_4)_{11}(\text{PO}_3\text{OH})^{\text{W}}\text{F}_2$, monoclinic, is a new mineral, the first Mg-dominant member of the arrojadite group. It was discovered in a pebble from the riverbed of the upper Marenola Creek, close to the village of Isallo, in the Magliolo municipality, Savona, Liguria, Italy ($\sim 44^\circ 11' 37'' \text{N}$; $\sim 8^\circ 15' 1'' \text{E}$). The locality is also known by mineral collectors as “Costa Balzi Rossi”. The general formula of the arrojadite group is $\text{A}_2\text{B}_2\text{CaNa}_{2+x}\text{M}_{13}\text{Al}(\text{PO}_4)_{11}(\text{PO}_3\text{OH}_{1-x})\text{W}_2$, where A = Ba, Sr, Pb or K, Na (*A1* site), and Na or vacancies (*A2* site); B = Fe^{2+} , Mn^{2+} , Mg at the *B1* sites and vacancies or Na at the *B1* and *B2* sites; Ca is dominant at the *Ca* site; Na is dominant at *Na1* and *Na2* sites and can eventually exchange the proton bonded to the acid phosphate group then occupying the *Na3* site; Mg sites contain Fe^{2+} , Mn^{2+} , and Mg, with minor Li and Zn; the *Al* site can host Fe^{3+} and minor Ti or Sc; W = OH, F. The species of the group named by a root name defined by the dominant divalent cation at the *M* sites [i.e., arrojadite (Fe), dickinsonite (Mn)] and suffixes (as extended Levinson modifiers) first of which is defined by the dominance in *A1* site and second by occupancy of *B* sites, which will depend of the excess at the *M* sites and will be the dominant cation at the *M* sites or Na in case that access ≤ 0.5 pfu. The third suffix is used when $x > 0.5$, meaning that the proton of the acid phosphate group is substituted by another ion (usually Na). The prefixes used in case anion substitution at *W* sites [i.e. “fluor” if OH is substituted by F] and/or in case a substitution of Al by Fe^{3+} at the *Al* sites. These rules defined the prefix and suffixes for fluorcarmoite-(BaNa) and the root name deserved for the first group member with Mg dominant at the *M* sites is after Monte Carmo di Loano, the highest peak in the area, namesake of the tectonic unit where the mineral was found and the first locality where phosphate mineralization has been found in the region. The erratic pebble in which the new mineral was found (in an anhedral centimetric nodule embedded in quartz) is related to phosphate-bearing quartzites where lazulite is the most widespread phosphate. The origin of phosphate mineralization is still debated. Fluorcarmoite-(BaNa) is associated with quartz and almandine and has microscopic inclusions of fluorapatite and possible graptolite. Other minerals found in the same locality, but not associated with fluorcarmoite-(BaNa), are: “adularia”, aeschynite-(Y), albite, allanite-(Ce), anatase, bastnäsite-(Ce), brookite, cassiterite, cerussite, chernovite-(Y), churchite-(Y), clinocllore, Fergusonite-(Y), gorceixite, goyazite, hematite, hingganite-(Y), hundolmenite-(Y), jarosite, magnetite, mitridatite, monazite-(Ce), monazite-(La), paraniite-(Y), pyrite, pyrrhotite, rhabdophane-(Nd), rutile, schorl-dravite tourmaline series, thortveitite, titanite, wulfenite, and xenotime-(Y). Fluorcarmoite-(BaNa) occurs as yellow orange translucent subhedral equant, thick, more or less platy prismatic crystals up to millimeter in size, on compact quartz. It has a yellow orange streak, a vitreous luster, does not fluoresce under short-wave or long-wave UV radiation. No cleavage or parting was observed. The mineral is brittle. The nanoindentation hardness

is 12.12 ± 0.47 GPa (elastic modulus 147 ± 3.6 GPa). The Vickers hardness is 1236 kg/mm^2 corresponding to $\sim 7\frac{1}{2}$ of Mohs scale; $D_{\text{meas}} = 3.40$ and $D_{\text{calc}} = 3.394 \text{ g/cm}^3$. Fluorcarmoite-(BaNa) is unreactive and insoluble in 2 M and 10% HCl and 65% HNO_3 . In plane-polarized light fluorcarmoite-(BaNa) is weakly pleochroic in light yellow tones. It is optically biaxial (+), $\alpha = 1.624$, $\beta = 1.626$, $\gamma = 1.638$ (589 nm), $2V_{\text{meas}} = 35(2)^\circ$, $2V_{\text{calc}} = 37.9^\circ$. Raman spectra (100 to 4000 cm^{-1}) show intense bands at 141, 162, 199, 253 (lattice vibrations of phosphate groups); series of broad bands at 441, 452, 553, 580, 639 (PO_4 bending); intense bands at 989 and 964 with shoulders at 949, 927, and 864 ($\nu_1 \text{ PO}_4$ symmetric stretching); 989 [stretching vibrations of $\text{PO}_3(\text{OH})$ units]; 1037, 1063, 1156 ($\nu_3 \text{ PO}_4$ antisymmetric stretching); 3011, 3422, 3545, 3586, 3746, 3913 (OH stretching modes). The details of Raman spectra are discussed. The average of 15 point electron probe WDS analyses is [wt% (range)]: Na_2O 5.83 (5.48–6.18), K_2O 0.36 (0.30–0.45), CaO 2.64 (2.53–2.79), SrO 0.46 (0.20–0.64), BaO 7.12 (6.14–8.07), MnO 2.01 (1.69–2.33), FeO 17.68 (16.90–18.09), MgO 15.12 (14.84–15.46), Al_2O_3 2.57 (2.48–2.76), P_2O_5 44.96 (43.51–45.29), F 2.14 (2.02–2.29), $-\text{O}=\text{F}_2$ 0.90 (0.85–0.97), H_2O (by stoichiometry) 0.33, total 100.32. The empirical formula based on 50 $\text{O}+\text{F}+(\text{OH})$ pfu and P_2O_5 value 42.53 wt% (reduced to obtain 12 P pfu as recommended by Chopin et al. 2006) is: $(\text{Na}_{3.77}\text{Ca}_{0.94}\text{Ba}_{0.93}\text{K}_{0.15}\text{Sr}_{0.09}\square_{0.12})_{\Sigma 6.00}(\text{Mg}_{7.52}\text{Fe}_{2.93}\text{Mn}_{2.57}\text{Fe}_{2.93}\text{Mn}_{2.57})_{\Sigma 13.02}\text{Al}_{1.01}(\text{PO}_4)_{11}(\text{PO}_3)(\text{OH}_{0.74}\text{F}_{0.26})\text{F}_2$. The strongest lines in the powder XRD pattern are [d Å (%; hkl)]: 4.959 (25; 020), 4.570 (24; 022), 4.524 (20; 114), 3.188 (28; 206), 3.012 (100; 424), 2.735 (32; 602), 2.818 (28; 332), 2.682 (39; 226), 2.526 (25; 424). The unit-cell parameters refined from the powder data are: $a = 16.426(9)$, $b = 9.920(8)$, $c = 24.43(3)$ Å, $\beta = 105.65(11)^\circ$, $V = 3832 \text{ \AA}^3$. The single-crystal XRD data collected on a crystal of $0.200 \times 0.133 \times 0.110$ mm at room temperature shows the mineral is monoclinic, space group *Cc*, $a = 16.4013(3)$, $b = 9.9487(1)$, $c = 24.4536(8)$ Å, $\beta = 105.725(2)^\circ$, $V = 3840.80 \text{ \AA}^3$, $Z = 4$. The crystal structure refined to $R_1 = 0.0342$ for 11 511 $F_o > 4\sigma(F)$ reflections ($R_1 = 0.0417$ for all 13 232 data). The crystal structure of fluorcarmoite-(Ba,Na) is topologically identical to that of arrojadite-(KNa): fourfold-, fivefold- and sixfold-coordinated cations are linked by (PO_4) groups and Al octahedra sharing apexes. The main structural unit is a complex polyanion $\text{M}_{12}\text{O}_{17}(\text{F},\text{OH})_6[\text{PO}_4]_{10}^6$ (four per unit-cell). The $\text{M}_{12}\text{O}_{17}(\text{F},\text{OH})_6[\text{PO}_4]_{10}^6$ unit repeat along [010] by sharing the (F,OH) anions with the adjacent units, configuring a sort of column. Within the (010) plane, the “columns” link by sharing (F,OH) anions and apexes of P-centered tetrahedra, plus further (PO_4) and (AlO_6) groups, as well as the *M1* tetrahedron. Monovalent and divalent alkane cations distribute mostly within the columns. The atoms of Mg order mostly in the *M1*, *M2b*, *M3a,b*, *M4a,b* and *M7a,b* sites, whereas the non-dominant Fe^{2+} and very minor Mn^{2+} show site preference for *M2a*, *M5a,b*, and *M6a,b*. The *A1* site is mostly populated by Ba, the *A2* site is empty, and minor Fe^{2+} occurs at the *B1b* site. Non-dominant amount of Na occupies the *Na3* site. Only Ca and Al are present at the *Ca* and *Al* sites, respectively. A fragment of the holotype is deposited in the Museo Regionale di Scienze Naturali di Torino, Sezione di Mineralogia, Petrografia e Geologia, Torino, Italy. **D.B.**

References cited

- Chopin, C., Oberti, R., and Cámara, F. (2006) The arrojadite enigma: II. Compositional space, new members and nomenclature of the group. *American Mineralogist*, 91, 1260–1270.

FOLVIKITE*

- M.A. Cooper, G. Raade, N.A. Ball, Y.A. Abdu, F.C. Hawthorne, and R. Rowe (2018) Folvikite, $\text{Sb}^{3+}\text{Mn}^{3+}(\text{Mg},\text{Mn}^{2+})_{10}\text{O}_8(\text{BO}_3)_4$, a new oxyborate mineral from the Kitteln mine, Nordmark ore district, Värmland, Sweden: Description and crystal structure. *Mineralogical Magazine*, 82(4), 821–836.

Folvikite (IMA 2016026), $\text{Sb}^{3+}\text{Mn}^{3+}(\text{Mg},\text{Mn}^{2+})_{10}\text{O}_8(\text{BO}_3)_4$, monoclinic, is a new oxyborate discovered at the Kitteln mine (was dumped there from, supposedly, Östra Mossgruvan or Brattforsgruvan), Nordmark ore field, north of Filipstad, Värmland, Sweden ($59^\circ 49' 59'' \text{N}$, $14^\circ 05' 59'' \text{E}$). This dump is also the type locality for another Sb-bearing oxyborate blatterite

although found in different association. Folvikite is a primary skarn mineral embedded in calcite and associated with hausmannite, tegengrenite, and a Mg-dominant analogue of sonolite or jerrygibbsite. The mineral forms black opaque to dark reddish-brown at thin edges, strongly lustrous submetallic elongated by [010] and striated (due to twinning) along the length prismatic crystals up to 0.3 mm with a reddish-brown streak. It does not fluoresce in UV radiation. Cleavage and parting were not observed. Folvikite is brittle, has conchoidal fracture and Mohs hardness of 6; $D_{\text{calc}} = 4.14 \text{ g/cm}^3$. In plane-polarized light folvikite is strongly pleochroic X (dark brown) $> Z$ (brown) $> Y$ (honey brown). It is optically biaxial, optic sign was not determined due to pervasive twinning; $2V = 68.9(4)^\circ$; $Y = \mathbf{b}$. Refractive indices were not measured; $n_{\text{calc}} = 1.85$. FTIR spectrum in the range 4000–650 cm^{-1} shows strong bands at 1335, 1275, 1240; medium to low intensity bands at 1124, 948, 934, 906 all assigned to B–O stretching vibrations; 723 and 666 (bending modes of the borate group). No bands observed in the region 4000–3000 cm^{-1} confirming the absence of OH and H₂O groups in the structure. The average of unspecified number of electron probe WDS analyses [wt% (range)] is Sb₂O₅ 18.15 (17.31–18.55), MgO 24.11 (22.79–25.06), MnO total 40.17 (39.04–41.64) [apportioned as MnO 29.73, Mn₂O₃ 11.62 based on structure assuming a cation sum without B³⁺ 11.74 apfu], Al₂O₃ 0.27 (0.24–0.31), Fe₂O₃ 0.45 (0.36–0.59), B₂O₃ 15.27 (calculated assuming B = 4 apfu), total 99.60. The empirical formula based of 20 anions pfu is (Sb_{0.02}³⁺Mn_{1.34}³⁺Al_{0.05}Fe_{0.05}Mg_{5.46}Mn_{3.82}□_{0.26})_{Σ12.00}O₆(BO₃)₄. The strongest X-ray powder diffraction lines [$d \text{ \AA}$ (hkl)] are 5.450 (100; 002), 4.973 (46; $\bar{1}01$), 3.112 (32; 020), 2.725 (82; 004), 2.591 (91; 121), 2.486 (31; 202), 2.033 (43; 220), 1.552 (37; 040). The unit-cell parameters refined from powder data are: $a = 5.388(2)$, $b = 6.220(2)$, $c = 10.933(3) \text{ \AA}$, $\beta = 94.40(3)^\circ$, $V = 365.27 \text{ \AA}^3$. Single-crystal XRD data obtained on a crystal of $5 \mu\text{m} \times 6 \mu\text{m} \times 40 \mu\text{m}$ shows folvikite is monoclinic, space group $P2_1$, $a = 5.3767(10)$, $b = 6.2108(10)$, $c = 10.9389(18) \text{ \AA}$, $\beta = 94.399(9)^\circ$, $V = 364.22 \text{ \AA}^3$, $Z = 4$. The crystal structure was solved by direct methods and refined to $R_1 = 4.1\%$ for 1070 $F_o > 4\sigma F$ unique reflections. It is related closely to the Sb-rich pinakiolite structure and contains eight positionally ordered M-cations sites with octahedral coordination, five positionally disordered X-cations sites partly occupied by Mn²⁺ > Mg with coordination numbers [4], [5], and [6], and two ordered [3]-coordinated B sites occupied by B. One M-site occupied by Sb³⁺ > Mg, two M sites occupied by Mg \geq Mn > Sb³⁺, two M sites occupied by Mn³⁺ > Mn²⁺, two M sites occupied by Mg > Mn²⁺, and one M-site occupied by Mg > □. Folvikite is a member of the (3 \AA) zigzag wallpaper-borate structures in which chains of edge-sharing octahedra extend along the c axis and are cross-linked by BO₃ groups. As with the other zigzag borates, the polyhedra are arranged in F-walls, C-walls, and S-columns. The name honors Harald O. Folvik (b. 1941) a prominent Norwegian amateur mineralogist with a particular interest in Långban type deposits who initially noticed and collected the specimen used for description. The polished mount used for electron probe analysis is kept at the Natural History Museum, University of Oslo, Norway. The crystal used for the structure study, powdered material used for IR spectroscopy and powder XRD studies along with a specimen that yielded this material were deposited at the Canadian Museum of Nature, Ottawa, Canada. **D.B.**

GADOLINITE-(Nd)*

R. Škoda, J. Plášil, R. Čopjaková, M. Novák, E. Jonsson, M. Vašinová Galiová, and D. Holtstam (2018) Gadolinite-(Nd), a new member of the gadolinite supergroup from Fe-REE deposits of Bastnäs-type, Sweden. *Mineralogical Magazine*, 82(S1), S133–S145.

Gadolinite-(Nd), (IMA 2016-013), ideally Nd₂FeBe₂Si₂O₁₀, monoclinic, is a new member of the gadolinite supergroup (Bačík et al. 2017), discovered in samples from the Malmkärä mine (60°4' N, 15°51' E) ~3.5 km WSW of Norberg, as well as at the Johanna and Nya Bastnäs mines, all belonging to the Fe-REE “Bastnäs-type” skarn deposits in the Bergslagen ore province (south-central Sweden). It occurs in association with fluorbritholite-(Ce), västmanlandite-(Ce), dollaseite-(Ce), bastnäsite-(Ce), and tremolite. The

mineralization is suggested to be the products of reactions between carbonate interlayers with Si, F, Cl, S, CO₂, and REE-bearing, high-temperature fluids of a magmatic origin. The Malmkärä deposit is hosted by a partly dolomitic marble that forms a conformable interlayer within the surrounding, typically extensively altered metavolcanic rocks. Gadolinite-(Nd) forms anhedral grains up to 150 μm , occurring as aggregates associated with tremolite, dollaseite-(Ce), västmanlandite-(Ce), fluorbritholite-(Ce), and bastnäsite-(Ce). It is olive green, transparent with a vitreous to adamantine luster and a white streak. No fluorescence under short- or long-wave UV radiation was observed. Gadolinite-(Nd) is brittle with a conchoidal fracture and no cleavage or parting. The Mohs hardness is 6½–7. $D_{\text{calc}} = 4.86 \text{ g/cm}^3$. In plane-polarized light gadolinite-(Nd) is weakly pleochroic in shades of olive green, optically biaxial (–), $\alpha = 1.78(1)$, $\beta_{\text{calc}} = 1.80$, $\gamma = 1.81(1)$ (white light), $2V_{\text{meas}} = 62(3)^\circ$; dispersion of optical axes is strong, $r < v$. The Raman spectrum (633 nm He-Ne laser) shows the most intense bands at 897 and 970 cm^{-1} (stretching of Be–O and Si–O in tetrahedral coordination); bands at the region 200–750 cm^{-1} (bending modes of Si–O and Be–O, stretching vibrations of REE–O and Fe–O and lattice modes); a weak band at 3525 cm^{-1} attributed to OH stretching. The average of eleven electron probe WDS analysis [wt% (range)] is: SiO₂ 21.77 (21.59–22.27), Y₂O₃ 5.49 (3.60–5.83), La₂O₃ 2.78 (2.04–3.08), Ce₂O₃ 14.04 (11.77–14.3), Pr₂O₃ 3.28 (3.12–3.79), Nd₂O₃ 19.27 (18.88–22.04), Sm₂O₃ 5.30 (5.04–6.08), Eu₂O₃ 0.24 (0.16–0.28), Gd₂O₃ 4.10 (3.60–4.43), Tb₂O₃ 0.36 (0.31–0.43), Dy₂O₃ 1.32 (1.05–1.52), Ho₂O₃ 0.18 (0.11–0.21), Er₂O₃ 0.38 (0.18–0.38), MgO 0.51 (0.40–0.92), CaO 0.14 (0.14–0.24), MnO 0.10 (0.10–0.20), FeO 10.62 (10.09–10.93), BeO (by stoichiometry) 8.99, B₂O₃ (by LA-ICP-MS) 0.10 (0.06–0.13), H₂O (by charge balance), total 99.52. The empirical formula based on 10 (O+OH) pfu is (Nd_{0.63}Ce_{0.47}Y_{0.27}Sm_{0.17}Gd_{0.13}Pr_{0.11}La_{0.09}Dy_{0.04}Ca_{0.01}Er_{0.01}Tb_{0.01}Eu_{0.01}Ho_{0.01})_{Σ1.96}(Fe_{0.82}Mg_{0.07}Mn_{0.01})_{Σ0.89}(Be_{1.98}B_{0.02})_{Σ2.00}Si₂O_{9.66}OH_{0.34}. The strongest lines in powder XRD pattern [$d \text{ \AA}$ (hkl)] are: 4.830 (72; 100), 3.603 (37; 021), 3.191 (52; $\bar{1}12$), 3.097 (35; 013), 2.888 (100; 121, $\bar{1}21$), 2.607 (49; 113, $\bar{1}13$), 2.412 (24; 200, 014). The unit-cell parameters refined from the powder data are $a = 4.826(1)$, $b = 7.717(2)$, $c = 10.147(2) \text{ \AA}$, $\beta = 90.16^\circ$, $V = 377.9(2) \text{ \AA}^3$. The single-crystal XRD data obtained on a platy crystal fragment (0.07 × 0.06 × 0.01 mm) shows gadolinite-(Nd) is monoclinic, space group $P2_1/c$, $a = 4.8216(3)$, $b = 7.6985(4)$, $c = 10.1362(6) \text{ \AA}$, $\beta = 90.234(4)^\circ$, $V = 376.24 \text{ \AA}^3$, $Z = 2$. The crystal structure refined to $R_1 = 0.0371$ for 607 observed $I > 3\sigma(I)$ reflections. Minerals of the gadolinite group possess a layer structure composed of two distinct sheets, which are alternating in the c direction. One sheet is represented by TO_4 and QO_4 tetrahedra and it alternates with a second sheet of AO_8 polyhedra and MO_6 octahedra. In the structure of gadolinite-(Nd), the T site is occupied dominantly by Si⁴⁺, the Q site by Be, the A site by Nd³⁺ (and other REE) and the M site by Fe²⁺. The name is given by analogy with the other members of the gadolinite subgroup (Bačík et al. 2017), as the Nd-dominant species. Type material is deposited at the Moravian Museum, Brno, Czech Republic. **F.C.**

References cited

Bačík, P., Miyawaki, R., Atencio, D., Cámara, F., and Fridrichová, J. (2017) Nomenclature of the Gadolinite Supergroup. *European Journal of Mineralogy*, 29, 1–16.

GORYAINOVITE*

G.Y. Ivanyuk, V.N. Yakovenchuk, Y.A. Pakhomovsky, T.L. Panikorovskii, N.G. Konoplyova, A.V. Bazai, V.N. Bocharov, A.A. Antonov, and E.A. Selivanova (2017) Goryainovite, Ca₂PO₄Cl, a new mineral from the Stora Sahavaara iron ore deposit (Norrbotten, Sweden). *GFF (Geologiska Föreningens Förhandlingar)*, 139(1), 75–82.

Goryainovite (IMA 2015-090), ideally Ca₂PO₄Cl, orthorhombic, is a new halophosphate, the chlorine analogue of “spodosite”, Ca₂PO₄F. It was discovered in the Stora Sahavaara deposit, Norrbotten county, Sweden (67.408° N; 23.297° E). Iron ore lenses up to 1.3 km long and 80 m thick are situated in the upper part of the Veikavaara greenstones at the contact of a 2.5–2.0 Ga Karelian greenstone rocks (metamorphosed conglomerate, quartzite, banded iron formation, black schist, dolomite, phyllite, tholei-

itic lava and tuff, and dolerite) in the footwall and 1.9 Ga Svecofennian medium-grade metamorphosed volcanic and sedimentary rocks in the hanging wall. Host diopside-amphibole skarn gradually transforms into a magnetite-serpentine rock with relics of diopside, tremolite, phlogopite and newly formed chlorite, pyrrhotite, pyrite, chalcocopyrite, and valleriite. Goryainovite was found in one specimen as small rounded grains of goryainovite (up to 20 μm) included in magnetite anhedral grains up to 1 mm in serpentine pseudomorphs after diopside with pyrrhotite, chalcocopyrite, and Cl-rich hydroxylapatite. Magnetite commonly contains octahedral inclusions up to 10 μm of spinel and, rarely, of anhydrite, thorianite, dolomite, and magnesite. Goryainovite is colorless with a vitreous luster and a white streak. Cleavage was not observed, the fracture is conchoidal. The Mohs hardness is ~ 4 ; $D_{\text{calc}} = 2.98 \text{ g/cm}^3$. In transmitted light, the mineral is colorless, optically biaxial (–) with $n_{\text{mean}} \approx 1.66$ (589 nm). Goryainovite has a bright orange cathodoluminescence, easy distinguishable from pale blue cathodoluminescence of co-existing hydroxylapatite. Synthetic $\text{Ca}_2\text{PO}_4\text{Cl}$ fluoresces pale orange under 254 nm UV radiation and does not fluoresces under 385 nm UV. Synthetic $\text{Ca}_2\text{PO}_4\text{Cl}$ is optically biaxial (–), $\alpha = 1.650$, $\beta = 1.663$, $\gamma = 1.670$ (λ not specified); $2V_{\text{meas}} = 75^\circ$; $X = \mathbf{b}$, $Y = \mathbf{a}$, $Z = \mathbf{c}$ (Mackay 1953). The Raman spectrum of goryainovite is similar to that of synthetic $\text{Ca}_2\text{PO}_4\text{Cl}$ and shows 18 bands corresponding to the ν_1 – ν_4 modes of the phosphate-anion vibration. It differs significantly from Raman spectrum of hydroxylapatite, except the most intense band at 958 cm^{-1} present in both and caused by ν_1 symmetrical stretching of the $(\text{PO}_4)^{3-}$. The mean of electron probe WDS analysis (5–6 point on each of 3 grains) [wt% (range)] is: P_2O_5 33.19 (32.84–33.47), Cl 16.96 (16.64–17.41), CaO 53.25 (52.43–54.84), $-\text{O}=\text{Cl}_2$ 3.83, total 99.57. No other elements with $Z > 9$ were detected. The empirical formula calculated on the basis of 3 cations pfu is $\text{Ca}_{2.01}[\text{P}_{0.99}\text{O}_{3.98}]\text{Cl}_{1.01}$. The strongest X-ray powder diffraction lines [d Å (hkl)] are: 2.845 (90; 113), 2.746 (100; 211), 2.333 (25; 114), 2.028 (15; 132), 1.957 (30; 115), 1.837 (20; 025), 1.756 (15; 040), 1.374 (15; 422). The XRD pattern indexed in orthorhombic unit cell, space group $Pbcm$ based on data for synthetic $\text{Ca}_2\text{PO}_4\text{Cl}$, Unit-cell parameters refined from the powder data are: $a = 6.215(2)$, $b = 7.011(2)$, $c = 10.788(3)$ Å, $V = 470.0$ Å³, $Z = 4$. The crystal structure of synthetic $\text{Ca}_2\text{PO}_4\text{Cl}$ is based on isolated distorted $[\text{PO}_4]^{3-}$ tetrahedra linked by eightfold-coordinated calcium cations with six Ca–O and two Ca–Cl bonds (Greenblatt et al. 1967). Goryainovite is an early-formed phosphate. When chlorine fugacity decreased, goryainovite was transformed into chlorapatite–hydroxylapatite, and only grains isolated in magnetite remained unaltered. The named honors Pavel Mikhailovich Goryainov (b. 1937) at the Geological Institute of the Kola Centre of Russian Academy of Sciences for his contribution to the knowledge of the geology and petrology of banded iron formation of the Fennoscandian Shield. The holotype specimen is deposited in the Mineralogical Museum of the St. Petersburg State University, Russia. **D.B.**

References cited

- Greenblatt, M., Banks, E., and Post, B. (1967) The crystal structures of the spodosite analogs, $\text{Ca}_2\text{CrO}_4\text{Cl}$ and $\text{Ca}_2\text{PO}_4\text{Cl}$. *Acta Crystallographica*, 23, 166–171.
Mackay, A.L. (1953) The unit cell and space-group of chlor-spodosite ($\text{Ca}_2\text{PO}_4\text{Cl}$). *Mineralogical Magazine*, 30, 166–168.

KRUIJENITE*

N.V. Chukanov, N.V. Zubkova, G. Blass, I.V. Pekov, D.A. Varlamov, D.I. Belakovskiy, D.A. Ksenofontov, S.N. Britvin, and D.Y. Pushcharovky (2019) Kruijenite, $\text{Ca}_4\text{Al}_4(\text{SO}_4)\text{F}_2(\text{OH})_{16}\cdot 2\text{H}_2\text{O}$, a new mineral with microporous structure from the Eifel paleovolcanic region, Germany. *Mineralogy and Petrology*, 113(2), 229–236.

Kruijenite (IMA 2018-057), ideally $\text{Ca}_4\text{Al}_4(\text{SO}_4)\text{F}_2(\text{OH})_{16}\cdot 2\text{H}_2\text{O}$, tetragonal, was discovered at the Feuerberg paleovolcano near Daun, Eifel paleovolcanic region, Rhineland-Palatinate, Germany. It was found in fragments of altered calcic xenolith from tephra whose initial size was about 20 cm. The xenolith is composed of fluorite, calcite, aragonite, cuspidine,

magnesioferrite, hematite, sharyginite, harmunite, and an insufficiently investigated hydrous Ca-Mg-Al silicate. It contains cavities incrustated by calcite. The minerals in xenolith are products of pyro-metamorphic and further hydrothermal alteration of a calcic xenolith under exposure of volatile components of magma. Kruijenite is one of the latest minerals in this association. The following sequence of mineral formation was proposed: sharyginite + harmunite \rightarrow magnesioferrite \rightarrow fluorite \rightarrow cuspidine \rightarrow calcite + kruijenite + hydrous Ca-Mg-Al silicate. Kruijenite forms long prismatic tetragonal crystals up to 0.1 mm \times 1 mm. These crystals occur in cavities and are typically combined in radiating or random clusters up to 2 mm in size, as well as dense aggregates intergrown with calcite. Kruijenite is pale greenish-yellow to colorless. The cleavage was not observed. It is brittle with Mohs hardness of 3. Density was not measured because of small sizes of crystals; $D_{\text{calc}} = 2.573 \text{ g/cm}^3$. In plane-polarized light kruijenite is colorless, non-pleochroic. It is optically uniaxial (–), $\omega = 1.576(3)$, $\varepsilon = 1.561(3)$. The IR spectrum of kruijenite has the following bands (cm^{-1} ; s – strong band, sh – shoulder): 3562, 3492, 3410sh (O–H stretching of H_2O and OH groups); 1635 (H_2O bending), 1140sh, 1085sh, 1069s [$\nu_3(\text{F}_2)$ – asymmetric stretching of SO_4^{2-} anions], 1028, 984s [$\nu_1(\text{A}_1)$ – symmetric stretching of SO_4^{2-} anions], 920, 870 ($\text{Al}\cdots\text{O}-\text{H}$ and $\text{Ca}\cdots\text{O}-\text{H}$ bending vibrations), 617 [$\nu_2(\text{F}_2)$ – SO_4^{2-} bending], 559, 515s (Al–O stretching), 471 [$\nu_2(\text{E})$ – bending mode of SO_4^{2-} anions], 385s (Ca–O stretching). Weak bands in the range from 2000 to 2400 cm^{-1} correspond to overtones and combination modes. The average of 18 WDS analyses of kruijenite is [wt% (range, standard deviation)]: CaO 32.38 (31.36–33.23, 0.43), Al_2O_3 27.75 (27.06–28.86, 0.43), Cr_2O_3 1.45 (0.67–2.06, 0.285), SO_3 8.09 (7.54–8.58, 0.28), F 5.84 (4.63–7.29, 0.85), H_2O (by structure) 25.64, $-\text{O}=\text{F}_2$ 2.46, total 98.69. The empirical formula is $\text{Ca}_{4.00}(\text{Al}_{3.77}\text{Cr}_{0.13})_{\Sigma 3.90}(\text{SO}_4)_{0.70}\text{F}_{2.13}(\text{OH})_{16.17}\cdot 1.79\text{H}_2\text{O}$ based on 22.89 (O+F) atoms pfu, in accord with refined site occupancies. The strongest lines in the powder X-ray diffraction pattern are [d Å (hkl)]: 9.12 (77; 110), 4.565 (100; 220), 4.084 (50; 310), 2.964 (74; 321), 2.694 (27; 411), 2.321 (24; 431), 2.284 (29; 511), 2.217 (22; 321, 530), 1.971 (40; 611). The crystal structure of kruijenite was solved by direct methods and refined to $R_1 = 12.1\%$. The new mineral is tetragonal, $P4/ncc$, $a = 12.9299(4)$, $c = 5.2791(3)$ Å, $V = 882.57$ Å³, and $Z = 2$. Kruijenite belongs to a novel structure type. Its structure is based on the microporous pseudo-framework built by $\text{Al}(\text{OH})_6$ octahedra and $\text{CaF}_2(\text{OH})_6$ eightfold polyhedra. Al-centred octahedra share edges to form zigzag chains running along the c axis, and Ca-centred polyhedra share the F–F edges to form dimers; adjacent dimers are also connected via common F–O(1) edges thus building columns along [001]. All H sites of OH groups are located inside the wide channels (with approximate diameter of 7.4 Å) running along the c axis. These channels also contain H_2O molecules and significantly distorted $[\text{SO}_4]$ tetrahedra. Kruijenite is chemically related to kuzelkite $\text{Ca}_4\text{Al}_2(\text{SO}_4)(\text{OH})_{12}\cdot 6\text{H}_2\text{O}$, which is also found only in calcic xenoliths hosted by basic igneous rocks. The mineral name honors Dutch collector of Eifel minerals Fred Kruijen (b. 1956), an author of numerous articles in popular scientific periodicals and an outstanding micro-mineral photographer who made a lot of high-quality photos of Eifel minerals. The type specimen is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **Yu.U.**

NATROWALENTAITE*

I.E. Grey, W.G. Mumme, A.R. Kampf, C.M. MacRae, and N.C. Wilson (2019) Natrowalentaite, a new mineral from the Griffins Find gold deposit, Western Australia. *Australian Journal of Mineralogy*, 20(1), 7–15.

Natrowalentaite (IMA 2018-023) [$(\text{Fe}^{3+}, \text{Na})(\text{H}_2\text{O})_6$][$\text{NaAs}_2^{3+}(\text{Fe}_{3-x}^{3+}, \text{W}^{6+})(\text{PO}_4)_2(\text{O}, \text{OH})_x$], $x \sim 0.7$, orthorhombic, is a new secondary phosphate mineral from the Griffins Find gold deposit (118°19'12" E, 33°4'11" S), located about 15 km northwest of Lake Grace and 275 km, southeast of Perth in Western Australia. Natrowalentaite was first identified by Ernie H. Nickel (Nickel 1987) in specimens collected by John Day at the Griffins Find gold deposit.

The deposit comprises surface enriched, gold-bearing, quartz–sulfide lodes in a highly metamorphosed greenstone, which has been intruded by recrystallized adamellite. Main ore minerals are pyrrhotite, löllingite, and arsenopyrite. The rocks have been heavily weathered and the primary sulfides and arsenides have been converted into a range of secondary minerals, including goethite, jarosite, scorodite, arseniosiderite, and natropharmacosiderite. Natrowalentaite occurs on fracture surfaces in iron-stained rock along with natropharmacosiderite and jarosite and is a product of supergene alteration. It forms dense mass of bright greenish-yellow blades on a 1.5 mm wide core of brown natropharmacosiderite. Individual blades are extremely thin (1–3 µm), typically 10–20 µm wide and up to 200 µm in length. Blades are flattened on {100} and elongated by [010]. Cleavage is perfect on {100}. $D_{\text{meas}} = 2.91(2)$; $D_{\text{calc}} = 2.93$ g/cm³. Natrowalentaite has no perceptible pleochroism, is optically biaxial (–), $\alpha = 1.650(3)$, $\beta = 1.728(3)$, $\gamma = 1.772(3)$ (white light), $2V_{\text{meas}} = 71(2)^\circ$; $X = \mathbf{a}$, $Y = \mathbf{c}$, $Z = \mathbf{b}$. Dispersion of optical axes is distinct, $r > v$. The average of 11 electron probe WDS analysis [wt% (range)/wt% (Nickel 1987)] is: Na₂O 3.52 (2.96–4.22)/–; K₂O 0.34 (0.21–0.57)/–; CaO 1.76 (1.48–1.95)/2.3; Fe₂O₃ 21.4 (19.4–22.3)/25.3; WO₃ 17.0 (13.4–19.1)/14.5; P₂O₅ 14.8 (13.3–15.6)/16.5; As₂O₃ 21.7 (19.4–24.1)/–; As₂O₅ –/24.9; H₂O 12.3 (from structure)/16.5 (100 – Σ oxides); total 92.8/100. The empirical formula based on 21 (O+OH) pfu is Na_{1.09}K_{0.07}Ca_{0.36}Fe_{3.57}W_{0.70}As_{2.10}P₂O₂₁H_{12.02}. The strongest lines in powder XRD pattern [d Å (hkl)] are: 12.95 (100; 200), 9.72 (9; 101), 6.72 (14; 301), 4.41 (10; 411), 3.020 (27; 022), 2.940 (15; 222), 2.759 (11; 802), 1.7840 (10; 824). The unit-cell parameters refined from the powder data are $a = 25.788(8)$, $b = 7.336(1)$, $c = 10.519(2)$ Å, $V = 1990.0$ Å³. The single-crystal XRD data obtained on a thin blade of $0.070 \times 0.007 \times 0.002$ mm at the macromolecular microfocus beam line MX2 of the Australian Synchrotron shows natrowalentaite is orthorhombic, space group *Imma*, $a = 25.770(3)$, $b = 7.3250(8)$, $c = 10.522(1)$ Å, $V = 1986.2$ Å³, $Z = 4$. The crystal structure was refined to $R_1 = 0.0681$ for 872 observed $I > 3\sigma(I)$ reflections. Natrowalentaite has a layered structure, with layers stacked along [100]. Hydrated-cation polyhedral and H₂O molecules are located between the layers and are hydrogen-bonded to the layers. The heteropolyhedral layers of composition (Fe_{2.33}W_{0.67})(PO₄)₂Φ₆, Φ = O, OH, comprise hexagonal rings of corner-connected (Fe, W)O₆ octahedra that are decorated with PO₄ tetrahedra, which share three vertices with three octahedra. The layer can be described as unit-cell twinned kintoreite, with the twin plane = (001), giving a characteristic sawtooth shape to the layers. There are two independent octahedral sites in the layer, *M1* and *M2*, and W is preferentially ordered into the latter, which has an occupancy of $0.65\text{Fe}^{3+} + 0.35\text{W}^{6+}$. Tungsten is displaced from the position occupied by iron by 0.4 Å to establish two short bonds of 1.78 Å, characteristic of the tungstenyl group. Pyramidal arsenite groups, As³⁺O₃, as well as sodium (with minor calcium and potassium), are attached to the surface of the heteropolyhedral layers, disordered over several closely spaced positions, corresponding to different locally ordered configurations, like in walentaite. Clusters are composed of corner-shared pairs of AsO₃ trigonal pyramids (*As2*), connected to a third AsO₃ pyramid (*As3*) by edge-sharing. Because natrowalentaite is present as a surface coating on natropharmacosiderite (contains arsenic only as As⁵⁺), the Eh range for arsenite stability (~–0.3 to 0.5) suggests that more reducing conditions, perhaps resulting from the decomposition of arsenopyrite, prevailed during the crystallization of the natrowalentaite. The name of the mineral is based on dominant sodium replacing calcium in walentaite. The holotype specimen is deposited in the Natural History Museum of Los Angeles County, California, U.S.A. F.C.

References cited

Nickel, E.H. (1987) Tungsten-bearing walentaite from Griffins Find gold deposit, Western Australia. *Australian Mineralogist*, 9–12.

NOLLMOTZITE*

J. Plášil, A.R. Kampf, R. Škoda, and J. Čejka (2018) Nollmotzite, Mg[U^v(U^vO₂)₂F₃O₄]₂·4H₂O, the first natural uranium oxide containing fluorine. *Acta Crystallographica*, B74(4), 362–369.

Nollmotzite (IMA 2017-100), Mg[U⁵⁺(U⁶⁺O₂)₂F₃O₄](H₂O)₄, monoclinic is a new uranium oxide fluoride discovered at the dump of famous the Clara mine, Black Forest Mountains, Baden-Württemberg, Germany. The mineral occurs in cavities in quartz gangue with abundant dark-violet to black fluorite and barite. It forms deep-violet brown thin prisms up to ~0.3 mm, elongated on [010], with chisel-like terminations. Crystal forms are: {100}, {001}, {120}. Nollmotzite has a vitreous luster. It is non-fluorescent under long-wave and short-wave UV radiation. The mineral is brittle with a perfect cleavage on {001}. In plane-polarized light it is strongly pleochroic, X – colorless $\ll Y$ – red-brown $< Z$ – deep violet. Nollmotzite is optically biaxial (–), $\alpha = 1.615(3)$, $\beta = 1.750(5)$, $\gamma = 1.765(5)$ (white light), $2V_{\text{meas}} = 37(1)^\circ$, $2V_{\text{calc}} = 34.6^\circ$; $X \approx \mathbf{c}^*$, $Y = \mathbf{b}$, $Z \approx \mathbf{a}$, $X^{\wedge}c \approx 9^\circ$ in obtuse angle β . Dispersion of optical axes is strong, $r > v$. Raman spectra recorded in two orientations: || \mathbf{c}^* (X), and || \mathbf{a} (Z), i.e., \perp and || to the sheet of U polyhedral. These spectra differ significantly in lines intensity. The bands are (cm^{–1}, s – strong, w – weak, sh – shoulder): 3488, 3437, 3239w || \mathbf{a} , and 3480w || \mathbf{c}^* (symmetric O–H stretching of H₂O); 1444w || \mathbf{c}^* (overtone); 815s || \mathbf{a} and 808w || \mathbf{c}^* [$\nu_1(\text{UO}_2)^{2+}$ symmetric stretching]; 716s || \mathbf{a} and 724 || \mathbf{c}^* (ν_1 U–F symmetric stretching); 676sh, 586sh || \mathbf{a} (libration modes of molecular H₂O); 466, 425, 339w || \mathbf{a} , and 427, 340 || \mathbf{c}^* [$\nu(\text{U–O}_{\text{ligand}})$]; 295w, 251w || \mathbf{a} and 240w || \mathbf{c}^* [$\nu_2(\delta)$ (UO₂)²⁺ doubly degenerate bending vibrations]; 179 || \mathbf{a} and 175w || \mathbf{c}^* (δ F–U–F bending); 194sh, 138w || \mathbf{a} and 136w || \mathbf{c}^* [translations and rotations of (UO₂)²⁺]. The average of six electron probe WDS analyses [wt% (range)] is MgO 4.20 (4.03–4.37), CuO 0.12 (0.05–0.35), UO₃ 84.18 (83.28–85.28) (apportioned by structural data to U₂O₇ 27.28 and UO₃ 56.12), F 5.87 (5.39–6.16), H₂O 6.80 (by structure), –O=F 2.47, total 97.92. (Mg_{1.06}Cu_{0.02})_{Σ1.08}[U⁵⁺(U⁶⁺O₂)₂F_{3.85}O_{4.15}][(H₂O)_{3.69}(OH)_{0.31}]_{Σ4.00} based on three U and 15 (O+F) apfu. The strongest lines in powder XRD pattern [d Å (hkl)] are: 8.10 (100; 001), 4.06 (31; 002), 3.518 (30; 200), 3.420 (54; $\bar{1}30, 20\bar{1}$), 3.237 (22; $\bar{1}3\bar{1}$), 3.083 (26; $\bar{1}3\bar{1}, 20\bar{1}$), 2.710 (17; $\bar{1}3\bar{2}, 00\bar{3}$), 2.015 (32; $\bar{3}30, 3\bar{3}\bar{1}, 20\bar{3}$). Unit-cell parameters refined from the powder data with whole pattern fitting are: $a = 7.117(6)$, $b = 11.786(7)$, $c = 8.203(6)$ Å, $\beta = 98.14(2)^\circ$, $V = 681.1$ Å³. Single-crystal X-ray data obtained from the crystal of $0.072 \times 0.012 \times 0.009$ mm shows nollmotzite is monoclinic, space group *Cm*, $a = 7.1015(12)$ Å, $b = 11.7489(17)$ Å, $c = 8.1954(14)$ Å, $\beta = 98.087(14)^\circ$, $V = 676.98(19)$ Å³, $Z = 2$. The crystal structure [twinned by reticular merohedry by reflection on (100)] refined to $R = 0.0369$ for 1527 unique observed $I > 3\sigma(I)$ reflections. It contains two U, one Mg, three F, and seven O sites (including three O sites of the molecular H₂O) and is based upon [U⁵⁺(U⁶⁺O₂)₂F₃O₄]^{2–} sheets of β -U₃O₈ topology and contains an interlayer with MgF₂(H₂O)₄ octahedra. Adjacent sheets are linked through F–Mg–F bonds, and via hydrogen bonds. The presence of fluorine and pentavalent uranium in the structure of nollmotzite has potentially important implications for the safe disposal of nuclear waste. The name nollmotzite honors two German mineral collectors who found this new mineral. It combines the first four letters of their surnames: Markus Noller (b.1977) and Reinhard Motzigemba (b.1952). Three cotype specimens deposited in the Natural History Museum of Los Angeles County, California, U.S.A. D.B.

QATRANAITE*

Y. Vapnik, E.V. Galuskin, I.O. Galuskina, J. Kusz, M. Stasiak, T. Krzykavski, and M. Dulski (2019) Qatranaita, CaZn₂(OH)₆·2H₂O: a new mineral from altered pyrometamorphic rocks of the Hatrurim Complex, Daba-Siwaqa, Jordan. *European Journal of Mineralogy*, 31(3), 575–584.

Qatranaita (IMA 2016-024), ideally CaZn₂(OH)₆·2H₂O, monoclinic, is a new mineral discovered in altered pyrometamorphic spurrite marbles of the Hatrurim Complex in the Daba-Siwaqa region, Um Al-Rasas Sub-district, 70 km southeast from Amman, Jordan (N31°24,23'; E36°15,06'). The origin of the pyrometamorphic rocks of the “Mottled zone” is discussed mainly between two hypotheses: combustion of dispersed organic matter (bitumen) within the host sedimentary rocks or a mud-volcanic formation by combustion of the sedimentary protoliths by methane

exhaling from tectonically active zones of the Dead Sea Transform. Dark spurrite marbles from qatranaitite type locality contain minerals of the fluorapatite–fluorellastadite and srebrodolskite–brownmillerite series with minor fluormayenite–fluorkuygenite and spinel–magnesian series minerals and, locally, gehlenite, periclase, lakargiite, vorlanite, larnite, zincite, monteponite, and sphalerite. Spurrite rocks are crosscut by cuspidine veins up to 10 cm thick and by networks of calcite–thaumasite (rarer ettringite) veins up to 1–2 mm thick. Qatranaitite was found in secondary low-temperature (<70 °C) veins from 10–20 µm to 1–2 mm exclusively in cuspidine zones with large spurrite crystal relics. It forms colorless or white crystals up to 0.3 mm and parallel intergrowths associated with Se-bearing thaumasite, calcite, awillite, barite, and sometimes replace sphalerite grains. The crystals forms are: {010}, {110}, {100}, {102}, {112}, {001}, {011}, {101}, {102}. Crystals are flattened on (010), show striations along [001]. Qatranaitite has a vitreous luster, white streak and irregular fracture. It is brittle. Cleavage and parting were not observed. The microindentation hardness $VHN_{25} = 171$ (163–178) kg/mm² corresponding to ~3.5 of the Mohs scale. The density was not measured due to abundance of small inclusions; $D_{\text{calc}} = 2.598$ g/cm³. In plane-polarized light qatranaitite is colorless, non-pleochroic. It is optically biaxial (–), $\alpha = 1.545(2)$, $\beta = 1.552(2)$, $\gamma = 1.554(2)$ (589 nm). $2V_{\text{meas}} = 45(5)^\circ$, $2V_{\text{calc}} = 50^\circ$, $Z = \mathbf{b}$, $X^\wedge c \sim 13^\circ$, dispersion of an optical axes $r > v$, weak. The main bands in the Raman spectrum of qatranaitite are related to vibrations in $Zn(OH)_4^{2-}$ tetrahedra (cm⁻¹): 297, 344 [$\nu_2 + \nu_4$ with possible contribution Ca–O vibrations within $Ca(OH)_4(OH)_2^{2-}$ octahedra]; 440, 449, 479 ($\nu_1 + \nu_3$); 990 (ν Zn–O–Zn); 1065 (ν Zn–OH). Bands at 2910, 3025, and 3190 cm⁻¹ are related to stretching vibrations of O–H in H₂O. Strong bands at 3497 and 3624 cm⁻¹ are due to O–H stretching in (OH) groups. The average of 10 electron probe WDS analyses [wt% (range)] is: CaO 17.69 (17.53–17.93), ZnO 52.66 (53.35–54.86), H₂O (by stoichiometry) 28.91, total 99.26. No other elements detectable by microprobe found. The empirical formula based on 3 cations and 8 O apfu is $Ca_{0.98}Zn_{2.02}(OH)_6 \cdot 2H_2O$. The strongest lines of the powder XRD pattern are [d Å ($P\%$; hkl)]: 6.25 (33; 100), 5.002 (14; 011), 3.992 (23; 021), 3.124 (47; 200), 2.881 (100; $\bar{1}31$), 2.723 (28; 012), 2.451 (12; 211), 1.575 (20; 260). The single-crystal X-ray data obtained on a crystal $0.09 \times 0.04 \times 0.03$ mm at 293(2) K shows qatranaitite is monoclinic, space group $P2_1/c$, $a = 6.3889(8)$, $b = 10.9692(14)$, $c = 5.7588(8)$ Å, $\beta = 101.949(14)^\circ$, $V = 394.84$ Å³, $Z = 2$. The crystal structure was refined (using the structure of the synthetic analog of qatranaitite – calcium hexahydroxodizincate dihydrate as a starting model) to $R_1 = 0.0377$ for 1528 $I > 2\sigma(I)$ unique reflections. In the structure Zn-centered tetrahedra form corner-sharing pyroxene-like chains $[Zn_2(OH)_6]^{2-}$, between which the $[Ca(OH)_2]^{2+}$ groups are located. The Ca atoms are eightfold-coordinated in $[Ca(OH)_4(OH)_2]$ polyhedra which share the four hydroxyl oxygen atoms with the Zn-centered tetrahedra. Qatranaitite was named after the village Al Qatran, at the Amman–Aqaba highway near the type locality. The holotype is deposited in the Fersman Mineralogical Museum Russian Academy of Sciences, Moscow, Russia. **D.B.**

TRIAZOLITE*

N.V. Chukanov, N.V. Zubkova, G. Möhn, I.V. Pekov, D.I. Belakovskiy, K.V. Van, S.N. Britvin, and D.Y. Pushcharovky (2018) Triazolite, $NaCu_2(N_3C_2H_2)_2(NH_3)_2Cl_3 \cdot 4H_2O$, a new mineral species containing 1,2,4-triazolate anion, from a guano deposit at Pabellón de Pica, Iquique Province, Chile. Mineralogical Magazine, 82(4), 1007–1014.

Triazolite (IMA 2017-025), ideally $NaCu_2(N_3C_2H_2)_2(NH_3)_2Cl_3 \cdot 4H_2O$, orthorhombic, was discovered in a guano deposit located on Pabellón de Pica Mountain, 1.5 km south of Chanabaya village, Iquique Province, Tarapacá Region, Chile. This deposit known as the type locality of several nitrogen-bearing and organic minerals. Triazolite occurs in the contact zone between altered guano and gabbro, which consists of amphibole, plagioclase, and minor clinocllore and containing accessory chalcopyrite.

Triazolite forms well-shaped prismatic crystals up to 0.1 mm × 0.15 mm × 0.75 mm elongated by **b** and their radial aggregates up to 1.5 mm in diameter which occur in cavities in aggregates of salammoniac with subordinate halite near the contact of a guano with the host rock, or grow over the surface of the host rock. Other associated minerals are ditmarite, joanneumite, chanabayaite, nitratine, natroxalate, and möhnite. Triazolite crystals formed by pinacoids {001}, {010}, and {100} and prism {*hk*0} or {*0kl*}. They are deep blue translucent with a blue streak and vitreous luster. Cleavage is perfect on {001} and imperfect on {100} and {010}. No parting is observed, and the fracture across the perfect cleavage plane is uneven. Triazolite is brittle and has Mohs hardness of 2. It is non-fluorescent in UV radiation. The measured density is ~1.85 g/cm³ while $D_{\text{calc}} = 2.028$ g/cm³. This discrepancy might be caused by numerous microcracks in triazolite crystals and common salammoniac micro-inclusions. Triazolite dissolves in dilute HCl and HNO₃ without gas evolution. It is insoluble in water, but crystals of triazolite become dull after exposure to warm water. If heated in a closed tube triazolite produces a white sublimate of NH₄Cl. Stronger heating results in reduction to metallic Cu. In plane-polarized light triazolite is distinctly pleochroic: Y (violet) $> X \approx Z$ (greenish-blue). It is optically biaxial (–), $\alpha = 1.582(4)$, $\beta = 1.625(3)$, $\gamma = 1.625(3)$ (589 nm); $2V_{\text{meas}} = 5(3)^\circ$; $X = \mathbf{b}$. The dispersion of optical axes is not observed. The IR spectrum shows (cm⁻¹): strong bands in the range 3100–3500 (N–H and O–H stretching); bands in the range 2800–3100 (C–H stretching of the 1,2,4-triazolate anion, possibly combined with N–H stretching); bands in the range 1620–1660 (degenerate bending of NH₃ and H₂O bending); strong bands in the range 1095–1510 (in-plane stretching and mixed vibrations of the 1,2,4-triazolate ring and symmetrical bending of NH₃); the bands in the range from 990 to 1062 (in-plane bending vibrations of C–H bonds); 887 (in-plane bending vibrations of the 1,2,4-triazolate ring); bands below 800 (out-of-plane vibrations of the 1,2,4-triazolate anion, rocking vibrations of NH₃ and librational vibrations of H₂O molecules). The broad bands at 1751 and 2050 cm⁻¹ are attributed to acid groups which may arise as a result of partial protonation of triazolite anions in accordance with the dynamic equilibrium $C_2N_3H_2 + H_2O \leftrightarrow C_2N_3H_3 + OH^-$. The average of four EDS analyses (H, N, C, and S by gas chromatography of products of ignition in oxygen at 1200 °C) is [wt% (range)]: Na 4.91 (4.26–5.48), Fe 1.51 (1.39–1.76), Cu 22.06 (20.57–23.94), Cl 19.80 (18.98–19.72), S 1.4 ± 0.02, C 7.7 ± 1.5, H 4.4 ± 0.7, N 24.2 ± 2.4, O (calculated from the ideal formula) 12.83, total 98.81. The WDS mode with higher beam current could not be used because of the instability of the mineral. Structural data and chemical tests show the absence of CO₃²⁻ anions, and hence all carbon atoms belong to the triazolite anion. The empirical formula of triazolite is $Na_{1.14}(Cu_{1.86}Fe_{0.14})_{22.0}N_{9.23}C_{3.43}H_{23.34}O_{4.29}(Cl_{2.99}S_{0.23})_{23.22}$ based on Cu+Fe = 2 atoms pfu. Reactions of triazolite solution in 20% HCl with potassium hexacyanoferrate(II) and potassium hexacyanoferrate(III) show that all the Cu in the mineral is bivalent. The strongest lines in the powder X-ray diffraction pattern of triazolite are [d Å ($P\%$; hkl)]: 10.22 (97; 101), 6.135 (40; 011), 5.696 (17; 301), 5.182 (59; 202), 5.119 (100; 211), 4.854 (19; 400), 3.752 (16; 312,501), 3.294 (18, 221). The crystal structure of triazolite was solved by direct methods and refined to $R_1 = 2.42\%$. Triazolite is orthorhombic, $P2_12_12_1$, $a = 19.3575(5)$, $b = 7.15718(19)$, $c = 12.5020(4)$ Å, $V = 1732.09$ Å³, $Z = 4$. The structure contains zigzag chains of the corner-sharing CuN_4Cl_2 octahedra (with N atoms belonging to four 1,2,4-triazole rings) running along **b**. Isolated $Cu^{2+}N_4Cl_2$ octahedra (with two N atoms belonging to two 1,2,4-triazole rings and two N atoms of ammonia molecules NH₃) are connected with these zigzag chains via 1,2,4-triazolate anions $C_2N_3H_2$. $Na(H_2O)_6$ octahedra share edges to form columns parallel to **b**. The system of hydrogen bonds formed by H₂O and NH₃ molecules connects isolated Cu-centred octahedra with each other and with the columns of $Na(H_2O)_6$ octahedra as well as the octahedral chains built by Cu and Na polyhedra. The mineral is named for the presence of 1,2,4-triazolate anion in its crystal structure. Holotype specimen is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **Yu.U.**