

New Mineral Names*†

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This New Mineral Names has entries for 16 new minerals, including minerals of the volcanic fumarols: acmonidesite, elasmochloite, russoite, and sbacchiite; ammoniolasalite; minerals of Ca-Al-rich inclusions in Allende CV3 chondrite: beckettite, burnettite, and paqueite; new terrestrial phosphides: grammatikopoulosite, halamishite, murashkoite, negevite, transjordanite, tsikourasite, and zuktamurrite; kamenevite and new data on oyelite.

ACMONIDESITE*

F. Demartin, C. Castellano, and I. Camprostrini (2019) Acmonidesite, a new ammonium sulfate chloride from La Fossa crater, Vulcano, Aeolian Islands, Italy. *Mineralogical Magazine* 83(1), 137–142.

Acmonidesite (IMA 2013-068), $(\text{NH}_4, \text{K}, \text{Pb}^{2+}, \text{Na})_6\text{Fe}_3^{2+}(\text{SO}_4)_3\text{Cl}_8$, orthorhombic, is a new mineral discovered in an active fumarole FA (T ~250 °C) at La Fossa crater, Vulcano, Aeolian Islands, Sicily, Italy. It occurs on a pyroclastic breccia with salammoniac, alunite and adranosite as brown prismatic crystals up to 0.1 mm with main forms: {100}, {120}, {011}, {010}, {102}, and no apparent twinning. The mineral has light brown streak, vitreous luster, and no cleavage. No fluorescence under UV radiation was observed. No data on hardness provided; $D_{\text{meas}} = 2.56(1)$, $D_{\text{calc}} = 2.551 \text{ g/cm}^3$. In plane-polarized transmitted light acmonidesite has intense brown color (pleochroism not mentioned). It is optically biaxial (+), $\alpha = 1.580(2)$, $\beta = 1.590(2)$, $\gamma = 1.635(2)$ (white light), $2V_{\text{meas}} = 53(3)^\circ$ and $2V_{\text{calc}} = 51.6^\circ$; $X = \mathbf{c}$, $Y = \mathbf{b}$, $Z = \mathbf{a}$. FTIR spectrum shows strong bands related to the presence of ammonium at 3214 (broad), 2921, 2851, and 1395 cm^{-1} ; typical sulfate absorptions at 740, 1005, 1083, 1137, and 1218 cm^{-1} . Weak bands at 1620 and 1730 cm^{-1} may be due to partial replacement of Cl⁻ by OH⁻. The average of eight electron probe EDS analyses (performed under 20 kV excitation voltage, 10 pA beam current, and 2 μm beam diameter to minimize the damage and deammonation under the beam) on unpolished surface [wt% (range)] is: $(\text{NH}_4)_2\text{O}$ (by structure) 11.05, K_2O 4.91 (4.28–6.14), Na_2O 2.82 (2.28–3.54), FeO 20.93 (19.51–21.88), MnO 0.42 (0.15–1.24), PbO 10.25 (7.03–12.23), SO_3 29.67 (27.46–32.51), Cl 20.80 (18.42–23.46), Br 0.45 (0.36–0.51), $\text{O}=\text{Cl}_2$ 4.75, total 96.55. The empirical formula based on 28 anions pfu is $(\text{NH}_4)_{5.77}\text{K}_{1.42}\text{Pb}_{0.62}\text{Na}_{1.24}\text{Fe}_{3.96}^{2+}\text{Mn}_{0.08}\text{S}_{5.04}\text{O}_{20.16}\text{Cl}_{17.97}\text{Br}_{0.08}$. The strongest reflections in the powder X-ray diffraction pattern are: $[d \text{ \AA} (I\% ; hkl)]$ 8.766 (100; 110), 1.805 (88; 390), 5.178 (45; 131), 4.250 (42; 221), 2.926 (42; 330), 2.684 (32; 261). The unit-cell parameters refined from the powder data are $a = 9.840(1)$, $b = 19.455(2)$, $c = 17.847(2) \text{ \AA}$, $V = 3416.6 \text{ \AA}^3$. Single-crystal XRD data shows acmonidesite is orthorhombic, space group $C222_1$, $a = 9.841(1)$, $b = 19.448(3)$, $c = 17.847(3) \text{ \AA}$, $V = 3415.7 \text{ \AA}^3$, $Z = 4$. The crystal structure was refined to final $R = 0.0363$ for 4614 observed independent $I > 2\sigma(I)$ reflections. The structure contains two different distorted octahedral sites, Fe1 (coordinated by 2 Cl atoms and 4 O atoms of the SO_4^{2-} groups) and Fe2 (coordinated by 3 Cl atoms and

3 O atoms of the SO_4^{2-} groups). Chains of four Fe^{2+} distorted octahedra sharing Cl vertexes with other vertexes bridged by three independent SO_4^{2-} tetrahedra make finite clusters, interacting each other only through the sulfate anions forming a three-dimensional framework with the voids occupied by 4 independent NH_4^+ ions (2 of them partially replaced by K^+), one $\text{Na}^+/\text{Pb}^{2+}$ site and one Cl^- ion. The name is from Acmonides (from the Greek Ακμωνίδης), one of Ovidius' Cyclops, helpers of Hephaistos, the mythological god of fire whose forge was alleged to be located at Vulcano. Holotype material is deposited in the Reference Collection of the Dipartimento di Chimica, Università degli Studi di Milano, Italy. **D.B.**

AMMONIOLASALITE*

A.R. Kampf, B.P. Nash, P.M. Adams, J. Marthy, and J.M. Hughes (2018) Ammoniolasalite, $[(\text{NH}_4)_2\text{Mg}_2(\text{H}_2\text{O})_{20}][\text{V}_{10}\text{O}_{28}]$, a new decavanadate species from the Burro Mine, Slick Rock District, Colorado. *Canadian Mineralogist*, 56(6), 859–869.

Ammoniolasalite (IMA 2017-094), ideally $[(\text{NH}_4)_2\text{Mg}_2(\text{H}_2\text{O})_{20}][\text{V}_{10}\text{O}_{28}]$, monoclinic, is a new decavanadate species discovered in the underground Burro mine, Slick Rock district, San Miguel County, Colorado, U.S.A. (38°2'42"N 108°53'23"W). The mine belongs to a 120 km long arcuate “Uraivan Mineral Belt” of bedded or roll-front deposits in sandstone of the Salt Wash member of the Jurassic Morrison Formation. The U and V primary ore mineralization was deposited in strongly reducing environment around accumulations of carbonaceous plant material. Ammoniolasalite along with other decavanadates $[\text{V}_{10}\text{O}_{28}]^{6-}$, protonated decavanadates, $[\text{H}_x\text{V}_{10}\text{O}_{28}]^{(6-x)-}$, mixed-valence decavanadates $[(\text{V}_x^{4+}\text{V}_{10-x}^{5+})\text{O}_{28}]^{(6-x)-}$ and uranium minerals resulted from the postmining oxidation of primary montroseite-corvusite assemblages at ambient temperatures. The ammonium derives from organic matter. The mineral forms crusts generally up to 2 mm thick on montroseite- and corvusite-rich sandstone with ammoniozippeite, and NH_4 -bearing decavanadates schindlerite and wernerbaurite. Bright orange to orange yellow ammoniolasalite crystals in the crusts exhibit parallel orientation. They are short prismatic by $[10\bar{1}]$ to equant, often with stepped or skeletal faces. The crystal forms are $\{001\}$, $\{110\}$, $\{10\bar{1}\}$, $\{111\}$, $\{11\bar{1}\}$, $\{201\}$, $\{31\bar{1}\}$. The mineral has a light orange streak and a vitreous luster. It mineral does not exhibit any fluorescence in UV radiation. Ammoniolasalite is brittle with conchoidal fracture and no cleavage. Mohs hardness is ~1; $D_{\text{meas}} = 2.28(2)$ and $D_{\text{calc}} = 2.278 \text{ g/cm}^3$ (2.271 for an ideal formula). At room temperature it is slowly soluble in water (minutes) and rapidly soluble in dilute HCl (seconds). Ammoniolasalite is pleochroic X (yellow) $< Y$ (yellow orange) $< Z$ (orange). It is optically biaxial (–), $\alpha = 1.740(3)$,

* 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/>.

$\beta = 1.769(3)$, $\gamma = 1.771(3)$ (white light), $2V = 31(1)^\circ$; $Y = \mathbf{b}$, $Z^*a = 38^\circ$ in β obtuse. Dispersion of an optical axes is very strong, $r > v$. FTIR spectrum is similar to that of lasalite with a broad strong multicomponent feature at $\sim 3700\text{--}300\text{ cm}^{-1}$ (O–H and N–H stretching), and strong peaks around 1700 cm^{-1} (H–O–H bending), around 1450 cm^{-1} (NH_4 deformation) and around 1000 cm^{-1} (VO stretching). The average of four points electron probe WDS analyses on three crystals [wt% (range)] is K_2O 0.95 (0.53–1.16), MgO 6.53 (6.36–6.79), V_2O_5 76.02 (75.12–76.84), $(\text{NH}_4)_2\text{O}$ 1.64 (1.34–1.75). Ammoniolasalite is very sensitive to dehydration and deammoniation in air and particularly during separating the crystals from matrix and under vacuum. The data obtained by CHN analysis shows $(\text{NH}_4)_2\text{O}$ 2.65, H_2O 19.76 wt%. The calculations based on structural study (considering the full occupancy of the NH_4/K site; $V = 10$ and $O = 48$ apfu) gave $(\text{NH}_4)_2\text{O}$ 3.26, and H_2O 25.70 wt%. The empirical formula based on 48 O, 10 V apfu, calculated values for $(\text{NH}_4)_2\text{O}$ and H_2O , and other elements normalized to provide a total of 100% (i.e. K_2O 0.81, MgO 5.56, V_2O_5 64.68) is $[(\text{NH}_4)_{1.76}\text{K}_{0.24}]_{\Sigma 2.00}\text{Mg}_{1.94}[\text{V}_{10}^{5+}\text{O}_{28}] \cdot 20\text{H}_2\text{O}$. The strongest lines in the diffraction pattern are [d Å (hkl)]: 10.64 (24; 200), 8.57 (21; $\bar{2}02$), 9.43(100; 110, $\bar{1}11$), 7.62 (26; 002, 111), 6.80 (32; 112, 311), 2.725 (23; 040, 621). Unit-cell parameters refined from the powder data with whole pattern fitting are $a = 24.471(9)$, $b = 10.935(9)$, $c = 17.456(9)$ Å, $\beta = 119.051(14)^\circ$, and $V = 4083$ Å³. The single-crystal XRD data shows ammoniolasalite is monoclinic, space group $C2/c$, $a = 24.478(3)$, $b = 10.9413(4)$, $c = 17.5508(12)$ Å, $\beta = 119.257(7)^\circ$, $V = 4100.9$ Å³, $Z = 4$. The structure was solved by direct methods and refined to $R_1 = 0.0357$ for 3628 $I > 2\sigma(I)$ independent reflections. Ammoniolasalite is isostructural with lasalite, $[\text{Na}_2\text{Mg}_2(\text{H}_2\text{O})_{20}][\text{V}_{10}\text{O}_{28}]$. Its atomic arrangement consists of structural unit $[\text{V}_{10}\text{O}_{28}]^{6-}$ decavanadate group and interstitial complex $[(\text{NH}_4)_x\text{K}_y(\text{H}_2\text{O})_{20}]^{6+}$. The Mg atoms bond to interstitial-unit H_2O groups and do not share any bonds with the decavanadate group or other polyhedra of the interstitial unit. The (NH_4/K) site links to four H_2O groups and three oxygen atoms of the decavanadate structural group. The occupancy of that site refined from the structure is $[(\text{NH}_4)_{1.30}\text{K}_{0.70}]_{\Sigma 2.00}$. The difference is assigned to a real variation in the relative amounts of NH_4 and K. The name reflects the chemical composition as NH_4 -dominant (over Na) analogue of lasalite. Five cotype specimens are deposited in the Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A. **D.B.**

BECKETTITE*, BURNETTITE*, PAQUEITE*

- C. Ma, J. Paque, and O. Tschauer (2016) Discovery of beckettite, $\text{Ca}_2\text{V}_6\text{Al}_6\text{O}_{20}$, a new alteration mineral in a V-rich Ca–Al-rich inclusion from Allende. 47th Lunar and Planetary Science Conference, session T335, 1704.
- C. Ma and J.R. Beckett (2016) Burnettite, CaVAISiO_6 , and paqueite, $\text{Ca}_3\text{TiSi}_2(\text{Al}_2\text{Ti})\text{O}_{14}$, two new minerals from Allende: clues to the evolution of a V-rich Ca–Al-rich inclusion. 47th Lunar and Planetary Science Conference, session T335, 1595.

Three new minerals: beckettite (IMA 2015-001), ideally $\text{Ca}_2\text{V}_6\text{Al}_6\text{O}_{20}$, triclinic, a member of aenigmatite group of the sapphirine supergroup; burnettite (IMA 2013-054), ideally CaVAISiO_6 , monoclinic, a member of pyroxene group; paqueite (IMA 2013-053), $\text{Ca}_3\text{TiSi}_2(\text{Al}_2\text{Ti})\text{O}_{14}$, trigonal, were discovered in a V-rich, fluffy Type A Ca–Al-rich inclusion (CAI) A-WP1 (0.6 × 1 mm) in Allende carbonaceous chondrite CV3. Phases of similar compositions were previously mentioned (Paque 1985, 1989) during the study of on the specimen USNM 7617 of the National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A. After completing the chemical and structural (EBSD) studies this specimen is considered as a holotype for all three new mineral species). Ti-rich phase similar to paqueite was characterized in CAIs from the CM2 Essebi chondrite (El Goresy et al. 1984). Burnettite and paqueite form micrometer-sized euhedral crystals within aluminous

melilite (Ak_9 and Ak_{11} , respectively) in A-WP1. Other primary phases in the CAI are spinel, perovskite, grossmanite-davissite, hibonite, and refractory metal grains. Beckettite occurs within highly altered areas of A-WP1 and forms aggregates of grains 48 μm in the central portions of alteration regions composed of fine-grained secondary corundum and grossular with anorthite, coulsonite, hercynite. Burnettite is supposed to be formed in reducing conditions from an ultra-refractory parent. Paqueite could be produced during late-stage dynamic crystallization or could be resulted of exsolution. Beckettite, probably formed in the parent body by the late-stage metasomatic reactions in which grossular, corundum, coulsonite, and hercynite, replace primary phases such as melilite, hibonite, spinel, perovskite, and burnettite. The mineral along with coulsonite might be a product of the destruction of what was a V-rich inclusion in melilite in that same spot. Alternatively, it could be resulted along with corundum from the breakdown of the primary hibonite in a hot V-rich fluid. Physical properties of new minerals were not determined due to a small size. The averages of five electron probe (mode is not specified) analyses for each of species [wt%, (standard deviation)] are: for beckettite, Na_2O 0.04 (0.01), CaO 13.58 (0.15), MgO 1.22 (0.03), FeO 0.35 (0.14), MnO 0.05 (0.06), Al_2O_3 44.14 (0.29), Sc_2O_3 0.7 (0.03), V_2O_5 31.6 (0.1), SiO_2 2.02 (0.03), TiO_2 5.54 (0.07), total 99.24, with corresponding empirical formula $(\text{Ca}_{1.99}\text{Na}_{0.01})_{\Sigma 2.00}(\text{V}_{3.47}^{3+}\text{Al}_{1.40}\text{Ti}_{0.57}^{4+}\text{Mg}_{0.25}\text{Sc}_{0.08}\text{Fe}_{0.04}\text{Mn}_{0.01})_{\Sigma 5.82}(\text{Al}_{5.72}\text{Si}_{0.28})_{\Sigma 6.00}\text{O}_{20}$ based on 20 O pfu; for burnettite / paqueite (deviations or ranges not given): Na_2O – / 0.62, CaO 24.83 / 29.58, MgO 1.51 / 0.18, Al_2O_3 23.36 / 15.21, V_2O_5 9.35 / 1.56, Sc_2O_3 6.89 / 0.84, SiO_2 25.69 / 24.43, TiO_2 8.49 / 27.51, total 100.12 / 99.93 with empirical formulae $\text{Ca}_{1.04}[(\text{V}_{3.29}^{3+}\text{Sc}_{0.24}\text{Ti}_{0.13}\text{Al}_{0.09})\text{Ti}_{0.13}^{4+}\text{Mg}_{0.08}]_{\Sigma 0.96}(\text{Si}_{1.01}\text{Al}_{0.99})_{\Sigma 2.00}\text{O}_6$ based on 4 cations (with $\text{Ti}^{4+} = \text{Ti}^{3+}$) apfu / $(\text{Ca}_{2.91}\text{Na}_{0.09})_{\Sigma 3.02}\text{Ti}^{4+}\text{Si}_2(\text{Al}_{1.64}\text{Ti}_{0.90}\text{Si}_{0.24}\text{V}_{0.12}^{3+}\text{Sc}_{0.07}\text{Mg}_{0.03})_{\Sigma 3.00}\text{O}_{14}$ based on 14 O pfu. The EBSD patterns of beckettite indexed with best fits obtained using the structure of rhönite. Beckettite is triclinic, space Group: $P\bar{1}$, $a = 10.367$, $b = 10.756$, $c = 8.895$ Å, $\alpha = 106.0^\circ$, $\beta = 96.0^\circ$, $\gamma = 124.7^\circ$, $V = 739.7$ Å³, $Z = 2$. The main lines of the calculated powder XRD pattern [d Å (hkl)] are: 2.684 (60; $\bar{2}41$), 2.683 (68; $\bar{2}03$), 2.544 (100; 420), 2.541 (81; 242), 2.540 (75; $\bar{2}13$), 2.104 (84; 251), 2.103 (84; $\bar{2}04$), 2.089 (89; $4\bar{1}1$) (Ma et al. 2015). Burnettite EBSD patterns can only be indexed by a $C2/c$ pyroxene structure. It is monoclinic, space group $C2/c$, $a = 9.80$, $b = 8.85$, $c = 5.36$ Å, $\beta = 105.62^\circ$, $Z = 4$. The main lines of the calculated powder XRD pattern [d Å (hkl)] are: 2.996 (100; $\bar{2}21$), 2.964 (33; 310), 2.909 (20), 2.581 (41; 002), 2.560 (29; $\bar{1}31$), 2.535 (47; 221), 2.131 (19; 331), 1.650 (17; 223) (Ma 2013). For paqueite the EBSD patterns were indexed and gave best fits using the $P321$ structure of synthetic high-pressure phase $\text{Ca}_3\text{TiSi}_2(\text{Al}_2\text{Ti})\text{O}_{14}$. Paqueite is trigonal, space group $P321$, $a = 7.943$, $c = 4.930$ Å, $Z = 1$. The main lines of the calculated powder XRD pattern [d Å (hkl)] are: 6.879 (20; 010), 3.093 (100; 111), 2.821 (68; 021), 2.600 (21; 120), 2.300 (43; 121), 1.908 (17; 130), 1.789 (28; 122) (Ma 2013). The names of the new minerals honors John R. Beckett, Donald S. Burnett, and Julie M. Paque, cosmochemists at the California Institute of Technology. **D.B.**

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ELASMOCHLOITE*

I.V. Pekov, S.N. Britvin, A.A. Agakhanov, M.F. Vígasina, and E.G. Sidorov (2019) Elasmochloite, $\text{Na}_3\text{Cu}_6\text{BiO}_4(\text{SO}_4)_5$, a new fumarolic mineral from the Tolbachik volcano, Kamchatka, Russia. *European Journal of Mineralogy*, 31(5-6), 1025–1032.

Elasmochloite (IMA 2018-015), ideally $\text{Na}_3\text{Cu}_6\text{BiO}_4(\text{SO}_4)_5$, monoclinic, was discovered in a single specimen collected in July 2013 at a depth of ~1 m in the central part of Arsenatnaya fumarole, the Second scoria cone of the Northern Breakthrough of the Great Tolbachik Fissure Eruption, Kamchatka. It is a new representative of a hydrogen-free alkaline-copper oxysulfates family deposited directly from hot gas at temperatures not lower than 350–400 °C. The new mineral is associating with tenorite, hematite, langbeinite, aphtitalite, krashennikovite, and johillerite. Elasmochloite forms lamellar quadratic or rectangular with cut vertices crystals up to $0.005 \times 0.07 \times 0.1$ mm flattened on [001], either separate or combined into open-work clusters up to 0.3 mm or interrupted crusts up to 1×1 mm on a surface of basalt scoria altered by fumarolic gas. Elasmochloite is green, transparent with a strong vitreous luster and a pale greenish streak. It is brittle with uneven fracture and no cleavage or parting observed. The Mohs hardness and density were not measured due to small crystal size and the open-work nature of aggregates; $D_{\text{calc}} = 3.844$ g/cm³. Elasmochloite is strongly pleochroic *O* (grass-green) > *E* (turquoise-blue), optically pseudo-uniaxial (–), $\alpha = 1.611(2)$, $\beta = \gamma = 1.698(2)$, $2V \approx 0^\circ$ (589 nm). The bands in the Raman spectrum (cm⁻¹; s – strong) are: 1283s, 1208, 1098 [$F_2(\nu_4)$ bending of SO_4^{2-}]; 1039, 1010s, 996s [$A_1(\nu_1)$ symmetric stretching of SO_4^{2-}]; 668, 627, 584 [$F_2(\nu_4)$ bending of SO_4^{2-}]; 503, 445 [$E(\nu_2)$ bending of SO_4^{2-}]; 268, 190s, and 124 (lattice modes). The features at 550–250 cm⁻¹ can also be assigned to $\text{Bi}^{3+}\text{–O}$ and $\text{Cu}^{2+}\text{–O}$ stretching vibrations. The absence of bands with frequencies higher than 1300 cm⁻¹ indicates the absence of groups with O–H, C–H, C–O, N–H, and N–O bonds. The averaged 7 point WDS electron probe analyses is [wt%, (range)]: Na₂O 6.67 (6.50–6.87), K₂O 0.82 (0.70–0.90), CuO 38.77 (38.37–39.34), ZnO 0.25 (0.00–1.06), PbO 3.17 (2.75–3.64), Bi₂O₃ 17.66 (17.17–18.84), SO₃ 32.81 (32.42–33.04), total 100.15. The empirical formula based on 24 O atoms pfu is $\text{Na}_{2.63}\text{K}_{0.21}\text{Cu}_{5.96}\text{Zn}_{0.04}\text{Bi}_{0.93}\text{S}_{5.01}\text{O}_{24}$. The strongest lines of the powder X-ray diffraction pattern are [d Å (hkl)]: 10.33 (100; 002), 7.04 (18; 110, 111), 6.33 (14; 111, 112), 3.576 (24; 221), 2.920 (14; 225), 2.529 (14; 402, 040), 2.460 (14; 227). The single-crystal XRD data shows elasmochloite is monoclinic (pseudo-tetragonal), $P2_1/n$, $a = 10.1273(9)$, $b = 10.1193(8)$, $c = 21.1120(16)$ Å, $\beta = 102.272(8)^\circ$, $V = 2114.1$ Å³, $Z = 4$. The crystal structure solved by dual space method and refined to $R_1 = 20.6\%$ is considered only as a model. Despite high R_1 value, the reliable values of thermal displacement parameters and interatomic distances, good values of bond-valence sums, good agreement between measured and calculated powder XRD patterns, zero charge balance in the structural formula and its agreement with electron microprobe data, confirm that the crystal structure model is correct. It is a novel structure, and contains two types of alternating polyhedral layers: (1) “copper-bismuth slabs” composed by $[\text{BiO}_4]$ polyhedra, $[\text{CuO}_5]$ square pyramids and $[\text{CuO}_4]$ squares and (2) “sodium slabs” consisting of $[\text{NaO}_3]$ and $[\text{NaO}_6]$ polyhedra. All cationic polyhedral and linked by corner-sharing $[\text{SO}_4]$ tetrahedra. Elasmochloite has some common structural features with nabokoite $\text{KCu}_7\text{Te}^{4+}\text{O}_4(\text{SO}_4)_5\text{Cl}$ and favreauite $\text{PbCu}_6\text{BiO}_4(\text{Se}^{4+}\text{O}_4)_4(\text{OH})\cdot\text{H}_2\text{O}$. The name is based on the Greek words $\epsilon\lambda\alpha\sigma\mu\alpha$, meaning lamella, and $\chi\lambda\omicron\eta$, meaning the green shoot or green grass, thus alluding to elasmochloite’s green color and lamellar crystal habit. The type specimen is deposited in the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **Yu.U.**

GRAMMATIKOPOULOSITE* AND TSIKOURASITE*

L. Bindi, F. Zaccarini, E. Ifandi, B. Tsikouras, C. Stanley, G. Garuti, and D. Mauro (2020) Grammatikopoulosite, NiVP, a new phosphide from

the chromitite of the Othrys ophiolite, Greece. *Minerals*, 10(2), 131. F. Zaccarini, L. Bindi, E. Ifandi, T. Grammatikopoulos, C. Stanley, G. Garuti, and D. Mauro (2019) Tsikourasite, $\text{Mo}_3\text{Ni}_2\text{P}_{1+x}$ ($x < 0.25$), a new phosphide from the chromitite of the Othrys ophiolite, Greece. *Minerals*, 9(4), 248.

Two new phosphides: grammatikopoulosite (IMA 2019-090), NiVP, orthorhombic, and tsikourasite (IMA 2018-156), $\text{Mo}_3\text{Ni}_2\text{P}_{1+x}$ ($x < 0.25$), cubic, were discovered in a heavy mineral concentrate separated from podiform chromitite hosted in strongly serpentinized dunite from a mantle tectonite composed of harzburgite and minor intercalations of plagioclase-bearing lherzolite. The main chromitite constituent is magnesiochromite. The interstitial assemblage is pervasively replaced by chlorite and hydrogrossular and minor talc and serpentine. Locally, hydrogarnet fills veins up to 50 µm thick crosscutting magnesiochromite. These veins are presumably associated with the rodingitized gabbro cross-cutting chromitites. Rare titanite, *kammererite*, pentlandite, and millerite also occur in the hydrogarnet veins. The genetic models of phosphide precipitation are discussed. The concentrate obtained by processing (crushing, treating with heavy liquid, panning, etc.) of ~10 kg of massive chromitite collected in the abandoned mine of Agios Stefanos ~10 km south of Domokos village, Mesozoic Othrys ophiolite complex, central Greece. The heavy minerals were prepared in epoxy blocks. No source of contamination is likely during sampling and subsequent treatments. In the polished sections grammatikopoulosite and tsikourasite occur as generally isolated grains less than 10 µm rarely up to ~80 µm. In poly-phase grains they associated with each other and nickelphosphide, awaruite and potential new minerals (under study) such as Ni-allabogdanite or Ni-barringerite and V-sulfide. Other minerals in polished sections include PGM:Ru–Os–Ir–Ni alloys, laurite, erlichmanite, Pd–Sb–Cu alloys, Pd–Cu–Pt alloys, irarsite, platarsite, hollingworthite, merenskyite, and cooperite-braggite. Both new minerals have metallic luster, are opaque and brittle. Density and hardness were not measured due to small size. Other properties and characteristics are as follows:

Grammatikopoulosite in reflected light is creamy-yellow, weakly birefractant, with measurable but not discernible pleochroism and slight anisotropy with indeterminate rotation tints. Internal reflections were not observed. Reflectance values in air (R_p/R_s % λ nm) are (**COM** wavelengths are bolded): 47.6/48.8 400, 47.9/49.1 420, 48.3/49.4 440, 48.6/49.9 460, **48.8/50.3 470**, 49.0/50.7 480, 49.4/51.5 500, 49.9/52.4 520, 50.3/53.3 540, **50.5/53.5 546**, 50.9/54.1 560, 51.4/54.9 580, **51.7/55.2 589**, 51.9/55.5 600, 52.4/56.2 620, 53.0/56.8 640, **53.2/57.1 650**, 53.8/58.0 680, 54.2/58.6 700. The average of five spot electron probe WDS analyses [wt% (range)] is: Ni 21.81 (21.69–21.98), Co 16.46 (16.33–16.66), Fe 3.83 (3.78–3.86), V 20.85 (20.48–21.05), Mo 16.39 (16.20–16.72), Si 0.14 (0.13–0.16), P 19.90 (19.65–20.38), S 0.41 (0.39–0.42), total 99.79. The empirical formula based on ΣMetals = 2 apfu, and considering structural results is $M_1(\text{Ni}_{10.57}\text{Co}_{0.32}\text{Fe}_{0.11})_{\Sigma 11.00}M_2(\text{V}_{0.63}\text{Mo}_{0.26}\text{Co}_{0.11})_{\Sigma 1.00}(\text{P}_{0.98}\text{S}_{0.02})_{\Sigma 1.00}$. The strongest X-ray powder diffraction lines are [d Å (hkl)]: 4.43 (10; 101), 2.950 (20; 102), 2.785 (25; 111), 2.273 (60; 112), 2.157 (100; 211), 2.118 (25; 103), 1.784 (20; 020). The unit-cell parameters refined from the powder data are $a = 5.8088(2)$, $b = 3.5993(2)$, $c = 6.8221(3)$ Å, $V = 142.63$ Å³. The single-crystal XRD data shows grammatikopoulosite is orthorhombic, space group $Pnma$, $a = 5.8893(8)$, $b = 3.5723(4)$, $c = 6.8146(9)$ Å, $V = 143.37$ Å³, $Z = 4$; $D_{\text{calc}} = 7.085$ g/cm³. The structure was refined (starting from the atomic coordinates of allabogdanite FeNiP) to $R_1 = 0.0276$ for 465 $F_o > 4\sigma(F_o)$ reflections. Grammatikopoulosite belongs to the group of natural phosphides (floremskyite FeTiP, allabogdanite (Fe,Ni)₂P, and andreyivanovite FeCrP) with the Co_2Si structure. In the structure M_1 links four P atoms and eight M_2 , whereas M_2 links five P, six M_1 , and two M_2 . The M –P distances are much shorter in the M_1 coordination sphere than in that of M_2 . If only the M –P distances are considered in the coordination polyhedra of the M atoms, M_1P_4 tetrahedra forming

corner-sharing chains along the **b**-axis or $M2P_5$ square pyramids forming zigzag chains along the **a**-axis can be observed. The mineral name honors Tassos Grammatikopoulos (b. 1966), geoscientist at the SGS Canada Inc., for his contribution to the economic mineralogy and mineral deposits of Greece. Holotype material is deposited in the Museo di Storia Naturale, Università di Pisa, Italy.

Tsikourasite in reflected light is white yellow with no birefractance, anisotropism or pleochroism. Internal reflections were not observed. Reflectance values in air ($R\% \lambda$ nm) are (**COM** wavelengths are bolded): 54.6 400, 54.9 420, 55.2 440, 55.5 460, **55.7 470**, 55.8 480, 56.1 500, 56.4 520, 56.7 540, **56.8 546**, 57.0 560, 57.3 580, **57.5 589**, 57.6 600, 58.0 620, 58.3 640, **58.5 650**, 58.6 660, 58.9 680, 59.2 700. The average of five spot electron probe WDS analyses [wt% (range)] is: Ni 23.9 (23.77–24.16), Co 7.59 (7.53–7.72), Fe 1.18 (1.14–1.20), V 14.13 (13.98–14.19), Mo 44.16 (43.56–44.65), P 7.97 (7.59–8.20), S 0.67 (0.64–0.71), total 99.60. The empirical formula based on Σ Metals = 5 apfu and considering the structural data is $(\text{Mo}_{1.78}\text{V}_{1.07}\text{Fe}_{0.08}\text{Co}_{0.07})_{\Sigma 3.00}(\text{Ni}_{1.57}\text{Co}_{0.43})_{\Sigma 2.00}(\text{P}_{0.98}\text{S}_{0.08})_{\Sigma 1.06}$. The powder XRD data was not obtained. The strongest lines of the calculated X-ray powder diffraction pattern are [d_{calc} Å ($I_{\text{calc}}\%$; hkl)]: 2.705 (13; 400), 2.483 (12; 331), 2.209 (42; 422), 2.083 (65; 422), 2.083 (35; 511), 1.913 (21; 440), 1.275 (14; 660), 1.275 (17; 822). The single-crystal study shows tsikourasite is cubic, space group $F\bar{4}3m$, $a = 10.8215(5)$ Å, $Z = 16$; $D_{\text{calc}} = 9.182$ g/cm³. The crystal structure was refined (starting from the atom coordinates of the $\text{Mo}_3\text{Ni}_2\text{P}_{1.16}$ compound synthesized at 1350 °C) to $R_1 = 0.0188$ for 216 $I > 2\sigma(I)$ reflections. The tsikourasite structure shows numerous metal–metal bonds (Ni–Ni, Mo–Ni, and Mo–Mo) in contrast to Mo–P and Ni–P bonds. The metal atoms are connected to only two or three P atoms, whereas 12 or 6 metal atoms surround the $P1$ and $P2$ sites, respectively. In the structure Mo atoms are arranged as $[\text{PMo}_6]$ -octahedra in a diamond-like network. Half of the octahedra, which are built by $\text{Mo}2$ atoms, are empty, while the second half formed by $\text{Mo}1$ atoms are occupied by $P2$, which shows partial occupancy (20%). These occupied octahedra are displayed in an fcc array. Unlike tsikourasite, similar in composition, monipite MoNiP , polekhovskiyite MoNiP_2 , and synthetic MoNiP_2 are hexagonal. Tsikourasite could represent the Mo equivalent of the grains of composition (Ni,Fe)₃P recently found in chromitites of the Alapaevsk (Russia) and Gerakini-Ormylia (Greece) ophiolites (Sideridis et al. 2018). The mineral honors Basilios Tsikouras (b. 1965) of the Universiti Brunei Darussalam for his contributions to the ore mineralogy and mineral deposits related to ophiolites. The type material is deposited in the Museo di Storia Naturale, Università di Firenze, Italy. **D.B.**

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HALAMISHITE*, MURASHKOITE*, NEGEVITE*, TRANSJORDANITE*, ZUKTAMRURITE*

S.N. Britvin, M. Murashko, Y. Vapnik, Y.S. Polekhovskiy, S.V. Krivovichev, O.S. Vereshchagin, V.V. Shilovskikh, N.S. Vlasenko, and M.G. Krzhizhanovskaya (2020) Halamishite, Ni_3P_4 , a new terrestrial phosphide in the Ni–P system. *Physics and Chemistry of Minerals*, 47, 3.

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S.N. Britvin, M. Murashko, Y. Vapnik, Y.S. Polekhovskiy, S.V. Krivovichev, O.S. Vereshchagin, N.S. Vlasenko, V.V. Shilovskikh, and A.N. Zaitsev (2019) Zuktamrurite, FeP_2 , a new mineral, the phosphide analogue of löllingite, FeAs_2 . *Physics and Chemistry of Minerals*, 46, 361–369.

Five new natural, terrestrial phosphides: halamishite (IMA 2013-105), Ni_3P_4 , hexagonal; murashkoite (IMA 2012-071), FeP , orthorhombic; negevite (IMA 2013-104) NiP_2 , cubic; transjordanite (IMA 2013-106), Ni_2P , hexagonal; and zuktamrurite (IMA 2013-107), orthorhombic were discovered in pyrometamorphic assemblages of the Hatrurim Formation (“Mottled Zone”). This is the world’s largest, geologically juvenile suite of pyrometamorphic rocks exposed across 150×200 km territory in the surroundings of the Dead Sea, in Israel, Palestinian Authority, and Jordan. The chalky-marly sediments of the Hatrurim formation underwent extensive and repetitive high-temperature (500–1350 °C) and low-pressure (~1 bar) metamorphism ~2.3–4 Ma. Two most popular hypothesis are explaining high temperature and (in a number of cases) strongly reducing environment as a result of burning bituminous rich sedimentary units or a result of a firing of hydrocarbons (mostly methane) from mud volcano explosions initiated by tectonic activity at the Dead Sea transform fault. Phosphides were usually considered as having meteoritic origin. Finding a bunch of new terrestrial phosphides along with previously found in the rocks of Hatrurim formation schreibersite, Fe_3P , and barringerite, Fe_2P , shows a wide variability of the M/P ratios making it substantially distinct from meteoritic minerals. Phosphide associations of the “Mottled Zone” are Earth’s richest example of the parageneses bearing siderophile rather than lithophile phosphorus. Two phosphide-bearing locations were found on both sides of the Dead Sea (Levantine) Transform Fault at Nahal Halamish (Halamish wadi), southern part of the Hatrurim Basin, Negev Desert, Israel (31° 09′ 47″ N; 35° 17′ 57″ E) and in phosphorite quarry at the Daba-Siwaqa complex, Transjordan Plateau, Al-Rasas Sub-District, 80 km SSE of Amman, Jordan (31° 21′ 52″ N; 36° 10′ 55″ E). The distance between location ~100 km. At the Halamish wadi phosphides are disseminated in fine-grained in hydrothermally altered micro-breccia consisting on colorless almost pure diopside (~50–60 vol%). Other associated minerals are merrillite, Cu-trevorite, hematite, magnetite, pyrrhotite, troilite, hydrous X-ray amorphous silicates and hydroxides of Ca, Mg, Fe, Ni, Ca-carbonates and sulfates. The interstices are filled with secondary calcite, fluorapatite, smectites and unidentified hydrous Ca–Fe–Ni–Mg phosphates. Halamishite (grains up to 20 μm) and negevite (grains up to 15 μm) are closely associated with zuktamrurite (grains ~10 μm, rarely up to 50 μm, sometimes hosting lamellae of molybdenite), transjordanite (irregular grains up to 0.2 mm), murashkoite (grains 10–200 μm, rarely up to 2 mm often intergrown with barringerite), and unnamed nickel phosphide–sulfide. Murashkoite also forms dendritic aggregates in the matrix of hydrous silicates. In Daba-Siwaqa complex same phosphide association (besides halamishite) found disseminated in centimeter-sized veins of medium-grained clinopyroxene (diopside-hedenbergite)–anorthite paravas of gabbro-dolerite compositions cross-cutting heterogeneous calcined marble conglomerates. Subordinate minerals of paravas are gehlenite, tridymite, cristobalite with accessory magnetite, troilite, pyrrhotite, hematite, merrillite, and fluorapatite. This primary association partially substituted by a late, low-temperature carbonates, silicates, and sulfates. Transjordanite was also found in iron ungrouped meteorite Cambria found in 1818 nearby Lockport, Niagara County, New York, U.S.A., where recrystallized microgranular (10–20 μm) troilite nicked with fragments of finely brecciated schreibersite frequently encrusted with 5–10 μm thick, onion-like rims composed of sub-microcrystalline

transjordanite-barringerite aggregate with the grain size less than 0.5 μm .

Halamishite is dark gray, transjordanite is grayish-white or gray and murashkoite is yellowish-gray. In reflected light they are white with a beige tint. Macroscopical colors are not given for zuktamurite and negevite due to its small size but in reflected light both are white with bluish tint more distinctive for transjordanite. All five new phosphides have metallic luster, are non-pleochroic, brittle (its grains are usually fractured) with no evidence of cleavage. The density values were not measured. Micro-indentation hardness data were obtained for murashkoite ($\text{VHN}_{20} = 468 \text{ kg/mm}^2$, corresponding to ~ 5 of Mohs scale) and for transjordanite (658 kg/mm^2). Other characteristics are as follows:

Halamishite, is moderately anisotropic and bireflectant ($\Delta R_{589} = 7.2\%$). The reflectance values [$R_{\text{max}}/R_{\text{min}}\%$ λ nm] **COM** wavelengths are bolded: 40.3/34.5 400; 41.5/35.2 420; 42.5/36.3 440; 43.7/37.3 460; **44.3/36.6 470**; 44.8/35.8 480; 46.2/39.6 500; 47.7/40.7 520; 48.9/41.9 540; **49.2/42.1 546**; 50.0/42.7 560; 50.9/43.7 580; **51.3/44.1 589**; 51.7/44.5 600; 52.4/45.3 620; 53.0/45.8 640; **53.3/46.1, 650**; 53.6/46.5 660; 54.2/46.9 680; 55.0/47.5 700. The average of three electron probe EDS analyses of the holotype (wt%): Ni 69.23, Fe 1.80, P 29.59, total 100.62 (ranges or deviations are not given). The empirical formula based on 9 atoms pfu is $(\text{Ni}_{4.90}\text{Fe}_{0.13})_{5.03}\text{P}_{3.97}$. $D_{\text{calc}} = 6.249 \text{ g/cm}^3$. Powder XRD data was not obtained. The strongest lines in the calculated XRD powder pattern [d_{calc} \AA ($I_{\text{calc}}\%$; hkl)] are: 3.121 (45; 103), 2.953 (56; 200), 2.498 (57; 104), 2.069 (57; 212), 2.015 (88; 204), 1.938 (69; 301), 1.908 (77; 213), 1.735 (100; 214), 1.705 (58; 220). The single-crystal XRD data obtained on a grain of $0.01 \times 0.01 \times 0.01 \text{ mm}$ shows halamishite is hexagonal, space group $P6_3mc$, $a = 6.8184(4)$, $c = 11.0288(8) \text{ \AA}$, $V = 444.04 \text{ \AA}^3$, $Z = 4$. The crystal structure was solved and refined to $R_1 = 0.031$ based on 425 unique observed [$I \geq 2\sigma(I)$] reflections. It contains eight unique Ni and P sites. A distinguished feature of halamishite structure is a short P–P bond (2.196 \AA) “P–P dumbbell” similar to S–S dumbbells in sulfide structure. The synthetic Ni_3P_4 , analogue of halamishite is widely used in electro- and photocatalytic applications. Due to chemical proximity to the Ni_3P_4 , end-member, halamishite can be used as a geothermometer indicating that formation of phosphide assemblages had occurred at a temperature below 870 $^\circ\text{C}$. The mineral was named for its type locality, the Halamish wadi. The holotype is deposited at the Mineralogical Museum of the Department of Mineralogy, St. Petersburg State University, St. Petersburg, Russia.

Murashkoite is weakly bireflectant ($\Delta R(589 \text{ nm}) = 1.2\%$) and distinctly anisotropic with rotation tints from yellow-gray to grayish blue. The reflectance values [$R_{\text{max}}/R_{\text{min}}\%$ λ nm] interpolated **COM** wavelengths are bolded: 42.7/40.8 400; 41.9/40.0 420; 41.5/39.8 440; 41.6/39.9 460; **41.65/40.0 470**; 41.7/40.1 480; 42.0/40.6 500; 42.2/40.7 520; 42.7/41.5 540; **42.9/41.7 546**; 43.3/42.1 560; 43.9/42.7 580; **44.2/43.0 589**; 44.5/43.4 600; 45.2/44.3 620; 45.9/45.2 640; **46.3/45.6, 650**; 46.6/46.0 660; 47.2/46.9 680; 48.0/47.7 700. The ranges for representative chemical compositions (electron probe, EDS) selected from over 100 analysis (wt%) are: Fe 51.63–64.34, Ni 0–13.25, P 34.84–36.49 (Co below 0.05%). The average of unspecified number of holotype analyses is (wt%) Fe 63.82, Ni 0.88, P 35.56, total 100.26; with corresponding empirical formula based on 2 apfu: $(\text{Fe}_{0.99}\text{Ni}_{0.01})_{1.00}\text{P}_{1.00}$. $D_{\text{calc}} = 6.108 \text{ g/cm}^3$. The strongest lines of the powder XRD pattern [d \AA ($I\%$; hkl)] are: 2.831 (75; 011,002), 2.548 (22; 200), 2.477 (46; 102,111), 1.975 (47; 112), 1.895 (100; 202,211), 1.779 (19; 103), 1.632 (45; 013,301,020). The unit-cell parameters refined from the powder data are $a = 5.098(5)$, $b = 3.251(1)$, $c = 5.699(3) \text{ \AA}$, $V = 94.5 \text{ \AA}^3$. The single-crystal XRD data obtained on a crystal of $0.05 \times 0.06 \times 0.12 \text{ mm}$ shows murashkoite is orthorhombic, space group $Pnma$, $a = 5.099(2)$, $b = 3.251(2)$, $c = 5.695(2) \text{ \AA}$, $V = 94.41 \text{ \AA}^3$, $Z = 4$. The crystal structure was solved and refined to $R_1 = 0.0305$ for 131 unique [$I > 2\sigma(I)$] reflections. Murashkoite crystallizes in the MnP structure type, which is an orthorhombically distorted homeotype of the hexagonal aristotype structure of nickeline, NiAs. The crystal structure of murashkoite is based upon layers of Fe and P

atoms alternating along the **a** axis. The layer of Fe atoms is a distorted planar 3^6 net consisting of chains of Fe–Fe atoms extended along the **b** axis. The layer of P atoms is a non-planar 3^6 net with no P–P contacts shorter than 3 \AA . The coordination of Fe is a distorted FeP_6 octahedron complemented by four additional Fe–Fe bonds. The P site is in distorted trigonal prismatic coordination by six Fe atoms complemented by two P–P. Murashkoite is the phosphide analogue of westerveldite, FeAs, and belongs to the modderite group being an only phosphide there. Murashkoite is a natural counterpart of synthetic FeP, the compound widely used in heterogeneous catalysis and electrocatalysis. The mineral name honors Mikhail Nikolaevich Murashko (b. 1952), for his contributions to the mineralogy of the Hatrum Formation. The holotype specimen is deposited in the Museum of the Mining Institute (Technical University), St. Petersburg, Russia.

Negevite is isotropic with no internal reflections. The reflectance values with bolded **COM** wavelengths [$R\%$, λ nm] are: 53.6 400, 53.9 420, 54.3 440, 54.5 460, **54.6 470**, 54.6 480, 54.8 500, 54.9 520, 55.0 540, **55.0 546**, 55.1 560, 55.2 580, **55.3 589**, 55.3 600, 55.4 620, 55.5 640, **55.6 650**, 55.7 660, 55.6 680, 55.8 700. The ranges for selected representative chemical compositions (electron probe, WDS) (wt%) are: Fe 2.876.41, Ni 37.77–42.57, Co 2.92–3.40, Ag 0–1.01, P 39.51–42.93, S 8.33–12.78, Se 0–0.24. The average of unspecified number of holotype analyses is (wt%) Fe 2.87, Ni 42.57, Co 3.40, P 42.93, S 8.33, total 100.10; with corresponding empirical formula based on 3 apfu: $(\text{Ni}_{0.88}\text{Co}_{0.07}\text{Fe}_{0.06})_{\Sigma 1.01}(\text{P}_{1.68}\text{S}_{0.31})_{\Sigma 1.99}$. $D_{\text{calc}} = 4.881 \text{ g/cm}^3$. Negevite is insoluble in cool 10% HCl. Powder XRD data was not obtained. The strongest lines in the calculated XRD powder pattern [d_{calc} \AA ($I_{\text{calc}}\%$; hkl)] are: 3.165 (54; 111), 2.741 (95; 002), 2.451 (42; 012), 2.238 (35; 112), 1.938 (54; 022), 1.653 (100; 113), 1.582 (17; 222), 1.465 (17; 123). Single-crystal XRD data obtained on a grain $\sim 10 \mu\text{m}$ shows negevite is cubic, space group $P\bar{a}3$, $a = 5.4816(5) \text{ \AA}$, $V = 164.71(3) \text{ \AA}^3$, $Z = 4$. The crystal structure was solved by direct methods and refined to $R_1 = 1.73\%$ for 52 observed independent [$I > 2\sigma(I)$] reflections. Negevite is the first natural phosphide of the pyrite structure type. It is a structural analog of vaesite (NiS_2), krutovite (NiAs_2), and penroseite (NiSe_2). The synthetic counterpart of negevite has well-explored catalytic and photocatalytic properties. Negevite is named for its type locality in the Negev Desert, Israel. The holotype is deposited in the Mineralogical Museum of the St. Petersburg State University, Russia.

Transjordanite is weakly bireflectant ($\Delta R(589 \text{ nm}) = 1.8\%$) and weakly anisotropic. The reflectance values [$R_{\text{max}}/R_{\text{min}}\%$ λ nm], **COM** wavelengths are bolded: 41.0/40.2 400; 42.2/41.1 420; 43.2/42.4 440; 44.5/43.5 460; **45.1/44.2 470**; 45.7/44.8 480; 47.1/46.1 500; 48.3/47.3 520; 49.6/48.3 540; **49.9/48.5 546**; 50.7/49.1 560; 51.6/49.9 580; **52.1/50.3 589**; 52.6/50.8 600; 53.4/51.4 620; 54.0/51.9 640; **54.3/52.1 650**; 54.5/52.3 660; 55.0/52.6 680; 55.5/53.0 700. A complete series of natural solid solutions exists between transjordanite (Ni_2P) and barringerite (Fe_2P) end-members. Variations of other elements (wt%) are: P 20.39–21.72, Co 0–3.09, Mo 0–3.09, and S up to 0.27 (in Cambria meteorite). The averages of unspecified numbers of electron probe WDS analysis of transjordanite from holotype / *Cambria meteorite* (wt%) are: Ni 67.80 / 60.55, Fe 10.20 / 18.16, Co 0 / 0.26, P 21.50 / 20.53, S 0 / 0.27, total 99.50 / 99.77. Corresponding empirical formulae based on 3 apfu are $(\text{Ni}_{1.72}\text{Fe}_{0.27})_{\Sigma 1.99}\text{P}_{1.02} / (\text{Ni}_{1.52}\text{Fe}_{0.48}\text{Co}_{0.01})_{\Sigma 2.01}(\text{P}_{0.98}\text{S}_{0.01})_{\Sigma 0.99}$. $D_{\text{calc}} = 7.297(5) \text{ g/cm}^3$. The strongest lines of the powder XRD pattern [d \AA ($I\%$; hkl)] are: 2.211 (100; 111), 2.028 (42; 201), 1.926 (37; 210), 1.697 (21; 300), 1.676 (18; 002), 1.672 (18; 211), 1.264 (15; 212), 1.192 (15; 302), 1.104 (20; 321). Single-crystal study on a grain $0.08 \times 0.06 \times 0.05 \text{ mm}$ shows transjordanite is hexagonal, space group $P6_2m$; unit-cell parameters for the holotype are: $a = 5.8897(3)$, $c = 3.3547(2) \text{ \AA}$, $V = 100.78 \text{ \AA}^3$, $Z = 3$. The crystal structure was solved and refined to $R_1 = 0.013$ for 190 observed independent [$I > 2\sigma(I)$] reflections. It consists of two types of infinite rods propagated along the **c** axis. The first rod is composed of corner-sharing $M(1)\text{P}_4$ tetrahedra alternating with the empty square pyramids $\square\text{P}_5$. The

next rod is built up of edge-sharing $M(2)P_5$ square pyramids alternating with the empty tetrahedra $\square P_4$. The rods are arranged into a framework via common P–P edges of adjacent metal-phosphorus polyhedra. The mineral was named for the type locality on the Transjordan Plateau in West Jordan. The holotype is deposited at the Mineralogical Museum of the St. Petersburg State University, Russia.

Zuktamurrite is weakly birefractant $\Delta R(589 \text{ nm}) = 2.8\%$ and distinctly anisotropic with bluish rotation tints. The reflectance values ($R_{\text{max}}/R_{\text{min}}\% \lambda \text{ nm}$), interpolated COM wavelengths are bolded: 52.5/49.8 400; 51.8/48.9 420; 51.2/48.2 440; 50.6/47.5 460; **50.4/47.2 470**; 50.2/46.9 480; 49.8/46.7 500; 49.5/46.4 520; 49.2/46.3 540; **49.16/46.23 546**; 49.0/46.2 560; 49.0/46.2 580; **48.97/46.16 589**; 49.0/46.2 600; 49.1/46.2 620; 49.3/46.3 640; **49.40/46.40 650**; 49.5/46.5 660; 49.8/46.7 680; 50.0/47.0 700. The ranges for 20 selected representative electron probe EDS analyses (wt%) are: Fe 37.37–46.76, Ni 1.37–9.84, Co 00.69, P 47.50–53.74, S 0–4.52. The average of five-point analyses of holotype is (wt%) Fe 40.23, Ni 7.97, P 51.70, total 99.90; with corresponding empirical formulae based on 3 apfu: $(\text{Fe}_{0.86}\text{Ni}_{0.16})_{1.02}\text{P}_{1.98}\cdot D_{\text{calc}} = 5.003 \text{ g/cm}^3$. The strongest lines of the powder XRD pattern [$d \text{ \AA}$ (%; hkl)] are: 3.714 (54; 110), 2.820 (31; 020), 2.451 (100; 120,101), 2.259 (25; 210), 2.242 (55; 111); 1.760 (37; 211), 1.579 (23; 310), 1.564 (26; 031). The unit-cell parameters refined from the powder data are $a = 4.927(5)$, $b = 5.645(1)$, $c = 2.815(3) \text{ \AA}$, $V = 78.3 \text{ \AA}^3$. The single-crystal XRD data obtained on a crystal of $0.01 \times 0.01 \times 0.01 \text{ mm}$ shows zuktamurrite is orthorhombic, space group $Pnmm$, $a = 4.9276(6)$, $b = 5.6460(7)$, $c = 2.8174(4) \text{ \AA}$, $V = 78.38 \text{ \AA}^3$, $Z = 2$. The crystal structure was solved by direct methods and refined to $R_1 = 0.0121$ based on 109 unique $I > 2\sigma(I)$ reflections. Zuktamurrite is the phosphide analogue of löllingite FeAs_2 . Distorted octahedra MP_6 ($M = \text{Fe, Ni}$) are arranged sharing common edges into infinite chains propagated along the c axis. The length of the c axis corresponds to the shortest M – M distance. Octahedra belonging to adjacent chains are connected via shared corners forming a three-dimensional framework. The characteristic feature of zuktamurrite structure is the occurrence of P–P bonds like the S–S in the marcasite. The P–P dumbbell in zuktamurrite plays the role of the anion and its structural formula can be written as $\text{Fe}^{2+}[\text{P}_2]^{2-}$. Zuktamurrite is the most phosphorus-rich phosphide found in nature so far. The mineral is named for the Zuk-Tamur cliff (Dead Sea) located nearby the type locality (Halamish Wadi). The holotype specimen is deposited in the Mineralogical Museum of Saint-Petersburg State University, St. Petersburg, Russia. **D.B.**

KAMENEVITE*

I.V. Pekov, N.V. Zubkova, V.O. Yapaskurt, D.I. Belakovskiy, I.S. Lykova, S.N. Britvin, A.G. Turchkova, and D.Y. Pushcharovky (2019) Kamenevite, $\text{K}_2\text{TiSi}_3\text{O}_9\cdot\text{H}_2\text{O}$, a new mineral with microporous titanosilicate framework from the Khibiny alkaline complex, Kola peninsula, Russia. *European Journal of Mineralogy*, 31(3), 557–564.

Kamenevite (IMA 2017-021), ideally $\text{K}_2\text{TiSi}_3\text{O}_9\cdot\text{H}_2\text{O}$, orthorhombic, was discovered in K-rich peralkaline pegmatites related to rissorhrites associated with apatite-nepheline rocks at two deposits: Oleniy Ruchey (Reindeer Stream) underground mine, Mt. Suoluav and Rasvumchorr mine, Mt. Rasvumchorr, Khibiny complex, Kola Peninsula, Russia. The holotype specimen originates from the pegmatite which was found in several lumps in the dump of Oleniy Ruchey apatite deposit. The pegmatite is mainly composed of potassic feldspar, nepheline, sodalite, aegirine, arfvedsonite series amphibole, lamprophyllite, lomonosovite, eudialyte with and the accessory shcherbakovite, sphalerite, galena, and molybdenite. Pockets with hydrothermal minerals (pectolite, villiaumite, ershovite, shaf-ranovskite) found in some part of the pegmatite enriched in green acicular aegirine. Minor minerals are umbite, sidorenkite, djerfisherite, rasvumite, and Na-bearing neotocite. Kamenevite replaces lomonosovite and fills cracks in crystals of slightly etched lomonosovite. It forms coarse lamellar

crystals up to $0.02 \times 0.1 \times 0.3 \text{ mm}$. Crystals are combined in aggregates up to 0.7 mm. Individual crystals are rectangular or irregular and flattened on [010]. Pinacoid {010} is the major crystal form, lateral faces are probably pinacoids {100} and {001}. Kamenevite from a dump material mined at the level +470 m of Rasvumchorr underground apatite mine was found later in a similar assemblage in a pegmatite mainly consisting of potassic feldspar, nepheline, sodalite, Na–Mg–Fe³⁺-enriched hedenbergite, aegirine, potassic-arfvedsonite, lamprophyllite, eudialyte, and lomonosovite; with subordinate and accessory annite, fluorapatite, shcherbakovite, lobanovite, sphalerite, galena, and molybdenite. Sporadically the pegmatite contains abundant and unusually diverse (especially in part of potassium-rich silicates and sulfides) hydrothermal mineralization forming lenticular or irregular nests up to 20 cm. These nests are formed of pectolite, natrolite, villiaumite, lovozerite-group minerals, shaf-ranovskite, zakharovite, ershovite (and highly hydrated products of its alteration), paraershovite, tinaksite, phosinaite-(Ce), umbite, tiettaite, lithosite, barytolamprophyllite, chkalovite, loparite, nacaphite, natrophosphate, K-rich vishnevite, cryptophyllite, shlykovite, mountaimite, fluorapophyllite-(K), neotocite, cobaltite, jersfisherite, chlorbartonite, and rasvumite. At the Rasvumchorr mine, kamenevite occurs as equant or flattened grains up to 0.15 mm across, or as cavernous and granular accumulations up to $0.1 \times 0.4 \text{ mm}$ embedded in aggregates of different hydrous silicates. Kamenevite is closely associated with shaf-ranovskite, altered ershovite and lovozerite. The new mineral is transparent, colorless in individual grains and white in aggregates. It has a white streak and vitreous lustre. Kamenevite is brittle with stepped fracture and good cleavage on {010}. The Mohs hardness is ca. 4; $D_{\text{meas}} = 2.69(2)$ and $D_{\text{calc}} = 2.698 \text{ g/cm}^3$ (both for the holotype). In plane-polarized transmitted light kamenevite is colorless, non-pleochroic. It is optically biaxial (–), $\alpha = 1.650(4)$, $\beta = 1.678(5)$, $\gamma = 1.685(5)$ (589 nm), $2V_{\text{meas}} = 60(10)^\circ$, $2V_{\text{calc}} = 52^\circ$; $Y = b$. Dispersion of optical axes was not observed. The average of 4 WDS analyses on the holotype [wt% (range)] is: Na_2O 0.48 (0.21–0.69), K_2O 24.37 (24.11–24.53), CaO 0.13 (0.10–0.16), Fe_2O_3 0.35 (0.13–0.52), SiO_2 48.78 (47.19–50.29), TiO_2 20.30 (19.75–20.66), ZrO_2 0.89 (0.41–1.83), Nb_2O_5 0.35 (00.63), H_2O 4.85 (by structure refinement based on 1 H_2O pfu), total 100.50. The empirical formula based on 10 O atoms pfu is $(\text{K}_{1.92}\text{Na}_{0.06}\text{Ca}_{0.01})_{\Sigma 1.99}(\text{Ti}_{0.94}\text{Zr}_{0.05}\text{Fe}_{0.02}\text{Nb}_{0.01})_{\Sigma 1.00}\text{S}_{3.01}\text{O}_9\cdot\text{H}_2\text{O}$. The strongest lines in the powder X-ray diffraction pattern are [$d \text{ \AA}$ (%; hkl)]: 7.92 (70; 110), 6.51 (47; 020), 5.823 (95; 101), 2.988 (84; 301,122), 2.954 (100; 041,320), 2.906 (68; 311,202), 2.834 (69; 141,212). The crystal structure of kamenevite was solved by direct methods and refined to $R_1 = 3.84\%$. The new mineral is orthorhombic, $P2_12_1$, $a = 9.9166(4)$, $b = 12.9561(5)$, $c = 7.1374(3) \text{ \AA}$, $V = 917.02(6) \text{ \AA}^3$, $Z = 4$. The crystal structure of kamenevite is based on a microporous heteropolyhedral framework built by $[\text{Si}_3\text{O}_9]^{6-}$ wollastonite-type chains linked by isolated Ti-centred octahedra. The K^+ cations and H_2O groups are located in wide and narrower [001] channels. Kamenevite is isostructural with umbite, $\text{K}_2\text{ZrSi}_3\text{O}_9\cdot\text{H}_2\text{O}$. The synthetic analogue of kamenevite known as titanosilicate *AM-2*, $\text{K}_2\text{TiSi}_3\text{O}_9\cdot\text{H}_2\text{O}$, which displays strong zeolitic properties. The mineral is named after the outstanding Russian geologist Evgeniy Arsenievich Kamenev (1934–2017) for his great contribution to the geological study and exploration of the Khibiny complex apatite deposits. The type specimen is deposited in the collections of the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia. **Yu.U.**

RUSOITE*

I. Campostrini, F. Demartin, and M. Scavini (2019) Russoite, $\text{NH}_4\text{ClAs}_3^+\text{O}_3(\text{H}_2\text{O})_{0.5}$, a new phylloarsenite mineral from Solfatara Di Pozzuoli, Napoli, Italy. *Mineralogical Magazine*, 83(1), 89–94.

Russoite (IMA 2015-105), $\text{NH}_4\text{ClAs}_3^+\text{O}_3(\text{H}_2\text{O})_{0.5}$, hexagonal, is a new mineral found in the volcanic fumarole “Bocca Grande” at Solfatara di Pozzuoli, near the town of Pozzuoli, Campi Flegrei area, Napoli, Italy. The fumarole has temperature $\sim 160^\circ \text{C}$. Russoite is closely associated

with alacránite, dimorphite, realgar, mascagnite, salammoniac, and an amorphous arsenic sulfide. Other minerals found in the same fumarole are adranosite, adranosite-(Fe), efremovite, huizingite-(Al), and godovikovite. Russoite forms rosette-like intergrowths or subparallel aggregates of hexagonal plates flattened on {001} and bounded by {100} up to $\sim 300 \times 15 \mu\text{m}$. The aggregates are sometimes yellowish due to admixed amorphous arsenic sulfide. Crystals are colorless to white, transparent to translucent, with vitreous luster, white streak and no apparent twinning. No fluorescence in UV radiation was observed. Russoite is brittle with perfect cleavage on {001} and irregular fracture. Mohs hardness was not determined; $D_{\text{meas}} = 2.89(1)$, $D_{\text{calc}} = 2.911 \text{ g/cm}^3$. The mineral is optically uniaxial (-), $\omega = 1.810(6)$ and $\epsilon = 1.650(5)$ (white light). FTIR spectrum shows bands at (cm^{-1}): 3254, 3145, 1403 (ammonium); 3454, 3398, 1625 (H_2O); 670, 604 (arsenite bands); ~ 2400 weak (atmospheric CO_2); 1110 (minor OH⁻, partially replacing the chloride ion). The average of six electron probe EDS analyses (performed under 20 kV excitation voltage, 10 pA beam current and 2 μm beam diameter to minimize the damage and deammonation under the beam) on a crystals flat surfaces [wt% (range)] is: K_2O 1.05 (0.65–1.22), As_2O_3 74.16 (73.25–75.80), Cl 11.96 (11.73–12.94), Br 0.44 (0.25–0.80), $[(\text{NH}_4)_2\text{O}$ 9.04 and H_2O 3.35 – by stoichiometry]; sum 100.00, $-\text{O}=\text{Cl}$, Br 2.75, total 97.25. No amounts of other elements above 0.1 wt% were detected. The empirical formula based on 4.5 anions pfu and $\text{K} + \text{NH}_4 = 1$ atom pfu is $[(\text{NH}_4)_{0.94}\text{K}_{0.06}\text{Cl}_{1.00}(\text{Cl}_{0.91}\text{Br}_{0.01})_{20.92}\text{As}_{2.02}\text{O}_3(\text{H}_2\text{O})_{0.5}]$. The strongest X-ray powder diffraction lines are [d Å (%; hkl): 12.63 (19; 001), 6.32 (100; 002), 4.547 (75; 100), 4.218(47; 003), 3.094 (45; 103), 2.627 (46; 110), 2.428 (31; 112), 1.820 (28; 115)]. The unit-cell parameters refined from powder XRD data are $a = 5.259(2)$, $c = 12.590(5)$ Å, $V = 301.55 \text{ \AA}^3$. Single-crystal XRD data shows russoite is hexagonal, space group $P622$, $a = 5.2411(7)$, $c = 12.5948(25)$ Å, $V = 299.6 \text{ \AA}^3$, $Z = 2$. The crystal structure was refined to $R = 0.0518$ for 311 reflections with $I > 2\sigma(I)$ using as starting model a russoite synthetic analogue (Edstrand and Blomqvist 1955). The refinement revealed a different location of the ammonium cation and H_2O groups compare to that reported for the synthetic phase. As for other minerals of phylloarsenite family (lucabindiite, torrecillasite, and gajardoite), the crystal structure of russoite contains electrically neutral As_2O_3 sheets formed by As^{3+}O_3 pyramids that share O atoms to form six-membered rings. These sheets are topologically identical to those found in lucabindiite and gajardoite. Ammonium cations are located between the sheets and the halide anions are outside of them. Additional ammonium cations and H_2O are in a layer between two levels of chloride anions interacting with each other via hydrogen bonds. The name russoite honors Massimo Russo (b. 1960), researcher at Osservatorio Vesuviano, Istituto Nazionale di Geofisica e Vulcanologia, Napoli, for his contributions to the mineralogy of Italian volcanoes. Holotype material is deposited in the Reference Collection of the DCSSI, Università degli Studi di Milano, Italy. **D.B.**

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SBACCHIITE*

I. Campostrini, F. Demartin, and M. Russo (2019) Sbacchiite, Ca_2AlF_7 , a new fumarolic mineral from the Vesuvius volcano, Napoli, Italy. *European Journal of Mineralogy*, 31(1), 153–158.

Sbacchiite (IMA 2017-097), Ca_2AlF_7 , orthorhombic, is a new mineral discovered in a fossil fumarole “cotunnite pit” (active since eruption in 1944) at the eastern rim of the crater of Vesuvius volcano, Napoli, Italy ($40^\circ 49' 21.98'' \text{ N}$; $14^\circ 25' 43.66'' \text{ E}$). The temperature in the fumarole have reached a maximum of $\sim 800^\circ \text{C}$ in 1950 and then was decreasing to $\sim 460^\circ \text{C}$ in 1960 and to $\sim 7080^\circ \text{C}$ currently. Sbacchiite occurs in small aggregates closely associating with gearsksutite, usovite, creedite, and opal. Other minerals discovered in the fumarole are artroite, ammineite,

fluornatrocoulsellite, and parascandolaite. The formation of sbacchiite took place between 1948 and 1960 or shortly thereafter being a high-temperature encrustation resulted from extracting aluminium and calcium from the rocks by HF activity. The mineral was found in only one specimen of $\sim 7 \text{ cm}$, later trimmed to a few. Sbacchiite crystals transparent or translucent, colorless, with vitreous luster and white streak. They have a very steep bipyramidal habit, are elongated by [100], and truncated by {100} pinakoid. The mineral is brittle with no distinct cleavage and no apparent twinning. Mohs hardness was not determined; $D_{\text{meas}} = 3.08(2)$, $D_{\text{calc}} = 3.116 \text{ g/cm}^3$. Sbacchiite is optically biaxial (+), $\alpha = 1.379(4)$, $\beta = 1.384(4)$, $\gamma = 1.390(4)$ (white light), $2V_{\text{meas}} = 83(2)$, $2V_{\text{calc}} = 85.1$. The average of six electron probe EDS analyses (performed under 20 kV excitation voltage, 10 pA beam current, and 2 μm beam diameter to minimize the damage and deammonation under the beam) on unpolished flat surface [wt% (range)] is: Ca 33.41 (32.98–34.57), Mg 0.26 (0.17–0.30), Al 10.97 (10.78–11.14), F 54.67 (54.06–55.22), total 99.31. The empirical formula based on 10 apfu is $\text{Ca}_{2.02}\text{Mg}_{0.03}\text{Al}_{0.95}\text{F}_{6.97}$. The strongest X-ray powder diffraction lines are [d Å (%; hkl): 3.840 (45; 200), 3.563 (85; 201), 3.499 (100; 020), 2.899 (55; 013), 2.750 (30; 212), 2.281 (20; 104), 2.255 (52; 302), 2.173 (36; 131)]. The unit-cell parameters refined from powder data are $a = 7.674(1)$, $b = 6.996(1)$, $c = 9.553(1)$ Å, $V = 512.9 \text{ \AA}^3$. Single-crystal XRD data obtained on a crystal fragment of $0.05 \times 0.01 \times 0.01 \text{ mm}$ shows sbacchiite is orthorhombic, space group $Pnma$, $a = 7.665(2)$, $b = 6.993(1)$, $c = 9.566(2)$ Å, $V = 512.2 \text{ \AA}^3$, $Z = 4$. The crystal structure was solved starting from the atomic positions of synthetic Ca_2AlF_7 (Domsele and Hoppe 1980) and refined to $R = 0.0479$ for 457 observed $I > 2\sigma(I)$ reflections. It represents a framework of “isolated” $[\text{AlF}_6]$ octahedra, $[\text{Ca}(1)\text{F}_7]$ distorted pentagonal bipyramids and $[\text{Ca}(2)\text{F}_{7+1}]$ distorted polyhedra. Ca(1) and Ca(2) polyhedra are linked by common edges alternating along [010] and along [001]. Along [100], only the Ca(1) pentagonal bipyramids are connected by bridging corners. anions. One end of $[\text{AlF}_6]$ octahedra is shared with the adjacent Ca(2) polyhedron and, on the opposite face, an edge and a corner are shared with two adjacent Ca(1) polyhedra. All fluorine atoms in five F sites are threefold coordinated. The sbacchiite structure has some common features with those of carlhintzeite $\text{Ca}_2\text{AlF}_7 \cdot \text{H}_2\text{O}$ (where “isolated” $[\text{AlF}_6]$ octahedra have also been observed but in different environment) and jakobssonite, CaAlF_5 (containing instead vertex-sharing chains of $[\text{AlF}_6]$ octahedra, interconnected by chains of $[\text{CaF}_7]$ pentagonal bipyramids). The name honors Massimo Sbacchi (b. 1958), biologist and mineral collector, for his long-time field collaboration and continuous supply of interesting material for study. A holotype specimen is deposited at the Dipartimento di Chimica, Università degli Studi di Milano, Italy. Cotype is in the Museum of Osservatorio Vesuviano (Ercolano, Napoli), Italy. **D.B.**

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NEW DATA

OYELITE

I.V. Pekov, N.V. Zubkova, N.V. Chukanov, V.O. Yapakurt, S.N. Britvin, A.V. Kasatkin, and D.Y. Pushcharovky (2019) Oyelite: new mineralogical data, crystal structure model and refined formula $\text{Ca}_5\text{BSi}_4\text{O}_{13}(\text{OH})_3 \cdot 4\text{H}_2\text{O}$. *European Journal of Mineralogy*, 31(3), 595–608.

The new data on chemistry, IR spectroscopy and a unique, novel structure type refinement for an “old” mineral oyelite were obtained on the specimen from its new location at Bazhenovskoe asbestos deposit, town of Asbest, Urals, Russia. Published data on that mineral were revisited. The new ideal formula is $\text{Ca}_5\text{BSi}_4\text{O}_{13}(\text{OH})_3 \cdot 4\text{H}_2\text{O}$. The mineral is triclinic, $P\bar{1}$, $a = 7.2557(5)$, $b = 10.7390(11)$, $c = 11.2399(8)$ Å, $\alpha =$

89.432(7), $\beta = 89.198(6)$, $\gamma = 72.097(8)^\circ$, $V = 833.30 \text{ \AA}^3$, $Z = 2$. The mineral was first reported (Heller and Taylor 1956) from the Crestmore quarries, Riverside County, California, U.S.A., as “the 10 Å hydrate” related to tobermorite. Considered relation to tobermorite was based on incomplete (no B was detected) semi-quantitative chemical data and some similarity of powder XRD patterns with refined parameters of orthorhombic unit cell: $a = 11.2$, $b = 7.32$, $c = 20.5 \text{ \AA}$. As it appeared later (Murdoch 1961) the mineral from Crestmore contains several percent of B_2O_3 . In 1980, “10 Å tobermorite” was described from the Fuka Mine, Fuka, Bitchu-cho, Okayama Prefecture, Japan (Kusachi et al. 1980). Next, the mineral was submitted and approved by IMA as a new mineral oyelite (IMA 1980-103) presumably belonging to the tobermorite group (Kusachi et al. 1981). The description was based on specimens from the Fuka Mine (holotype) and from Crestmore. The simplified formula was suggested as $\text{Ca}_{10}\text{Si}_8\text{B}_2\text{O}_{29} \cdot n\text{H}_2\text{O}$ ($n = 9.5\text{--}12.5$) with orthorhombic unit-cell dimensions $a = 11.25$, $b = 7.25$, $c = 20.46 \text{ \AA}$. In 1986 oyelite was reported from Suisho-dani, Ise City, Mie Prefecture, Japan, and formula was adjusted to $\text{Ca}_{10}\text{Si}_8\text{B}_2\text{O}_{29} \cdot 12\text{H}_2\text{O}$. Next find in Kalahari Manganese Field, South Africa, in the N’Chwaning II mine (Von Bezing et al. 1991) produced spectacular oyelite specimens well-known and desirable for mineral collectors, however the quality of crystals did not allow the structural study. Raman spectroscopy and thermal studies were added, parameters of the orthorhombic or pseudo-orthorhombic sub-cell were given as $a' = 5.578(6)$, $b' = 3.596(4)$, $c' = 20.46(2) \text{ \AA}$, and the simplified formula was modified to $\text{Ca}_3\text{BSi}_4\text{O}_{14}(\text{OH}) \cdot 6\text{H}_2\text{O}$ (Biagioli et al. 2012). Oyelite is a hydrothermal mineral formed in late-stage assemblages related to various geological formations. At Crestmore and Fuka, the oyelite-bearing parageneses are related to classic calcic skarns, at Suisho-dani to rodingite embedded in serpentinite and at N’Chwaning to strata-bound manganese ores in metamorphosed volcanogenic-sedimentary rocks. At Bazhenovskoe deposit oyelite found in rodingite body at the Southern open pit. It is associated with tatarinovite, pectolite, xonotlite, and calcite in cavities in rodingite consisting of pale pinkish orange grossular with subordinate white to pale gray diopside. Oyelite forms elongated lamellar crystals up to $0.3 \times 4 \text{ mm}$, divergent and combined in fan-shaped aggregates or radial rosettes up to 8 mm in diameter and their clusters up to $7 \times 12 \text{ mm}$. Single crystals of oyelite are colorless, and aggregates are pearly-white. The chemical composition of oyelite crystal used for single-crystal study determined by electron probe WDS analysis is [wt%]: CaO 42.29, B_2O_3 5.38, SiO_2 36.65, H_2O 15.07 [by structure and based on $(\text{OH})_3(\text{H}_2\text{O})_4$ pfu], total 99.39. The empirical formula is $\text{Ca}_{4.96}\text{B}_{1.02}\text{Si}_{4.01}\text{O}_{13}(\text{OH})_3 \cdot 4\text{H}_2\text{O}$. The bands in IR absorption spectra

of the oyelite are (cm^{-1}): 2200–3500 (O–H-stretching); including bands at 2885–2905 and 2233–2239 (acid OH groups forming strong and very strong hydrogen bonds, respectively); 1500–1800 (H–O–H bending); 1220–1270 and 850–1100 (B–O- and Si–O-stretching modes, respectively); 500–800 (mixed B–O–H, Si–O–H, O–Si–O and O–B–O bending modes); 400–500 (Si–O–Si stretching). The bands at 3969–3315 and 1350 cm^{-1} are assigned to BO–H and SiO \cdots H stretching vibrations, respectively. The difference between the IR spectra of oyelite from Bazhenovskoe and N’Chwaning and that of tobermorite is discussed. The strongest lines in the powder X-ray diffraction pattern are [$d \text{ \AA}$ ($I\%$; hkl)]: 10.22 (71; 010), 4.921 (29; 012, $\bar{0}\bar{1}2$), 3.409 (23; $\bar{1}2$, $\bar{2}\bar{1}1$, $\bar{1}21$, 030), 3.067 (24; 212), 3.031 (38; 023, $\bar{2}\bar{1}2$), 2.917 (100; $\bar{2}02$, 032, 222), 2.812 (42; $\bar{2}\bar{3}1$, 004). The crystal structure of oyelite was solved by direct methods and refined to $R_1 = 12.01\%$. It contains two different kinds of tetrahedral units of different topology, both linear and running along [100]. The first type (I) is the borosilicate chain $[\text{BSi}_2\text{O}_7(\text{OH})_2]^\infty$ consisting of disilicate groups Si_2O_7 connected via single $\text{BO}_2(\text{OH})_2$ tetrahedra. The second type (II) is the interrupted chain (“dotted line”) formed by $\text{Si}_2\text{O}_6(\text{OH})$ disilicate groups bonded to each other by very strong H-bonds. The tetrahedral units I and II are linked to (010) layers of sevenfold-coordinated Ca polyhedra of three different types: $\text{CaO}_6(\text{H}_2\text{O})$, $\text{CaO}_3(\text{H}_2\text{O})_4$, and CaO_6OH . The structural formula of oyelite is $\text{Ca}_3[\text{BSi}_2\text{O}_7(\text{OH})_2][\text{Si}_2\text{O}_6(\text{OH})] \cdot 4\text{H}_2\text{O}$. The structure can be considered as “the intermediate link” between inosilicates with wollastonite-type chains and sorosilicates with isolated disilicate groups. Oyelite is crystal-chemically close to vistepite, $\text{SnMn}_4\text{B}_2\text{Si}_4\text{O}_{16}(\text{OH})_2$, in part of the tetrahedral BSiO-chain, and also to some Ca-rich silicates, mostly of tobermorite-supergroup, in the structure of the layered motif built by Ca-centred polyhedra. **Yu.U.**

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