

New Mineral Names: Diamonds, Dumps, and Fumaroles

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IN THIS ISSUE

In this series of New Mineral Names, a thematic approach is used to help provide context for advances and discoveries in mineralogy. Planet Earth is ever-changing, and unique crystals are found in the tiniest of micro-geologic niches. With emerging analytical techniques, the formerly inaccessible becomes accessible. New minerals inspire creative approaches to overcoming chemical and technological challenges and can reveal what the Earth was like billions of years ago. In this issue, we look at recently described minerals that are associated with diamonds, dumps, and fumaroles: crowningshieldite, goldschmidtite, breyite, cardite, grimmite, hrabákite, freitalite, dioskourite, dobrovolskyite, ferrofremovite, and vasilseverginite.

CROWNSHIELDITE

Crowningshieldite (Smith et al. 2021), $(\text{Ni}_{0.90}\text{Fe}_{0.10})\text{S}$, was named in honor of the pioneering gemologist George Robert Crowningshield (1919–2006). His accomplishments were extensive (Moses and Shigley 2003), but most notable are his work on the color origin of yellow diamonds and the diamond grading system.

The mineral was found as inclusions in a type IIa diamond belonging to the CLIPPIR group (Cullinan-Like, Inclusion-Poor, Pure, Irregular, Resorbed) of super deep origin from the Letseng mine in Lesotho. The Letseng mine is a kimberlite deposit that erupted approximately 85 Ma. Crowningshieldite is the analog of a synthetic α -NiS and has the NiAs-type structure. The synthetic α -NiS is metastable and readily converts to millerite (β -NiS) below 379 °C (Sowa et al. 2004; Wang et al. 2006), and therefore the long-term preservation of this natural material is quite remarkable. The authors postulate two hypotheses for the stability of crowningshieldite. The first may be that the presence of Fe in the structure slows the transformation to β -NiS. The second may be that the residual confining pressure within the diamond provides a stable environment.

A potential application of crowningshieldite is use in high-capacity energy storage systems (Shombe et al. 2020). Currently, it is quite difficult to keep the alpha phase stable, but the geologic stability crowningshieldite may provide insight into ways of making the α -NiS material stable for the long term at ambient temperatures.

Crowningshieldite crystallizes in space group $P6_3/mmc$ with $a = 3.44(1)$ Å, $c = 5.36(1)$ Å, and has a calculated density of 5.47(1) g/cm³. The mineral was approved in 2018 (Commission on New Minerals, Nomenclature and Classification, IMA 2018-072), and the holotype was deposited at the Museum of Mineralogy of the University of Padova (MM 20501).

GOLDSCHMIDTITE

Goldschmidtite (Meyer et al. 2019), ideally $(\text{K,REE,Sr})(\text{Nb,Cr})\text{O}_3$, has been named in honor of eminent geologist Victor Moritz Goldschmidt (1888–1947). His contributions to geology essentially led to the creation of modern-day geochemistry. A mineral has not been named in his honor likely because of past iterations of the Goldschmidt name in minerals. Goldschmidtite was first used by in 1899 (Hobbs 1899) for a supposed silver-gold-telluride mineral to honor crystallographer Victor Mordechai Goldschmidt (later determined to be sylvanite). Then goldschmidtine was named to honor Victor Moritz Goldschmidt (Peacock 1939) for a silver antimonide, however, the next year Peacock showed that goldschmidtine was in fact stephanite.

The new goldschmidtite mineral was found as an inclusion in a diamond from the Kaapavaal craton in South Africa. From single-clinopyroxene geothermobarometry, the authors estimate that the pressure-temperature of formation was 53 kbar (≈ 105 miles or 175 km depth) and at a temperature of about 1190 °C. Goldschmidtite belongs to the perovskite group and is the fifth such perovskite found in the deep mantle (the four others being CaTiO₃-perovskite, CaSiO₃-perovskite, tausonite, and bridgemanite). A synthetic KNbO₃ perovskite exists as an important ferroelectric industrial material for use in lead-free piezoelectric ceramics and new photovoltaics.

Goldschmidtite crystallizes in space group $Pm\bar{3}m$ with $a = 3.9875(1)$ Å with a calculated density of 5.32(1) g/cm³. The mineral was approved in 2018 (IMA 2018-034) and the holotype is deposited at the Royal Ontario Museum (M58208).

BREYITE

The ring-silicate mineral breyite (Brenker et al. 2021), CaSiO₃, has been named in honor of Gerhard P. Brey, professor and high-pressure experimental petrologist at the Institute of Geosciences, Goethe University in Frankfurt, Germany.

The mineral was found as an inclusion in a diamond from the Sao Luiz placer deposits (Juina area, Mato Grosso State, Brazil). Based on previous works (see Brenker et al. 2021 for complete list), breyite is only found in super-deep diamonds ranging from 300–800 km. The mineral was shown to be isostructural with walstromite (Ca₂BaSi₃O₉) (Barkley et al. 2011), which is stable at ambient pressure and temperature, and Barkley et al. further state that wollastonite-II and wolstromite-CaSiO₃ are identical in structure with walstromite. The work of Brenkner et al. solved the structure breyite and showed it to be same as determined by Joswig et al. (2003) having the Si₃O₉ rings being topological different than those wollastonite-II. The stability of breyite was determined to be a result of residual pressure (around 3 GPa) in the diamond.

Breyite crystallizes in space group $P\bar{1}$ with $a = 6.6970(4)$ Å, $b = 9.2986(7)$ Å, $c = 6.6501(4)$ Å, $\alpha = 83.458(6)^\circ$, $\beta = 76.226(6)^\circ$, $\gamma = 69.581(7)^\circ$, and has a calculated density of 3.072 g/cm³. The mineral was approved in 2018 (IMA 2018-062) and the holotype is deposited at the Museum of Mineralogy of the University of Padova (MMP 20371).

CARDITE

Cardite (Elliott 2021), $[\text{Zn}_{3.5}(\text{AsO}_4)_2(\text{AsO}_4\text{OH})(\text{OH})_3 \cdot 3\text{H}_2\text{O}]$, named after George William Card (1865–1943) who was a petrologist and mineralogist with the Geological Survey of New South Wales and a Curator of the Mining Museum in Sydney. Card worked extensively on minerals from the Broken Hill Pb-Zn ore body.

The cardite holotype specimen was found on the mine dumps from the Block 14 Openpit, Broken Hill, New South Wales, Australia. Although cardite was found on the mine dumps, it is believed to have formed as a

* All minerals have been approved by the IMA CNMMC. For a complete listing of all IMA-validated unnamed minerals and their codes, see <http://cnmmc.main.jp/> (click on “IMA list of minerals”).

secondary mineralized product from a sulfide zone with leached sulfide minerals. The cardite specimen had grown on a coarse-grained, highly weathered sulfide ore from the Block 14 Opencut. The structure of cardite is built of brucite-like sheets, and the sheets are topologically identical to the atacamite, clinoatacamite, botallackite, claringbullite, and bobkingite.

Cardite crystallizes in space group $Cmcm$ with $a = 15.110(3)$ Å, $b = 15.492(3)$ Å, $c = 6.3850(13)$ Å with a calculated density of 4.02 g/cm³. The holotype specimen of cardite was approved by the CNMNC in 2015 (IMA 2015-125) and is deposited in the collection of the South Australian Museum (G34301).

GRIMMITE

Grimmite (Škácha et al. 2021), ideally NiCo₂S₄, is a new thiospinel mineral from the tailings of the Příbram ore area in central Bohemia, Czech Republic. The name is to honor Johann Grimme (1805–1874) who was a long-time miner and geologist in the area. Grimme had spent years modernizing and advancing mining equipment, and he also wrote books on geology and mining techniques. He later became Director of the Příbram Mining College, which was located in the modern-day Czech Republic. The college was closed during World War II, reopened briefly in 1945, and was soon moved to the Ostrava region (now Technical University of Ostrava).

The ore deposits of Příbram are a mineralogically diverse area, with over 200 minerals known from the extensively hydrothermally altered rocks. The main ore consists of base metals (but primarily mined for uranium), making it an important economic resource for the area. The presence of grimmite in these rocks is a geochemical indicator of base metal remobilization by hydrothermal fluids rich in reduced sulfur.

The NiCo₂S₄ was first described by Bouchard et al. (1965) as a synthetic material for superconductivity applications. Since then, numerous studies report on use of this material (and related doped materials) for Li-ion battery anodes as well as micro-supercapacitors for energy storage applications.

Grimmite crystallizes in space group $Fm\bar{3}m$ with $a = 9.3933(3)$ Å, and has a calculated density of 4.843 g/cm³. The mineral name was approved in 2020 (IMA 2020-060), and cotypes have been deposited (as two polished sections) in the Department of Mineralogy and Petrology of the National Museum Prague, Czech Republic (PIP 49/2020) and in the collection of the Mining Museum Příbram, Czech Republic (3/2020).

HRABÁKITE

Hrabákite (Sejkora et al. 2021), ideally Ni₉PbSbS₈, is named in honor after Josef Hrabák (1833–1921) born in Sirá, in the present Czech Republic. He studied at the Příbram Mining College (now the Technical University of Ostrava). Hrabák would eventually become a professor of the Příbram Mining College and wrote several articles and books on mining technology and the history and geology of mining in the Czech Republic.

One hand sample of hrabákite was found at the mine dump for shaft No. 9-Jerusalem near Příbram. This area was actively mined from about 1951 to 1991 to a depth of ≈600 m. The structure of hrabákite is similar to hauchecomite consisting of alternating layers of Ni atoms and S, Pb, and Sb atoms, parallel to (100), and is the first Pb-containing member of the hauchecomite group. Evidence presented in the paper suggests that hrabákite forms paragenetically late and likely formed during younger hydrothermal mineralization events.

Hrabákite crystallizes in space group $P4/mmm$ with $a = 7.3085(4)$ Å, $c = 5.3969(3)$ Å with a calculated density is 6.37 g/cm³. The mineral was approved by the CNMNC in 2020 (IMA 2020-034) and the cotype material (two polished sections) is deposited in the Mineralogical Collection of the Department of Mineralogy and Petrology of the National Museum, Prague, Czech Republic (PIP 30/2020) and in the mineralogical collection of the Mining Museum Příbram, Czech Republic (1/2020).

FREITALITE

Freitalite (Witzke et al. 2021), (C₁₀H₁₄), is a new aromatic hydrocarbon mineral from Paul Bernt Mine, Freital, Döhlen basin near Dresden, Ger-

many. Freitalite is isostructural with the chemical compound anthracene, which can be found in tobacco smoke, tars, and coal. Anthracene is commonly used to manufacture dyes, plastics, and a mixture of phenanthrene [ravatite IMA 1992-019 (Nasdala and Pekov 1993)], and anthracene is used to coat water storage tanks to prevent rust. There are many industrial applications of the synthetic forms of freitalite and related materials.

Around 1960, the Paul Bernt Mine dump spontaneously combusted and was on fire until it was extinguished in 2014. Freitalite was found in a fumarole on the Paul Bernt Mine dumps, about 5–40 cm below the surface, where it formed by the combustion process in a low oxygen fugacity environment and sublimated from the gas phase. Usually, the mineral was found crystallized on native sulfur. The anthracene compound is light sensitive and will undergo photodimerization when exposed to UV-light, however, photosensitivity of freitalite was not reported by the authors, so the crystalline state may help stabilize it from photo-induced changes.

Freitalite crystallizes as three conjoined benzene rings in the space group $P2_1/a$ with $a = 8.5572(9)$ Å, $b = 6.0220(5)$ Å, $c = 11.173(1)$ Å, $\beta = 124.174(1)^\circ$. The calculated density from single-crystal diffraction data 1.242 g/cm³ closely matches the measured density of 1.240 g/cm³. The co-types were approved by the CNMNC in 2019 (IMA 2019-116) and are deposited in the Mineralogical Collection of the TU Bergakademie, Freiberg, German (MiSa72396 and MiSa84590).

DIOSKOURITE

Dioskourite (Pekov et al. 2021b), ideally CaCu₄(OH)₄Cl₆·4H₂O, is named after the twin half-brothers Castor and Pollux, known together as the Dioskouri (or Dioscuri) because they were inseparable. The mineral dioskourite occurs as two co-localized polytypes, disokourite-2M (the monoclinic polytype) and disokourite-2O (the orthorhombic polytype), and they are indistinguishable and can occur interstratified. The mineral was found in an active fumarole from the Great Tolbachik Fissure Eruption 1975–1976, Tolbachik volcano, Kamchatka Peninsula, Russia. The crystals were situated in a basaltic vug altered by fumarolic gasses. The temperatures of the gasses measured during sample collection were between 100 and 120 °C.

The differences in the polytypes arise from layer stacking along the c-axis. The layers are identical in structure and composition, and the layer stacking offset is represented by the beta angle change between the orthorhombic and monoclinic polytypes. The authors postulate that the intergrowths of the two polytypes may be an indicator of the cyclic changes in temperatures of the fumarole gasses.

The authors point out that the structure of the Cu-oxide layers forms a kagomé net. Kagomé nets are 2D arrays of triangles and hexagons forming stars (visualize a repeating the Star of David pattern). These kagomé geometries are studied intensively because of the unique magnetic properties such structures can possess as a result of strong electron-electron interactions between the layers. Although the authors report no anomalous magnetic properties for dioskourite, they mentioned more work in this area needs to be performed. Other Cu minerals having kagomé geometry include atacamite, clinoatacamite, leningradite, chloroxiphite, and ilskite.

Dioskourite-2M crystallizes in space group $P2_1/c$ with $a = 7.2792(8)$ Å, $b = 10.3000(7)$ Å, $c = 20.758(2)$ Å, $\beta = 100.238(11)^\circ$, and has a calculated density of 2.820 g/cm³. Dioskourite-2O crystallizes in $P2_12_12_1$ with $a = 7.3193(7)$ Å, $b = 10.3710(10)$ Å, $c = 20.560(3)$ Å with a calculated density of 2.765 g/cm³. The type specimen of dioskourite was approved by the CNMNC in 2015 (IMA 2015-106), and is deposited in the systematic collection of the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia (95282).

DOBROVOLSKYITE

Dobrovolskyite (Shablinskii et al. 2021), ideally Na₄Ca(SO₄)₃, is named in honor of Vladimir Vitalievich Dolivo-Dobrovolsky (1927–2009) who was a prominent Russian mineralogist and petrologist and a professor at St. Petersburg Mining Institute.

The Tolbachik Fissure Eruption (1975–1976 and 2012–2013) has led to at least 18 type mineral species described from this area and likely contains even more. The latest, dobrovol'skiyite was found in the Second scoria cone on the Kamchatak Peninsula, Russia, in a fumarole that developed from the Great Tolbachik fissure (1975). Dobrovol'skiyite was found to have crystallized from the vapor-state on the fumarole vent substrate about 20 cm below the surface ($T \approx 200$ °C). The collected crystals were immediately wax sealed in a glass vial to minimize interaction with moisture.

The authors postulated that dobrovol'skiyite likely formed from higher temperature phase α - Na_2SO_4 , but in the presence of Ca-rich gasses. It is possible that dobrovol'skiyite is a quenched phase, analogous to metathénordite. In the metathénordite paper (Pekov et al. 2019), the authors stated that crystals with compositions near the end-member of Na_2SO_4 were unstable and lost transparency to become milky-white after several days to months after collection. Metathénordite that contained small amounts of divalent cations (Ca, Cu, Zn, Mg) (such as Co-type #1 ($\text{Na}_{1.54}\text{K}_{0.22}\text{Ca}_{0.09}\text{Cu}_{0.01}\text{Mg}_{0.01}$) [SO_4]) were stable under ambient conditions for years.

Dobrovol'skiyite crystallizes in space group $R\bar{3}$ with $a = 15.728(11)$ Å, $c = 22.004(22)$ Å, and has a calculated density 2.664 g/cm³. The type material was approved by the CNMNC in 2019 (IMA2019-106), and is stored in the Saint-Petersburg State University Mineralogical Museum, St. Petersburg, Russia (1/19829).

FERROEFREMOVITE

Ferroefremovite (Kasatkin et al. 2021), ideally $(\text{NH}_4)_2\text{Fe}_2(\text{SO}_4)_3$, is named after the Mg member efremovite. The name efremovite was used to honor the Soviet geologist, paleontologist, and science fiction writer Ivan Anntonovich Efremov (1907–1972).

Ferroefremovite was found in the “Bocca Grande” fumarole, Solfatara di Pozzuoli, Flegrean Volcanic Complex, Naples Province, Campania, Italy. Efremovite is also a fumarolic mineral found on burning-coal mine dumps in the Chelyabinsk coal basin, Southern Urals, Russia. Efremovite is hydroscopic and will convert to boussingaultite $[(\text{NH}_4)_2\text{Mg}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}]$. There is an Fe end-member of boussingaultite, mohrite $[(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}]$, which is also reported from coal burning dumps. The hydroscopic properties of ferroefremovite were not discussed.

Ferroefremovite crystallizes in space group $P2_13$ with $a = 10.0484(9)$ Å with a measured and calculated density of 2.69(1) and 2.700 g/cm³, respectively. The holotype specimen was approved by the CNMNC in 2019 (IMA 2019-008), and is deposited in the collections of the A.E. Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow, Russia (5368/1).

VASILSEVERGINITE

Vasilseverginite (Pekov et al. 2021a), ideally $\text{Cu}_6\text{O}_4(\text{AsO}_4)_2(\text{SO}_4)_2$, has been named in memory of the Russian mineralogist, geologist, and chemist, Vasilii Mikhailovich Severgin (1765–1826). He wrote the first books on geology and mineralogy in Russia and was one of the founders of the Russian Mineralogical Society in 1817.

Vasilseverginite is a new fumarolic mineral from the apex of the Second scoria cone from the Great Tolbachik Fissure Eruption. The cone itself was formed in 1975 and is approximately 300 m tall. Many fumaroles on this cone have had measured vent temperatures up to 490 °C. The type specimen of vasilseverginite was collected from a vent of ≈ 360 –380 °C at a depth of 1–1.5 m from the surface. The bright green vasilseverginite crystals likely grew from the vapor-state on the basaltic scoria.

An interesting aspect of vasilseverginite is that it contains polyoxocarbonate chains (analogous to popovite and dolerophanite), and these chains and clusters have may have interesting magnetic properties (Kondinski and Monakhov 2017). Even if they do not have novel magnetic properties, understanding their crystallization mechanisms in nature may help inform new synthesis strategies.

Vasilseverginite crystallizes in space group $P2_1/n$ with $a = 8.113(4)$ Å, $b = 9.918(2)$ Å, $c = 10.992(6)$ Å, $\beta = 110.90(4)^\circ$, and has a calculated

density of 4.409 g/cm³. The type specimen was approved by the CNMNC in 2015 (IMA 2015-083) and is deposited in the systematic collection of the Fersman Mineralogical Museum of the Russian Academy of Sciences, Moscow (95280).

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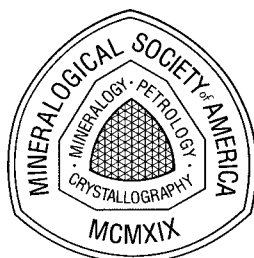
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1. Publication Title: **American Mineralogist (The)**

2. Publication Number: **0020-7601**

3. Filing Date: **10/1/2021**

4. Issue Frequency: **twelve issues/yr; six print issues/yr**

5. Number of Issues Published Annually: **six (print) issues**

6. Annual Subscription Price: **\$165.00**

7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and ZIP+4®):
**Mineralogical Society of America
 3635 Concorde Pkwy, Ste 500
 Chantilly, VA 20151-1110**

8. Complete Mailing Address of General Business Office of Publisher (Not printer):
**Mineralogical Society of America
 3635 Concorde Pkwy, Ste 500
 Chantilly, VA 20151-1110**

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor (Do not leave blank):
**Publisher (Name and complete mailing address):
 Mineralogical Society of America
 3635 Concorde Pkwy, Ste 500
 Chantilly, VA 20151-1110**
**Editor (Name and complete mailing address):
 Don Baker, Hengwu Xu, and Ian Swainson, Mineralogical Society of Am.
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Ann E. Benbow, Executive Director Date: **10/1/2021**

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