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State of the art and challenges in cave minerals studies

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Abstract. The present note is an updated inventory of all known cave minerals as March 2011. After including the new minerals described since the last edition of the *Cave Minerals of the World* book (1997) and made the necessary corrections to incorporate all discreditations, redefinitions, or revalidation proposed by the Commission on New Minerals, Nomenclatures and Classification (CNMNC) of the International Mineralogical Association (IMA), we summed up 319 cave minerals, many of these only known from caves. Some of the minerals building up speleothems are powerful tracers of changes in Quaternary climate, other minerals are useful for reconstructing landscape evolution, or allow discriminating between various speleogenetic pathways. Thus, it is expected that the search for new cave minerals will continue and even more attention will be given to those species that carries information that allow for addressing different problems in various earth sciences fields. In view of the exponential increase of cave minerals over the past 50 years, cave mineralogy conceivably has the potential to grow in the future, especially considering the new advances in analytical facilities.

Key words: Cave minerals, nomenclature, classification, database.

INTRODUCTION

Likewise other fields across earth sciences, mineralogy has witnessed over the last decade a rapid growth as a result of fast-paced and revolutionary advances of analytical facilities. For cave mineralogy this translates into an exponential increased of the number of minerals identified (Fig. 1) and described from a variety of cave environments (Onac, 2005, 2011).

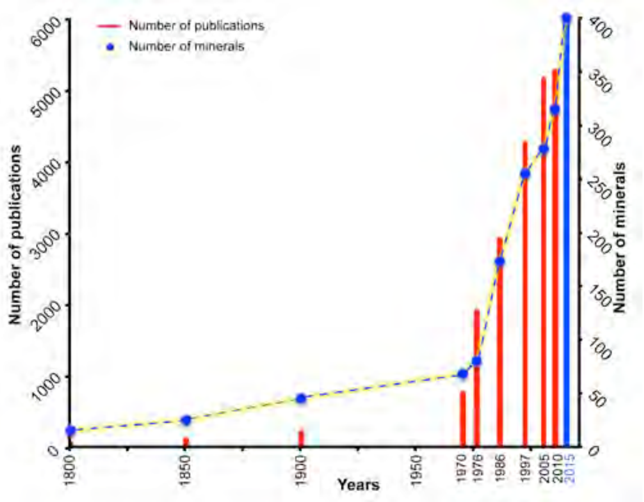

Fig. 1. *The evolution of cave mineral studies since 1800; number of minerals vs number of cave minerals-related publications.*

Below are some milestones in cave mineral studies since 1750 to present. Although short, non-scientific descriptions on mainly calcite and gypsum from caves are scattered throughout various publications prior to 1750, the beginning of cave mineralogy as a novel field of research dates back to the second part of the 18th century, when the first detailed presentation of calcite from Dâmbovicioara Cave (Romania) appeared in *Mineralogia Magni Principatus Tranylvaniae* treatise (Fridvaldszky, 1767). By the beginning of 1800, a total of ten cave minerals were described from Dâmbovicioara, Stufe di San Calogero, Alum, and Pulo di Molfetta caves in Romania and Italy (Forti, 2002; Onac and Forti, 2011). Detailed studies carried out at the end of the 19th century on some cave deposits from Mona Island, USA, and Australia, increased the number of cave minerals and related publications on this topic to about 50 and 250, respectively. Moore (1970), published a checklist of 68 cave minerals from around the world. The exponential trend seen in Fig. 1 has its origin, however, in the publication of *Cave Minerals* book (Hill, 1976). Although it includes only 80 minerals, primarily described from United States caves, the number of publications cited nearly topped 2000. Subsequently, Hill and Forti (1986, 1997) published two editions of the *Cave Minerals of the World* pushing the number of cave minerals to 173 and 255, respectively. About half of these minerals (*i.e.*, 86 and 125) were either ore-related or were precipitated in some very particular cave settings (sulfuric-acid caves, lava tubes, caves hosting large quantities of guano, gypsum caves, etc.). It was not only the

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number of cave minerals that increased, but also the number of publications dedicated to them, which exceeded 4000 titles in the 2nd edition of their book. At the threshold of the third millennium, almost 275 minerals had been described in over 5000 publications (Forti, 2002; Hill and Forti, 2007), and these numbers are going up every year (*e.g.*, Onac, 2005, 2011; Forti et al., 2006; Onac et al., 2007a, 2009a, 2011).

CHALLENGES IN CAVE MINERAL STUDIES

Although it is a major factor in cave mineral investigations, the nature of each sample and the available analytical resources aspect has not been often discussed within the cave science community. Yet the success of a detailed and accurate mineral description depends precisely on which investigation method is used and how well the sample was preserved since the time of collection, until it is ready to be analyzed. As a consequence of the analytical challenges posed, details of various cave mineralizations (*e.g.*, earthy crusts and powders) remain unknown. Even in the case of the growth of calcite or aragonite helictites and eccentrics, with studies spanning several decades focused on these issues — formation mechanisms remain ambiguous.

The main analytical challenges associated to cave mineral investigations are related to (i) the complexity of heterogeneous natural samples, which often contain multiple mineral phases, (ii) extreme sample environments, and (iii) the size and nature of some of the compounds. However, recent developments in a suite of techniques (*e.g.*, X-ray powder or single-crystal diffraction, X-ray fluorescence, inductively coupled plasma-mass spectrometry, electron microprobe, scanning electron microscopy, stable isotopes, etc.) give mineralogists unprecedented opportunities to advance the understanding of caves as minoregenic environments. The results of cave minerals studies, when integrating stable isotope analyses with other micro-analytical techniques, can be reassembled to test and improve conceptual ideas in mineral precipitation and to quantify the geochemical processes associated with it.

ABOUT THIS NEW CAVE MINERALS LIST

Because mineral nomenclature has suffered a number of revisions (Nickel and Grice, 1998; Burke, 2006, 2008; Mills et al., 2009; Nickel and Nichols, 2009; Pasero et al., 2010) and new cave minerals were reported since 1997 (Rodgers et al., 2000; De Waele and Forti, 2005; Forti, 2005; Forti et al., 2003, 2006, 2007, 2009; Onac & White, 2003; Onac and Effenberger, 2007; Onac et al., 2002, 2005, 2006, 2009a, b), a compilation of all cave minerals became essential for the cave science community, but not only. The present list incorporates all grandfathered species and species that have been redefined, renamed, or revalidated as proposed by the IMA-CNMNC (Nickel and Nichols, 2009). Also included, but written in *italics* are names used to designate a group of species (series) and species that were discredited or not approved by the CNMNC. Names of mineral species reported since the last edition of the book *Cave Minerals of the World* (CMW2; Hill and Forti, 1997) are in bold face.

The format of mineral presentation follows the class scheme presented in the book *Dana's New Mineralogy* (Gaines et al., 1997), in which each mineral is in alphabetic order, followed but its chemical formula, and the cave type locality of the mineral. The crystal system was included only for polymorphs (e.g., calcite, aragonite, vaterite, etc.) and abbreviations are as follow: monoclinic (mon.), triclinic (tric.), orthorhombic (orth.), tetragonal (tetr.), trigonal (trig.), hexagonal (hex.), and cubic (cub.). To understand the stoichiometry of mineral formulae the charge for altervalent elements is also shown. A vacancy in a structural position is denoted by the □ symbol. With very few exceptions, all mineral formulas included in our compiled list are identical to those reported by Nickel and Nichols (2009). These exceptions were dictated by changes that occurred after the IMA-CNMNC list of minerals was released (e.g., Pasero et al., 2010).

Of the more than 5500 references describing these minerals, over 4000 are listed in Hill and Forti (1997). To keep the length of this note within reasonable limits, we choose to include a selective reference list that contains the major contributions in which the new 63 minerals were reported since 1997. A Commission of Cave Minerals was established in 1997 within the International Union of Speleology with the main purpose of keeping track of all minerals described from caves, including lava tubes and caves intersected by mines.

The official cave mineral database of this commission it is assembled now (work is in progress) and can be accessed at https://www.lib.usf.edu/caveminerals/ca/.

Native elements

Bismuth – Bi; Oilloki Mine Cave, France (Audra, 2007)
Sulfur – S; Turia Cave, Romania
Gold – Au; Valea Rea Cave, Romania (Ghergari et al., 1997)

Sulfides

Chalcocite – Cu_2S; Tyuya-Muyun, Kyrgyzstan
Chalcopyrite – $CuFeS_2$; Magian & Marguzor caves, Tajikistan
Cinnabar – HgS (trig.); Magian & Marguzor caves, Tajikistan
Galena – PbS; Dalnegorskaya Cave, Russia
Marcasite – FeS_2 (orth.) – Dachstein-Mammuthöhle, Austria
Metacinnabar – HgS (cub.); Fata Morgana caves, Turkmenistan
Orpiment – As_2S_3; Aghia Paraskevi caves, Greece (Lazarides et al., 2011)
Pyrite – FeS_2 (cub.); Lauback Cave, TX, USA
Pyrrhotite – $Fe_{1-x}S$ ($x < 0.17$) (mon.); Dalnegorskaya Cave, Russia

Realgar – AsS; Chauvai, Kyrgyzstan
Sphalerite – ZnS (cub.); Trzebionka mine caves, Poland
Stibnite – Sb_2S_3; Alay Ridge caves, Kyrgyzstan

Oxides & Hydroxides

Akaganeite – $(Fe^{3+},Ni^{2+})_8(OH,O)_{16}Cl_{1.25}\cdot nH_2O$; Ruatapu Cave, New Zealand (Rodgers et al., 2000)
Arsenolite – As_2O_3 (cub.); Corkscrew Cave, AZ, USA (Onac et al., 2007b)
Asbolane – $Mn^{4+}(O,OH)_2(Co,Ni,Mg,Ca)_x(OH)_{2x}\cdot nH_2O$; Tyuya-Muyun, Kyrgyzstan
Birnessite – $(Na,Ca,K)_{0.6}(Mn^{4+},Mn^{3+})_2O_4\cdot 1.5H_2O$; Weber Cave, IA, USA
Böhmite – AlO(OH) (orth.); Dachstein-Mammuthöhle, Austria
Braunite – $Mn^{2+}(Mn^{3+})_6SiO_{12}$; Vântului Cave, Romania
Cesàrolite – $Pb(Mn^{4+})_3O_6(OH)_2$; in Santa Barbara Cave, Sardinia, Italy (De Waele and Forti, 2005)
Chalcophanite – $Zn(Mn^{4+})_3O_7\cdot 3H_2O$; Bisbee mine cave, AZ, USA
Claudetite – As_2O_3 (mon.); Corkscrew Cave, AZ, USA (Onac et al., 2007b)
Coronadite – $Pb(Mn^{4+})_2(Mn^{2+})_6O_{16}$; in Santa Barbara Cave, Sardinia, Italy (?) (De Waele and Forti, 2005)
Cristobalite – SiO_2 (tetr.); Medicine Lake lava tubes, California, USA
Cryptomelane – $K(Mn^{4+},Mn^{2+})_8O_{16}$; cavities in Nikopol'skoye iron ore, Russia
Cuprite – Cu_2O; Bisbee mine cave, AZ, USA
Gibbsite – $Al(OH)_3$ (mon.); Harlansburg & Hineman caves, PA, USA
Goethite – FeO(OH) (orth.); Tintic district, UT, USA
Hausmannite – $Mn^{2+}(Mn^{3+})_2O_4$; Vântului Cave, Romania
Hematite – Fe_2O_3; cavities in the Tintic district, UT, USA
Hetaerolite – $Zn(Mn^{3+})_2O_4$; in Santa Barbara Cave, Sardinia, Italy (De Waele and Forti, 2005)
Hollandite – $(Ba,K,Ca,Sr)(Mn^{4+},Mn^{3+},Ti,Fe^{3+})_8O_{16}$; Vântului Cave, Romania (Onac et al., 1997)
Hydrohetaerolite – $HZn(Mn^{3+})_{1.7}O_4$; in Santa Barbara Cave, Sardinia, Italy (De Waele and Forti, 2005)
Ice – H_2O; Kungur Cave, Russia
Lepidocrocite – $Fe^{3+}O(OH)$ (orth.); Dachstein-Mammuthöhle, Austria
*Limonite – **NOT** a mineral but generic term used for undifferentiated hydrated iron oxides; **NOT** approved by IMA-CNMNC*
Lithiophorite – $(Al,Li)Mn^{4+}O_2(OH)_2$; Martel Cave, Venezuela
Maghemite – $(Fe,\sim)_3O_4$; Cueva la Milagrosa, Venezuela
Magnetite – $Fe^{2+}(Fe^{3+})_2O_4$; Dachstein-Mammuthöhle, Austria
Manganite – $Mn^{3+}O(OH)$ (mon.); Najdema Cave, Slovenia
Monteponite – CdO; cave in Monteponi mine, Sardinia
Nordstrandite – $Al(OH)_3$ (tric.); Lechuguilla Cave, USA (Polyak and Provencio, 2001)
Opal – $SiO_2\cdot nH_2O$; Doombera granite cave, Ceylon
Periclase – MgO; Valea Rea Cave, Romania
Plattnerite – PbO_2; Bisbee mine cave, AZ, USA
Portlandite – $Ca(OH)_2$; lava tube on Mt. Etna, Italy
Pyrolusite – MnO_2; Blue John Cavern, UK
Quartz – SiO_2 (trig.); granite cave near Rio de Janiero, Brazil
Ralstonite – $Na_{0.5}(Al,Mg)_2(F,OH)_6\cdot H_2O$; volcanic caves on Surtsey Island, Iceland
Ranciéite – $(Ca,Mn^{2+})_{0.2}(Mn^{4+},Mn^{3+})O_2\cdot 0.6H_2O$; *cave type locality unknown*
Romanèchite – $(Ba,H_2O)_2(Mn^{4+},Mn^{3+})_5O_{10}$; Zbrasov Cave, Czech Republic
Silhydrite – $Si_3O_6\cdot H_2O$; Gaping Hole/Arch Sink, Mammoth, and Table Mountain, lava tubes in California, USA
Tenorite – CuO; Bisbee mine cave, AZ, USA
Todorokite – $(Na,Ca,K,Ba,Sr)_{1-x}(Mn,Mg,Al)_6O_{12}\cdot 3\text{-}4H_2O$; caves in KY, TN, GA (USA)
Tridymite – SiO_2 (tric.); Cango Cave, South Africa
Vernadite – $(Mn,Fe,Ca,Na)(O,OH)_2\cdot nH_2O$; Shopov's cave system, Bulgaria (?)
*Wad – **NOT** a mineral but a generic term used for poorly crystalline, undifferentiated hydrated manganese oxides and hydroxides; **NOT** approved by IMA-CNMNC*
Woodruffite – $Zn_2(Mn^{4+})_5O_{12}\cdot 4H_2O$; Cueva de las Velas, Naica, Mexico (Forti et al., 2007)

Halogenides

Atacamite – $Cu_2Cl(OH)_3$ (orth.); Jingemia Cave, Australia
Bromargyrite – AgBr; Bisbee mine cave, AZ, USA
Carnallite – $KMgCl_3\cdot 6H_2O$; Verhnekamsk caves, Russia
Chlormagnesite – $MgCl_2$; Pelagalli Cave, Italy
Fluorite – CaF_2; Blue John Cavern, UK
Halite – NaCl; *cave type locality unknown*
Salammoniac – NH_4Cl; volcanic cave on Vulcano Island, Italy; *Renamed with approval from IMA-CNMNC*
Sylvite – KCl; Cutrona Cave Mt. Etna, Italy

Carbonates

Aragonite – $CaCO_3$ (orth.); *cave type locality unknown*
Ankerite – $CaFe^{2+}(CO_3)_2$; cave in Russia
Artinite – $Mg_2CO_3(OH)_2·3H_2O$; Shopov's cave system, Bulgaria
Aurichalcite – $Zn_5(CO_3)_2(OH)_6$; Blanchard mine caves, NM, USA
Azurite – $Cu_3(CO_3)_2(OH)_2$; Bisbee mine cave, AZ, USA
Baylissite – $K_2Mg(CO_3)_2·4H_2O$; Shopov's cave system, Bulgaria
Brianyoungite – $Zn_3CO_3(OH)_4$; cave in Su Zurfuru mine, Sardinia, Italy (De Waele and Forti, 2005)
Burbankite – $(Na,Ca)_3(Sr,Ba,Ce)_3(CO_3)_5$; Cioclovina Cave, Romania (Onac et al., 2009a)
Calcite – $CaCO_3$ (trig.); cave in the Julian Alps, Italy
Cerussite – $PbCO_3$; Blue John Cavern, UK (?)
Dolomite – $CaMg(CO_3)_2$; cave in France
Gaspéite – $NiCO_3$; cave in San Benedetto mine, Sardinia, Italy (De Waele and Forti, 2005)
Glaukosphaerite – $(Cu,Ni)_2CO_3(OH)_2$; Water Cave from Codreanu mine, Romania (Onac, 2002)
Huntite – $CaMg_3(CO_3)_4$; Dorog, Hungary
Hydromagnesite – $Mg_5(CO_3)_4(OH)_2·4H_2O$; Carlsbad Caverns, NM, USA
Hydrozincite – $Zn_5(CO_3)_2(OH)_6$; Island Ford Cave, VA, USA
Ikaite – $CaCO_3·6H_2O$; Scărişoara Cave, Romania (Onac, 2008)
Kutnohorite – $CaMn^{2+}(CO_3)_2$; Caverna Pocala, Italy
Lansfordite – $MgCO_3·5H_2O$; Valea Rea Cave, Romania (Onac, 2003)
Magnesite – $MgCO_3$; Moulis Cave, France (?)
Malachite – $Cu_2CO_3(OH)_2$; Bisbee mine cave, AZ, USA
Monohydrocalcite – $CaCO_3·H_2O$; Eibengrotte, Germany
Natron – $Na_2CO_3·10H_2O$; Pisgah lava tubes, CA, USA
Nesquehonite – $MgCO_3·3H_2O$; Wolkberg Cave, South Africa
Norsethite – $BaMg(CO_3)_2$; Crystal's Cave, Codreanu mine, Romania (Onac, 2002)
Paralstonite – $BaCa(CO_3)_2$; Cova des Pas de Vallgornera, Mallorca, Spain (Merino et al., 2009)
Phosgenite – $Pb_2CO_3Cl_2$; cave in Monteponi mine, Sardinia, Italy (De Waele and Forti, 2005)
Rhodochrosite – $MnCO_3$; cavities in Andalgala mining district, Argentina
Rosasite – $(Cu,Zn)_2CO_3(OH)_2$; Bisbee mine cave, AZ, USA
Siderite – $FeCO_3$; Jewel Cave, SD, USA
Smithsonite – $ZnCO_3$; cave in Iowa, USA
Strontianite – $SrCO_3$; cave in Terrace Mountain, NY, USA
Thermonatrite – $Na_2CO_3·H_2O$; Salzburgerschacht, Austria
Trona – $Na_3(HCO_3)(CO_3)·2H_2O$; Pisgah lava tubes, CA, USA
Vaterite – $CaCO_3$ (hex.); Closani Cave, Romania
Witherite – $BaCO_3$; Lilburn Cave, CA, USA

Nitrates

Darapskite – $Na_3(SO_4)(NO_3)·H_2O$; Flower Cave, TX, USA
Gwihabaite – $(NH_4)NO_3$; Gwihaiba Cave, Botswana
Hydrombobomkulite – $(Ni,Cu)Al_4(NO_3)_2(SO_4)(OH)_{12}·14H_2O$; Mbobo Mkulu Cave, South Africa
Mbobomkulite – $(Ni,Cu)Al_4(NO_3,SO_4)_2(OH)_{12}·3H_2O$; Mbobo Mkulu Cave, South Africa
"Nickelalumite" – not approved by IMA-CNMNC (use mbobomkulite)
Niter – KNO_3; Pulo din Molfetta caves, Italy
Nitrammite – NH_4NO_3; *discredited by IMA-CNMNC (use gwihabaite)*
Soda niter – $NaNO_3$; *cave type locality unknown*
Nitrocalcite – $Ca(NO_3)_2·4H_2O$; Pulo di Molfetta caves, Italy
Nitromagnesite – $Mg(NO_3)_2·6H_2O$; Great Cave, KY, USA (?)
Sveite – $KAl_7(NO_3)_4(OH)_{16}Cl_2·8H_2O$; Autana Cave, Venezuela

Borates

Tincalconite – $Na_2B_4O_5(OH)_4·3H_2O$; Tincalconite Cave, CA, USA

Sulfates

Alpersite – $(Mg,Cu^{2+})SO_4·7H_2O$; Cave at -150 m in Naica Mine, Mexico (*originally described as Cu-pentahydrite*; Forti, 2010)
Alum-(K) – $KAl(SO_4)_2·12H_2O$; Doombera granite cave, Ceylon; *Renamed with approval from IMA-CNMNC*
Alum-(Na) – $NaAl(SO_4)_2·12H_2O$; Alum Cave, Italy; *Renamed with approval from IMA-CNMNC*
Aluminite – $Al_2SO_4(OH)_4·7H_2O$; Mbobo Mkulu Cave, South Africa
Aluminocopiapite – $(Al,Mg)(Fe^{3+})_4(SO_4)_6(OH,O)_2·20H_2O$; Alum Cave, Italy
Alunite – $KAl_3(SO_4)_2(OH)_6$; Fourgassié Cave, French Guiana
Alunogen – $Al_2(SO_4)_3(H_2O)_{12}·5H_2O$; Grotta dello Zolfo, Italy
Ammoniojarosite – $NH_4(Fe^{3+})_3(SO_4)_2(OH)_6$; Cueva Alfredo Jahn, Venezuela

Anglesite – $PbSO_4$; Ahumada mine cave, Mexico
Anhydrite – $CaSO_4$; Diana Cave, Romania
Antlerite – $(Cu^{2+})_3SO_4(OH)_4$; Cave at -150 m in Naica Mine, Mexico (Forti, 2010)
Aphthitalite – $K_3Na(SO_4)_2$; Murra-el-elevyn Cave, Australia
Arcanite – K_2SO_4; Murra-el-elevyn Cave, Australia *(originally described as taylorite, name that is now discredited by IMA-CNMNC)*
Aubertite – $Cu^{2+}Al(SO_4)_2Cl·14H_2O$; Alum Cave, Italy
Barite – $BaSO_4$; paleokarst cavities in Derbyshire, UK
Basaluminite – Discredited by IMA-CNMNC (use felsőbányaite)
Bassanite – $CaSO_4·0.5H_2O$; Tăuşoare Cave, Romania
Bechererite – $Zn_7Cu(OH)_{13}[SiO(OH)_3SO_4]$; cave in Su Zurfuru mine, Sardinia, Italy (De Waele and Forti, 2005)
Bianchite – $ZnSO_4·6H_2O$; cave in Campo Pisano mine, Sardinia, Italy (De Waele and Forti, 2005)
Blödite – $Na_2Mg(SO_4)_2·4H_2O$; Lee Cave (Mammoth cave system), USA
Boussingaultite – $(NH_4)_2Mg(SO_4)_2·6H_2O$; Gwihaiba Cave, Botswana
Brochantite – $Cu_4SO_4(OH)_6$; Bingham mine caves, USA
Burkeite – $Na_4(SO_4)(CO_3)$; El Malpais lava tubes, USA
Celestine – $SrSO_4$; Crystal Cave, Ohio, USA
Cesanite – $Na_7Ca_3(SO_4)_6(OH)·H_2O$; Lighthouse Cave, San Salvador, Bahamas (Onac et al., 2001a)
Chalcanthite – $CuSO_4·5H_2O$; Bisbee mine caves, USA
Chalcoalumite – $CuAl_4SO_4(OH)_{12}·3H_2O$; Mbobo Mkulu Cave, South Africa
Clairite – $(NH_4)_2(Fe^{3+})_3(SO_4)_4(OH)_3·3H_2O$; Lone Creek Fall Cave, South Africa
Copiapite – $Fe^{2+}(Fe^{3+})_4(SO_4)_6(OH)_2·20H_2O$; Alum Cave, Italy
Coquimbite – $(Fe^{3+})_2(SO_4)_3·9H_2O$; Alum Cave, Italy
Cyanotrichite – $Cu_4Al_2SO_4(OH)_{12}·2H_2O$; Bingham mine caves, USA
Despujolsite – $Ca_3Mn^{4+}(SO_4)_2(OH)_6·3H_2O$; Shopov's cave system, Bulgaria
Devilline – $CaCu_4(SO_4)_2(OH)_6·3H_2O$; Monte Rosso Cave, Italy
Epsomite – $MgSO_4·7H_2O$; gypusm cave near Bologna, Italy
Felsőbányaite – $Al_4(SO_4)(OH)_{10}·4H_2O$; Tateishi-Shônyû-dô Cave, Japan
Ferrohexahydrite – $Fe^{2+}SO_4·6H_2O$; Cupp-Coutunn Cave, Turkmenistan
Fibroferrite – $Fe^{3+}SO_4(OH)·5H_2O$; Ferrata Cave, Umbria, Italy
Galeite – $Na_{15}(SO_4)_5ClF_4$; volcanic caves on Surtsey Island, Iceland
Glauberite – $Na_2Ca(SO_4)_2$; Grillid volcanic cave, Surtsey Island, Iceland
Gypsum – $CaSO_4·2H_2O$; Mammoth cave system, USA
Halotrichite – $Fe^{2+}Al_2(SO_4)_4·22H_2O$; Alum Cave, Italy
Hexahydrite – $MgSO_4·6H_2O$; Wyandotte Cave, Indiana, USA
Hydrobasaluminite – $Al_4SO_4(OH)_{10}·15H_2O$; Alum Cave, Italy
Hydroglauberite – $Na_{10}Ca_3(SO_4)_8·6H_2O$; Grillid volcanic cave, Surtsey Island, Iceland
Hydroniumjarosite – $(H_3O)(Fe^{3+})_3(SO_4)_2(OH)_6$; Iza Cave, Romania (?) (Tămaş and Ghergari, 2003)
Jarosite – $K(Fe^{3+})_3(SO_4)_2(OH)_6$; Turia Cave, Romania
Jurbanite – $AlSO_4(OH)·5H_2O$; Serpents Cave, France (Audra and Hobléa, 2007)
Kainite – $KMg(SO_4)Cl·3H_2O$; Grillid volcanic cave, Surtsey Island, Iceland (Forti, 2005)
Kalinite – $KAl(SO_4)_2·11H_2O$; Alum Cave, Italy
Kieserite – $MgSO_4·H_2O$; Tana di Val Serrata Cave, Italy
Kogarkoite – Na_3SO_4F; Cave #13 (lava tube), Mt. Suswa, Kenya (Forti et al., 2003)
Koktaite – $(NH_4)_2Ca(SO_4)_2·H_2O$; Cueva Alfredo Jahn, Venezuela
Konyaite – $Na_2Mg(SO_4)_2·5H_2O$; Tăuşoare Cave, Romania (Onac et al., 2001b)
Kröhnkite – $Na_2Cu(SO_4)_2·2H_2O$; Cioclovina Cave, Romania (Onac et al., 2011)
Lecontite – $(NH_4)Na(SO_4)·2H_2O$; cave near Las Piedras, Honduras
Leonite – $K_2Mg(SO_4)_2·4H_2O$; Tăuşoare Cave, Romania (Onac et al., 2001b)
Lonecreekite – $NH_4(Fe^{3+})(SO_4)_2·12H_2O$; Lone Creek Fall Cave, South Africa
Löweite – $Na_{12}Mg_7(SO_4)_{13}·15H_2O$; Grillid volcanic cave, Surtsey Island, Iceland
Mascagnite – $(NH_4)_2SO_4$; Ruatapu Cave, New Zealand (Rodgers et al., 2000)
Melanterite – $FeSO_4·7H_2O$; Wilson Cave (?), Nevada, USA
Mendozite – $NaAl(SO_4)_2·11H_2O$; Kitum Cave, Kenya (Forti et al., 2003)
Meta-aluminite – $Al_2SO_4(OH)_4·5H_2O$; Valea Rea Cave, Romania (Feier, 2003)
Metavoltine – $K_2Na_6Fe^{2+}(Fe^{3+})_6O_2(SO_4)_{12}·18H_2O$; Alum Cave, Italy
Millosevichite – $Al_2(SO_4)_3$; Alum Cave, Italy
Mirabilite – $Na_2SO_4·10H_2O$; *cave type locality unknown*
Misenite – $K_8(SO_4)(SO_3OH)_6$; Grotta dello Zolfo, Italy
Natroalunite – $NaAl_3(SO_4)_2(OH)_6$; Lechuguilla Cave, USA
Natrojarosite – $Na(Fe^{3+})_3(SO_4)_2(OH)_6$; Jungle Pot Cave, South Africa
Pickeringite – $MgAl_2(SO_4)_4·22H_2O$; Grotta dello Zolfo, Italy
Picromerite –$K_2Mg(SO_4)_2·6H_2O$; Cutrona lava tube, Mt. Etna, Italy
Plumbojarosite – $Pb_{0.5}(Fe^{3+})_3(SO_4)_2(OH)_6$; +50 Cave Naica, Mexico (Forti, 2010)
Polyhalite – $K_2Ca_2Mg(SO_4)_4·2H_2O$; Cutrona lava tube, Mt. Etna, Italy

Rapidcreekite – $Ca_2(SO_4)(CO_3)\cdot4H_2O$; Diana Cave, Romania (Onac et al., 2009b)
Römerite – $Fe^{2+}(Fe^{3+})_2(SO_4)_4\cdot14H_2O$; Carlsbad Caverns, USA
Rozenite – $Fe^{2+}SO_4\cdot4H_2O$; Faggeto Tondo, Italy
Sabieite – $NH_4Fe^{3+}(SO_4)_2$; Lone Creek Fall Cave, South Africa
Serpierite – $Ca(Cu,Zn)_4(SO_4)_2(OH)_6\cdot3H_2O$; Cave #4, Runcului Hill, Romania (Zaharia et al., 2003)
Siderotil – $(Fe,Cu)(SO_4)\cdot5H_2O$; Ruatapu Cave, New Zealand (Rodgers et al., 2000)
Spangolite – $Cu_6AlSO_4(OH)_{12}Cl\cdot3H_2O$; Bingham mine caves, USA
Starkeyite – $MgSO_4\cdot 4H_2O$; Cueva de las Velas, Naica, Mexico (Forti et al., 2007)
Syngenite – $K_2Ca(SO_4)_2\cdot H_2O$; Murra-el-elevyn Cave, Australia
Szmikite – $MnSO_4\cdot H_2O$; Cueva de las Velas, Naica, Mexico (Forti et al., 2007)
Szmolnokite – $FeSO_4\cdot H_2O$; Cueva de las Velas, Naica, Mexico (Forti et al., 2007)
Tamarugite – $NaAl(SO_4)_2\cdot6H_2O$; Grotta dello Zolfo, Italy
Thenardite – Na_2SO_4; Grotta delle Argille, Modena, Italy
Tschermigite – $NH_4Al(SO_4)_2\cdot12H_2O$; Ruatapu Cave, New Zealand
Voltaite – $K_2(Fe^{2+})_5(Fe^{3+})_3Al(SO_4)_{12}\cdot18H_2O$; Grotta dello Zolfo, Italy
Zaherite – $Al_{12}(SO_4)_5(OH)_{26}\cdot20H_2O$; Alum Cave, Italy (Forti et al., 1996)

Cromates

Crocoite – $PbCrO_4$; Scărişoara Ice Cave, Romania (?) (Onac, 2001)

Phosphates, Arsenates, Vanadates

Phosphates

Archerite – H_2KPO_4; Petrogale Cave, Australia
Ardealite – $Ca_2(PO_3OH)(SO_4)\cdot4H_2O$; Cioclovina Cave, Romania
"Arnhemite" – $K_4Mg_2(P_2O_7)\cdot5H_2O$; Arnhem Cave, Namibia; *Not approved by IMA-CNMNC*
Berlinite – $AlPO_4$; Cioclovina Cave; Romania (Onac et al., 2002)
Biphosphammite – $H_2(NH_4)PO_4$; Murra-el-elevyn Cave, Australia
Bobierrite – $Mg_3(PO_4)_3\cdot8H_2O$; Imperial Canyon lava tubes, Kenya
Brushite – $Ca(PO_3OH)\cdot2H_2O$; Skipton lava tubes, Australia
Carbonate-fluorapatite – Discredited by IMA-CNMNC
Carbonate-hydroxylapatite – Discredited by IMA-CNMNC
Chlorapatite – $Ca_5(PO_4)_3Cl$; Lyon Cave, Philippines
Churchite-(Y) – $YPO_4\cdot2H_2O$; Cioclovina Cave, Romania (Onac et al., 2005)
Collinsite – $Ca_2Mg(PO_4)_2\cdot2H_2O$; Blue Lagoon Cave, South Africa
Crandallite – $CaAl_3(PO_4)_2(PO_3OH)(OH)_6$; caves on Isla Mona, Puerto Rico
Diadochite – $(Fe^{3+})_2(PO_4)(SO_4)(OH)\cdot6H_2O$; Feengrotten, Germany
Dittmarite – $(NH_4)MgPO_4\cdot H_2O$; Skipton lava tubes, Australia
Evansite – $Al_3PO_4(OH)_6\cdot6H_2O$; sandstone cave in Columbia, SouthAmerica
Fluorapatite – $Ca_5(PO_4)_3F$; Slaughter Canyon Cave, New Mexico, SUA
Foggite – $CaAlPO_4(OH)_2\cdot H_2O$; Cioclovina Cave, Romania (Onac et al., 2005)
Francoanellite – $K_3Al_5(PO_3OH)(PO_4)_2\cdot12H_2O$; Castellana caves, Italy
Gordonite – $MgAl_2(PO_4)_2(OH)_2\cdot8H_2O$; Parwan Cave, Victoria, Asutralia
Hannayite – $(NH_4)_2Mg_3(PO_3OH)_4\cdot8H_2O$; Skipton lava tubes, Australia
Hopeite – $Zn_3(PO_4)_2\cdot4H_2O$ (orth.); Broken Hills mine caves, Zambia
Hydroxylapatite – $Ca_5(PO_4)_3(OH)$; caves on Isla Mona, Puerto Rico
Kingsmountite – $Ca_4Fe^{2+}Al_4(PO_4)_6(OH)_4\cdot12H_2O$; Rossillo Cave, Quatro Cienegas Desert, Mexico (Forti et al., 2006)
Koninckite – $Fe^{3+}PO_4\cdot3H_2O$; Oni-Ana Cave, Japan
Leucophosphite – $K(Fe^{3+})_2(PO_4)_2(OH)\cdot2H_2O$; Bomi Hill caves, Liberia
Lipscombite – $Fe^{2+}(Fe^{3+})_2(PO_4)_2(OH)_2$; Perak Tong Cave, Malaysia
Minyulite – $KAl_2(PO_4)_2F\cdot4H_2O$; Boon Cave, Transvaal, South Africa
Mitridatite – $Ca_2(Fe^{3+})_3O_2(PO_4)_3\cdot3H_2O$; Boon Cave, Transvaal, South Africa
Monetite – $Ca(PO_3OH)$; caves on Isla Mona, Puerto Rico
Montgomeryite – $Ca_4MgAl_4(PO_4)_6(OH)_4\cdot12H_2O$; et-Tabun Cave, Israel
Mundrabillaite – $(NH_4)_2Ca(PO_3OH)_2\cdot H_2O$; Petrogale Cave, W. Australia
Newberyite – $Mg(PO_3OH)\cdot3H_2O$; Skipton lava tubes, Australia
Niahite – $(NH_4)Mn^{2+}PO_4\cdot H_2O$; Niah Great Cave, Sarawak, Malaysia
Parahopeite – $Zn_3(PO_4)_2\cdot4H_2O$ (tric.); Hudson Bay mine caves, British Columbia, Canada
Phosphammite – $(NH_4)_2(PO_3OH)$; Toppin Hill caves, Australia
Phosphosiderite – $Fe^{3+}(PO_4)\cdot2H_2O$; Bomi Hill caves, Liberia
Purpurite – $(Mn^{3+},Fe^{3+})PO_4$; Gunong Keriang, Malaysia
"Pyrocoproite" – $(K,Na)_2Mg(P_2O_7)$; Arnhem Cave, Namibia; *Not approved by IMA-CNMNC* (Martini, 1997)
Pyromorphite – $Pb_5(PO_4)_3Cl$; cave in Friedricksgessen mine, Germany
"Pyrophosphite" – $K_2CaP_2O_7$; Arnhem Cave, Namibia; *Not approved by IMA-CNMNC*

Sampleite – $NaCaCu_5(PO_4)_4Cl·5H_2O$; Mbobo Mkulu Cave, Transvaal, South Africa
Sasaite – $Al_6(PO_4)_5(OH)_3·36H_2O$; West Driefontein Cave, South Africa
Schertelite – $(NH_4)_2Mg(PO_3OH)_2·4H_2O$; Skipton lava tubes, Australia
Scholzite – $CaZn_2(PO_4)_2·2H_2O$; cave in Virginia, USA
Spencerite – $Zn_4(PO_4)_2(OH)_2·3H_2O$; Hudson Bay mine caves, British Columbia, Canada
Stercorite – $(NH_4)Na(PO_3OH)·4H_2O$; Petrogale Cave, W. Australia
Strengite – $Fe^{3+}PO_4·2H_2O$; Bomi Hill caves, Liberia
Struvite – $(NH_4)MgPO_4·6H_2O$; Skipton lava tubes, Australia
Swaknoite – $(NH_4)_2Ca(PO_3OH)_2·H_2O$; Arnhem Cave, Namibia
Taranakite – $K_3Al_5(PO_3OH)_6(PO_4)_2·18H_2O$; Minerva Cave, France
Tarbuttite – $Zn_2PO_4(OH)$; Broken Hills mine caves, Zambia
Tinsleyite – $KAl_2(PO_4)_2(OH)·2H_2O$; Cioclovina Cave, Romania (Marincea et al., 2002)
Tinticite – $(Fe^{3+})_{5.3}(PO_4)_4(OH)_6·6.7H_2O$; cavity in the Tintic district, UT, USA
Variscite – $AlPO_4·2H_2O$; Drachenhöhle Cave, Austria
Vashegyite – $Al_{11}(PO_4)_9(OH)_6·38H_2O$; Oni-Ana; Tateishi-Shônyû-dô caves, Japan
Vivianite – $(Fe^{2+})_3 (PO_4)_2·8H_2O$; Niah Great Cave, Sarawak, Malaysia
Wavellite – $Al_3(PO_4)_2(OH)_3·5H_2O$; Valea Rea Cave, Romania
Whitlockite – $Ca_9Mg(PO_3OH)(PO_4)_6$; El Chapote Cave, Mexico
Woodhouseite – $CaAl_3(SO_4)(PO_4)(OH)_6$; Jade Lotus Cave, Yangshuo, China

Arsenates

Arseniosiderite – $Ca_2(Fe^{3+})_3O_2(AsO_4)_3·3H_2O$; Tyuya-Muyun Cave, Kyrgyzstan
Beudantite – $Pb(Fe^{3+})_3(AsO_4)(SO_4)(OH)_6$; Island Ford Cave, USA
Conichalcite – $CaCuAsO_4(OH)$; Corkscrew Cave, Grand Canyon, USA
Hedyphane – $Ca_2Pb_3(AsO_4)_3Cl$; cave in Santa Barbara mine, Sardinia, Italy (De Waele and Forti, 2005)
Hörnesite – $Mg_3(AsO_4)_2·8H_2O$; Corkscrew Cave, Grand Canyon, USA (*not cited in CMW2*) (Wenrich and Sutphin, 1994)
Manganberzeliite – $NaCa_2(Mn^{2+})_2(AsO_4)_3$; Cueva Alfredo Jahn, Venezuela
Mimetite – $Pb_5(AsO_4)_3Cl$; Bisbee mine cave, AZ, USA
Olivenite – $Cu_2AsO_4(OH)$; cavities in the Tintic district, UT, USA
Pharmacolite – $Ca(AsO_3OH)·2H_2O$; Corkscrew Cave, Grand Canyon, USA (Onac et al., 2007b)
Strashimirite – $Cu_4(AsO_4)_2(OH)_2·2.5H_2O$; Dupkata na Mara Cave, Bulgaria
Talmessite – $Ca_2Mg(AsO_4)_2·2H_2O$; Corkscrew Cave, Grand Canyon, USA
Yukonite – $Ca_7(Fe^{3+})_{15}(AsO_4)_9O_{16}·25H_2O$ (?); Grotta della Monaca, Italy (Garavelli et al., 2009)

Vanadates

Calciovolborthite – Discredited by IMA-CNMNC (use tangeite)
Carnotite – $K_2(UO_2)_2(VO_4)_2·3H_2O$; Tyuya-Muyun Cave, Kyrgyzstan
Descloizite – $PbZnVO_4(OH)$; Tyuya-Muyun Cave, Kyrgyzstan
Metatyuyamunite – $Ca(UO_2)_2(VO_4)_2·3H_2O$; Spider Cave, New Mexico, USA
Tangeite – $CaCuVO_4(OH)$; Zelania Cave, Tyuya-Muyun, Kyrgyzstan
Tyuyamunite – $Ca(UO_2)_2(VO_4)_2·3H_2O$; Tyuya-Muyun Cave, Kyrgyzstan
Vanadinite – $Pb_5(VO_4)_3Cl$; Broken Hills mine caves, Zambia

Molybdates

Powellite – $CaMoO_4$; Corkscrew Cave, Grand Canyon, USA (*not cited in CMW2*) (Wenrich and Sutphin, 1994)

Organic compounds

Acetamide – CH_3CONH_2; Prilepnata Cave, Bulgaria
Glushinskite – $MgC_2O_4·2H_2O$; Temple of Dome Cave, Namibia
Guanine – $C_5H_3(NH_2)N_4O$; Murra-el-elevyn Cave, Australia
Mellite – $Al_2C_6(COO)_6·16H_2O$; Romanelli Cave, Apulia, Italy
Oxammite – $(NH_4)_2C_2O_4·H_2O$; Petrogale Cave, W. Australia
Urea – $CO(NH_2)_2$; Wilgie Mia Cave, W. Australia
Uricite – $C_5H_4N_4O_3$; Dingo Donga Cave, W. Australia
Weddellite – $CaC_2O_4·2H_2O$; Toppin Hill Cave, W. Australia
Whewellite – $CaC_2O_4·H_2O$; Parakietgat Cave, Namibia

Silicates

Allophane – $Al_2O_3(SiO_2)_{1.3\text{-}2.0}·2.5\text{-}3H_2O$; Tyuya-Muyun Cave, Kyrgyzstan
Apophyllite-(KOH) – $KCa_4Si_8O_{20}(OH,F)·8H_2O$; Kitum Cave, Kenya (Forti et al., 2003)
Benitoite – $BaTiSi_3O_9$; Iza Cave, Romania
Boltwoodite – $KUO_2(SiO_3OH)·H_2O$; cave in northern Chihuahua, Mexico
Chrysocolla – $(Cu,Al)_2H_2Si_2O_5(OH)_4·nH_2O$; Tyuya-Muyun Cave, Kyrgyzstan

Clinochlore – $Mg_6Si_4O_{10}(OH)_8$; Monte Rosso Cave, Reggio Emilia, Italy
Clinoptilolite-Na – $Na_6(Si_{30}Al_6)O_{72}\cdot 20H_2O$; Cave in the Culachao mine, Chile (De Waele et al., 2009)
Dickite – $Al_2Si_2O_5(OH)_4$; Iza Cave, Romania
Endellite – Discredited by IMA-CNMNC (use Halloysite-10Å)
Epidote – $Ca_2Fe^{3+}Al_2(Si_2O_7)(SiO_4)O(OH)$; Santo Cave, Mt. Etna, Italy
Fraipontite – $(Zn,Al)_3(Si,Al)_2O_5(OH)_4$; Cupp-Coutunn Cave, Turkmenistan
Halloysite-7Å – $Al_2Si_2O_5(OH)_4$ (mon.); Faggeto Tondo Cave, Italy
Halloysite-10Å – $Al_2Si_2O_5(OH)_4\cdot 2H_2O$; caves in the Guadalupe Mountains, USA
Hectorite – $Na_{0.3}(Mg,Li)_3Si_4O_{10}(F,OH)_2\cdot nH_2O$; Cueva de las Espadas, Naica, Mexico (Forti et al., 2009)
Hemimorphite – $Zn_4Si_2O_7(OH)_2\cdot H_2O$; Hudson Bay mine caves, Canada
Howlite – $Ca_2SiB_5O_9(OH)_5$; Ordinskaya Cave, Kungur, Russia (Potapov and Parshima, 2010)
Hydroxyapophyllite – Discredited by IMA-CNMNC [*use Apophyllite-(KOH)*]
Hydroxylellestadite – $Ca_{10}(SiO_4)_3(SO_4)_3(OH)_2$; Cioclovina Cave, Romania (Onac et al., 2006)
*Illite – **NOT** a mineral; Name used to designate a group of species*
Ilvaite – $CaFe^{3+}(Fe^{2+})_2O(Si_2O_7)(OH)$; hydrothermal skarn caves at Primarsky Kray, Russia
Kaolinite – $Al_2Si_2O_5(OH)_4$ (tric.); Cupp-Coutunn Cave, Turkmenistan
Montmorillonite – $(Na,Ca)_{0.3}(Al,Mg)_2)Si_4O_{10})(OH)_2\cdot nH_2O$; Carlsbad Caverns, USA
Nacrite – $Al_2Si_2O_5(OH)_4$ (mon.); Valea Rea Cave, Romania (Ghergari and Tămaş, 1996)
Natrolite – $Na_2(Si_3Al_2)O_{10}\cdot 2H_2O$; Big Cave from Bolfu mine III, Romania
Nontronite – $Na_{0.3}(Fe^{3+})_2(Si,Al)_4O_{10}(OH)_2\cdot nH_2O$; Kartchner Caverns, USA
Orientite – $Ca_8(Mn^{3+})_{10}(SiO_4)_3(Si_3O_{10})_3(OH)_{10}\cdot 4H_2O$; Cueva de las Velas, Naica, Mexico (Forti et al., 2007)
Palygorskite – $(Mg,Al)_2Si_4O_{10}(OH)\cdot 4H_2O$; Broken Hill caves, New Zealand
Phillipsite-K – $K_6(Si_{10}Al_6)O_{32}\cdot 12H_2O$; Kitum Cave, Kenya (Forti et al., 2003)
Rectorite – $(Na,Ca)Al_4(Si,Al)_8O_{20}(OH)_4\cdot 2H_2O$; Kartchner Caverns, USA
Saponite – $(Ca,Na)_{0.3}(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2\cdot 4H_2O$; Vântului Cave, Romania
Sauconite – $Na_{0.3}Zn_3(Si,Al)_4O_{10}(OH)_2\cdot 4H_2O$; Cupp-Coutunn Cave, Turkmenistan
Sepiolite – $Mg_4Si_6O_{15}(OH)_2\cdot 6H_2O$; Zbrasov Cave, Czech Republic
Shattuckite – $Cu_5(SiO_3)_4(OH)_2$; Bisbee mine caves, USA

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