



Article

CNMNC guidelines for the nomenclature of polymorphs and polysomes

Frédéric Hatert^{1*} , Stuart J. Mills², Marco Pasero³, Ritsuro Miyawaki⁴ and Ferdinando Bosi⁵ 

¹Laboratoire de Minéralogie, Université de Liège B18, B-4000 Liège, Belgium; ²Geosciences, Museum Victoria, GPO Box 666, Melbourne, Victoria 3001, Australia; ³Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, I-56126 Pisa, Italy; ⁴Department Geology and Palaeontology, National Museum of Nature and Science, 4-1-1 Amakubo, Tsukuba 305-0005, Japan; and ⁵Dipartimento di Scienze della Terra, Sapienza Università di Roma, I-00185 Roma, Italy

Abstract

New guidelines for the nomenclature of polymorphs and polysomes have been approved by the the Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (IMA–CNMNC). Several cases can be distinguished. (i) Polymorphs with different crystal systems are distinguished by the prefixes cubo- (cubic), hexa- (hexagonal), tetra- (tetragonal), trigo- (trigonal), ortho- (orthorhombic), clino- (monoclinic) and anortho- (triclinic). (ii) Polymorphs with different crystal systems but showing a pseudosymmetry should show the prefix ‘pseudo-’. (iii) Polymorphs with the same crystal system but different space groups are distinguished by the prefix ‘para-’. If three or more polymorphs show the same crystal system but different space groups, the space group notation may be added as a suffix, though such a nomenclature should be avoided if possible. (iv) Polymorphs with the same space group are distinguished by the prefix ‘para-’. (v) Minerals with polymorph suffixes but with different chemical compositions cannot be considered as true polymorphs, so we recommend using the prefix ‘meta-’, which indicates a close but significantly different chemical composition. (vi) Polysomatic symbols should be placed as a suffix, which indicates the number and types of modules that alternate in the structure, such as in the högbomite supergroup, or as prefixes as in the sartorite homologous series. These recommendations have to be applied for future new mineral proposals, when the authors decide to use structural prefixes or suffixes, however modifications of historical and well-established names have to pass through the CNMNC for approval. In order to be consistent with the new guidelines, 25 mineral names are now modified: domeykite- β becomes trigodomeykite; fergusonite-(Y)- β becomes clinofergusonite-(Y); fergusonite-(Ce)- β becomes clinofergusonite-(Ce); fergusonite-(Nd)- β becomes clinofergusonite-(Nd); ice-VII becomes cubo-ice; roselite- β becomes anorthoroselite; sulphur- β becomes clinosulphur; mertieite-II becomes mertieite; mertieite-I becomes pseudomertieite; uranophane- α becomes uranophane; uranophane- β becomes parauranophane; gersdorffite- $P2_13$ becomes gersdorffite; gersdorffite- $Pa3$ becomes paragersdorffite; gersdorffite- $Pca2_1$ becomes orthogersdorffite; betalomonosovite becomes paralomonosovite; lammerite- β becomes paralammerite; nováčekite-I becomes hydronováčekite; nováčekite-II becomes nováčekite; halloysite-7Å becomes halloysite; halloysite-10Å becomes hydrohalloysite; metauranocircite-I becomes metauranocircite; taimyrite-I becomes taimyrite; uranocircite-II becomes uranocircite; andorite IV becomes quatrandorite; and andorite VI becomes senandorite.

Keywords: IMA–CNMNC guidelines, polymorphs, polysomes, structural suffixes, mineral name modifications

(Received 3 October 2022; accepted 7 February 2023; Accepted Manuscript published online: 11 April 2023; Associate Editor: Sergey V Krivovichev)

Introduction

The Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association (IMA–CNMNC) is an international non-profit organisation that evaluates new mineral proposals, defines mineral nomenclature guidelines, and establishes mineral classification schemes. The results of the votes on new mineral and nomenclature proposals are published bimonthly as Newsletters in the *European Journal of Mineralogy* and in *Mineralogical Magazine*, and an official IMA–CNMNC list of minerals is freely available on the CNMNC website (Pasero, 2023).

A careful examination of the CNMNC mineral name list shows that there are still some inconsistencies in the mineralogical nomenclature, mainly concerning the use of polymorph suffixes. The guidelines for the use of suffixes and prefixes in mineral names are reported in Hatert *et al.* (2013); however, these guidelines mainly concern chemical prefixes and suffixes. The present paper is a follow-up of our previous guidelines and presents recommendations for the nomenclature of polymorphs and polysomes approved by the CNMNC including suggesting some minor changes to a few mineral names, especially concerning the use of structural suffixes.

These recommendations have to be applied for future new mineral proposals, when the authors decide to use structural prefixes or suffixes, however modifications of historical and well-established names in the scientific literature have to pass through the CNMNC for approval. The goal of this paper is to provide consistent guidelines for future proposals and to fix a few

*Author for correspondence: Frédéric Hatert, Email: fhatert@uliege.be

Cite this article: Hatert F., Mills S.J., Pasero M., Miyawaki R. and Bosi F. (2023) CNMNC guidelines for the nomenclature of polymorphs and polysomes. *Mineralogical Magazine* 87, 225–232. <https://doi.org/10.1180/mgm.2023.13>

minor inconsistencies in mineral names, but it is not to initiate a massive modification of mineral names.

Definitions

General guidelines for mineral nomenclature, currently in use by the CNMNC, were established by Nickel and Grice (1998) and define a mineral species on the basis of its chemical composition and crystallographic properties: “If a mineral is found whose composition or crystallographic properties (or both) are substantially different from those of any existing mineral species, there is a possibility that it may be a new species.” Quasicrystals and amorphous substances can also be accepted as valid mineral species, if an enough appropriate characterisation of their chemical and physical properties demonstrates that they are distinct minerals (e.g. Bindi *et al.*, 2011, 2015; Pratesi *et al.*, 2003; Grey *et al.*, 2022).

Each mineral species is consequently characterised by an ideal chemical formula (often corresponding to an end-member formula), however mineral samples generally show significant chemical variations, compared to the ideal composition. The possible ranges of these variations, and the boundaries between mineral species involved in solid solutions, are defined by the

Dominant-Constituent Rule and the *Dominant-Valency Rule* (Hatert and Burke, 2008; Bosi *et al.*, 2019).

Two substances with the same composition may also be defined as separate mineral species if their crystal structures are *substantially* different. This means that their bonding schemes must show significant differences. Many mineral species are known that show the same ideal formula but distinct crystal structures, such as pyrite/marcasite, calcite/aragonite, or andalusite/kyanite/sillimanite. These phases are known as polymorphs (Nickel and Grice, 1998; Fig. 1).

Most polymorphs show very different crystal structures, thus leading to distinct unit-cell parameters and space groups. However, space group and/or unit-cell parameters variations may also be induced by some order/disorder variations in crystal structures or structural distortion; in these cases, the two polymorphs show essentially the same bonding scheme. Such substances are named topologically similar polymorphs (we suggest here using the term ‘structurally similar polymorphs’), and are not considered as distinct mineral species (Nickel and Grice, 1998). A well-known example is given by analcime, which forms several structurally similar polymorphs characterised by different symmetries, induced by variations in the Al–Si ordering scheme (e.g. Mazzi and Galli, 1978; Pechar, 1988).

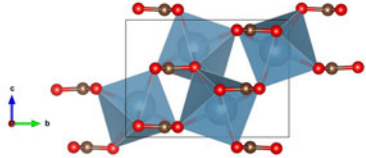
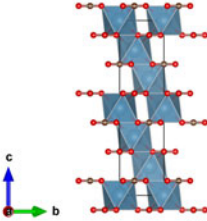
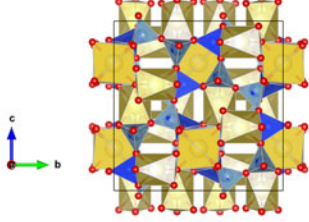
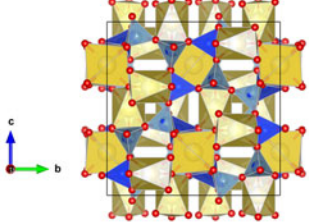
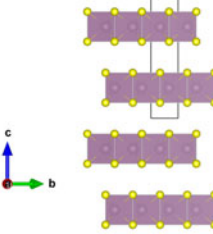
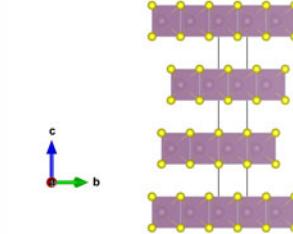
Mineral A	Mineral B	Structural relationships
 <p>Aragonite - $Pm\bar{3}n$</p>	 <p>Calcite - $R\bar{3}c$</p>	<p>POLYMORPHS</p> <ul style="list-style-type: none"> • Same chemical compositions • Completely different crystal structures • Different mineral species
 <p>Analcime - $I4_1/acd$</p>	 <p>Analcime - $Ibca$</p>	<p>STRUCTURALLY SIMILAR POLYMORPHS</p> <ul style="list-style-type: none"> • Same chemical compositions • Similar crystal structures • Different ordering schemes • Different unit-cell parameters and/or space group • Same mineral species
 <p>Molybdenite-2H - $P6_3/mmc$</p>	 <p>Molybdenite-3R - $R3m$</p>	<p>POLYTYPE</p> <ul style="list-style-type: none"> • Same chemical compositions • Same building units (layers) • Different stacking sequences • Different unit-cell parameters and/or space group • Same mineral species

Fig. 1. Examples of crystal structures illustrating the difference between polymorphs, structurally similar polymorphs, and polytypes. The structure models were drawn with the program Vesta (Momma and Izumi, 2011) starting from the structural data of Graf (1961), de Villiers (1971), Schönfeld *et al.* (1983) and Mazzi and Galli (1978).

Polytypes show crystal structures built by the stacking of layers of nearly identical compositions, but due to differences in the stacking sequences of the layers, variations of unit-cell parameters and/or space groups are induced. Such polytypes are not considered as separate mineral species as all layers constituting their structures have essentially the same basic topologies. Many examples of polytypes exist in the mineral kingdom and are distinguished by the addition of a polytype suffix that is not part of the mineral species name [see Guinier *et al.* (1984) for the nomenclature of polytype suffixes], e.g.: molybdenite-3R and molybdenite-2H (Traill, 1963; Wickman and Smith, 1970; Frondel and Wickman, 1970; Fig. 1); muscovite-1M, muscovite-2M and muscovite-3T (Velde, 1965; Güven and Burnham, 1967; Takeda *et al.*, 1971); and sapphirine-1A, sapphirine-2M, sapphirine-3A, sapphirine-4M and sapphirine-5A (Grew *et al.*, 2008). Those polytype suffixes can also be used to distinguish structurally similar polymorphs.

Polytypoids are also characterised by layered structures in which different stacking sequences occur; however, they do not follow the strict definition of the polytype as their chemical compositions show significant variations. Such a situation occurs in pyrrhotite, for example, which exists in many structural forms having distinct stacking sequences of nickeline-type layers; the presence of

vacancies in the layers induces variations of the Fe/S ratio (Pósfai and Dódonny, 1990a and 1990b; Fig. 2). Polytypoids are not considered as separate mineral species (Nickel and Grice, 1998).

Polysomes are characterised by different arrangements of a few basic structural units (blocks or layers), leading to minerals with structural analogies, but with significant chemical variations. Such polysomatic and homologous series are well-known in sulfosalts (e.g. Makovicky, 1997; Moëlo *et al.*, 2008), as well as in hōgbomite-supergroup minerals (Armbruster, 2002; Fig. 2). They may be considered as separate valid mineral species (Nickel and Grice, 1998).

Suffixes in mineral nomenclature

There are many mineral names that have included a suffix. Various systems are described below, note however some of these suffixes have now changed due to the CNMNC proposal described in the new guidelines below.

Levinson suffixes. The most common suffixes are the so-called Levinson suffixes, to be used in all cases in which rare earth elements, excluding scandium [= yttrium (Y) + lanthanides (La–Lu), hereafter abbreviated as REE], are an essential chemical

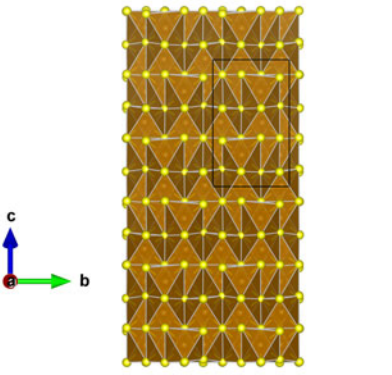
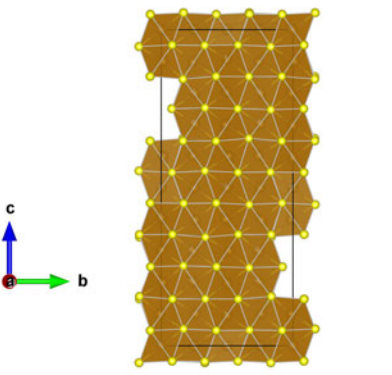
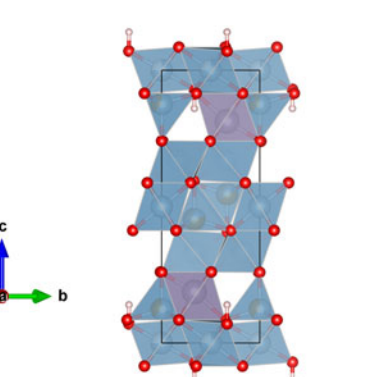
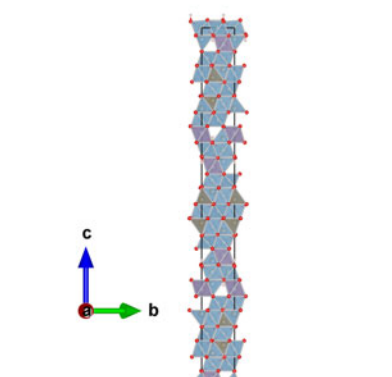
Mineral A	Mineral B	Structural relationships
 <p>Pyrrhotite – $C2/c$</p>	 <p>Pyrrhotite – $Cmca$</p>	<p>POLYTYPOIDS</p> <ul style="list-style-type: none"> Slightly different chemical compositions Nearly the same building units (layers) Different stacking sequences Different unit-cell parameters and/or space group Same mineral species
 <p>Ferronigerite-2N1S – $P\bar{3}m$</p>	 <p>Ferronigerite-6N6S – $R\bar{3}$</p>	<p>POLYSOMES</p> <ul style="list-style-type: none"> Different chemical compositions Different types of building units Different stacking sequences Different unit-cell parameters and/or space group Different mineral species

Fig. 2. Examples of crystal structures illustrating the difference between polytypoids and polysomes. The structure models were drawn with the program *Vesta* (Momma and Izumi, 2011) starting from the structural data of de Villiers *et al.* (2009), Powell *et al.* (2004), Arakcheeva *et al.* (1995) and Armbruster and Feenstra (2004).

component (Levinson, 1966). In such cases the most abundant REE (in atoms per formula unit) is mentioned in parentheses after the root-name [e.g. bastnäsite-(Nd); Miyawaki *et al.*, 2013]. Species differing only in the dominant REE are considered as separate species such as those in the epidote supergroup [e.g. allanite-(Ce) and allanite-(Y) or ferriallanite-(La) and ferriallanite-(Ce); Armbruster *et al.*, 2006; Mills *et al.*, 2009; Kolitsch *et al.*, 2012].

Modified Levinson suffix. This derives from the nomenclature adopted for REE-bearing minerals, and refers to specific cations, or anions, other than REE. Those suffixes are used in cases of two or more minerals having the same structural arrangement, and differing only in one chemical component at a given site [e.g. pumpellyite-(Al) and pumpellyite-(Mn²⁺); pertsevite-(F) and pertsevite-(OH); tetrahedrite-(Fe), tetrahedrite-(Hg), and tetrahedrite-(Zn); ardenite-(V) and ardenite-(As); Hatert *et al.*, 2007; Schreyer *et al.*, 2003; Biagioni *et al.* 2020; Barresi *et al.*, 2007]. The use of modified Levinson suffixes aims at avoiding the proliferation of trivial names. Rarely, suffixes are multiples [e.g. fluorarjadite-(BaFe), arjadite-(BaNa) and dickinsonite-(KMnNa); jahnsite-(MnMnMg) and jahnsite-(MnMnFe); Chopin *et al.*, 2006; Vignola *et al.* 2016, 2019a, 2019b].

Dominant extra-framework cations. These are occasionally used as suffixes, such as in minerals of the zeolite family. Such a notation is similar to the modified Levinson suffix, the only difference being that brackets are not used [e.g. dachiardite-Ca and lévyne-Na; labuntsovite-Fe, labuntsovite-Mg and labuntsovite-Mn; meurigite-K and meurigite-Na; obradovite-KCu, obradovite-NaCu and obradovite-NaNa; Coombs *et al.*, 1997; Khomyakov *et al.*, 2001; Kampf *et al.*, 2009, 2012].

Minerals of the högbomite supergroup. Suffixes such as -2N1S, -2N2S, -2N'2S, -2N3S, -2N4S, -2N6S, -6N'3S or -6N6S are used for the högbomite-supergroup members, which refer to polysomatic sequences of nolanite and spinel modules (Armbruster, 2002).

Joséite. The suffixes -A and -B are used to denote two sulfide-tellurides with different Te:S ratios, Bi₄TeS₂ and Bi₄Te₂S (Cook *et al.*, 2007, 2021). These species are regarded as 'questionable' by the IMA.

Greek symbols α and β . These symbols, which denote polymorphs, are usually placed as prefixes in the chemical literature. In the CNMNC list of mineral names, these polymorph symbols are placed as suffixes, as recommended by Hatert *et al.* (2013): domykite- β , fergusonite-(Ce)- β fergusonite-(Nd)- β , fergusonite-(Y)- β , lammerite- β , roselite- β , sulphur- β , uranophane- α and uranophane- β . The only exception is betalomonosovite, for which a prefix-type nomenclature has been preferred (Sokolova *et al.*, 2015).

Roman numerals. The following cases exist with Roman numerals: andorite IV, andorite VI, baumhauerite II (questionable), mertieite-I, mertieite-II, metauranocircite-I, nováčekite-I, nováčekite-II, rathite-IV (questionable), taimyrite-I and uranocircite-II, ice-VII.

Gersdorffite. The suffixes -Pa3, -P2,3, and Pca2₁ are used to denote three distinct polymorphs with different space groups of gersdorffite, the compound NiAsS (Bayliss, 1986).

Halloysite-10Å and halloysite-7Å. These are both monoclinic, but due to different hydration degrees, the interlayer distances, $d_{001} = c \cdot \sin\beta$, are different (Bailey, 1980).

The use of chemical prefixes and suffixes in mineral nomenclature was recently revised by Hatert *et al.* (2013); however, no clear guidelines were established for the use of structural prefixes and suffixes, as demonstrated by the inconsistencies listed above.

The aim of this paper is to provide CNMNC recommendations for structural prefixes and suffixes that have to be followed when naming minerals. In addition, as some mineral names appear to present unnecessary or ambiguous suffixes, they have been modified (Table 1).

Guidelines for nomenclature of polymorphs

A variety of different symbol types have been used historically to designate polymorphs, for example Greek symbols, Roman numerals, or space-group notations. The use of a new coherent nomenclature scheme for these polymorphs is recommended for the following three different situations:

Polymorphs showing different crystal systems

When polymorphs show different crystal systems, we recommend adding a prefix to distinguish them. The root-name, which was the first to be historically defined, remains unchanged, and the prefix is added to the new polymorphs to designate their distinct crystal systems.

Accepted prefixes are: cubo- (cubic); hexa- (hexagonal); tetra- (tetragonal); trigo- (trigonal); ortho- (orthorhombic); clino- (monoclinic); and anortho- (triclinic). Some valid mineral names already use these prefixes to designate the crystal systems of polymorphs:

Cubic: cuboargyrite.

Hexagonal: hexacelsian, hexaferrum, hexahydroborite, hexamolybdenum.

Tetragonal: tetra-auricupride, tetraferroplatinum, tetraaroseveltite, tetrataenite, tetrawickmanite.

Orthorhombic: bario-orthojoaquinite, orthobrannerite, orthocuproplatinum, orthojoaquinite-(Ce), orthojoaquinite-(La), orthominasragrite, orthopinakiolite, orthoserpierite, orthowalpurite.

Monoclinic: clinoatacamite, clinobeboite, clinobisvanite, clinocerantite, clinoenstatite, clino-ferri-holmquistite, clino-ferro-ferri-holmquistite, clinoferosilite, clinohumite, clinojimthompsonite, clinokurchatovite, clinometaborite, clino-oscar Kempffite, clinophosinaite, clinosafflorite, clino-suenoite, clinotobermorite, clinoungemachite, clinozoisite.

Triclinic: anorthominasragrite.

Other mineral species have used these prefixes to designate chemical, morphological or physical features of minerals e.g.: hexahydrite and hexahydroborite (six H₂O molecules in the formula); tetradymite (fourling twins); tetraferriannite and tetraferriphlogopite (Fe³⁺ tetrahedrally coordinated); trigonite (triangular crystal shape); orthoclase (cleavage planes at 90°); clinoclase (inclined optic axis and green colour); clinoclase (oblique cleavage planes); clinohedrite (inclined faces of the crystals); and clinoptilolite *s.l.* (morphology of oblique feathers). We do not recommend changing the names of these valid historical species, however in the future, such prefixes should only be used to designate crystal systems.

It is worth mentioning that the prefix 'iso-' was also used to designate cubic polymorphs, in isocubanite (cubic polymorph of cubanite), isoferroplatinum (cubic polymorph of tetraferroplatinum), and isolueshite (cubic polymorph of lueshite). However, the prefix 'cubo-' is preferred.

This nomenclature scheme can be applied to simplify the nomenclature of several species names containing Greek symbols or Roman numerals:

Table 1. Summary of the mineral species renamed in the present paper.

Previous name	New name	Formula	Space group
Domeykite- β	Trigodomeykite	Cu_3As	$P\bar{3}c$
Fergusonite-(Y)- β	Clinofergusonite-(Y)	YNbO_4	$I2/a$
Fergusonite-(Ce)- β	Clinofergusonite-(Ce)	CeNbO_4	$I2/a$
Fergusonite-(Nd)- β	Clinofergusonite-(Nd)	NdNbO_4	$I2/a$
Ice-VII	Cubo-ice	H_2O	$Pn\bar{3}m$
Roselite- β	Anorthoroselite	$\text{Ca}_2\text{Co}(\text{AsO}_4)_2 \cdot 2\text{H}_2\text{O}$	$P1$ or $P\bar{1}$
Sulphur- β	Clinosulphur	S	$P2_1$
Mertieite-II	Mertieite	$\text{Pd}_8(\text{Sb,As})_3^*$	$R\bar{3}c$
Mertieite-I	Pseudomertieite	$\text{Pd}_{5+x}(\text{Sb,As})_{2-x}$ ($x = 0.1-0.2$)*	Monoclinic pseudo-hexagonal
Uranophane- α	Uranophane	$\text{Ca}(\text{UO}_2)_2(\text{SiO}_3\text{OH})_2 \cdot 5\text{H}_2\text{O}$	$P2_1$
Uranophane- β	Parauranophane	$\text{Ca}(\text{UO}_2)_2(\text{SiO}_3\text{OH})_2 \cdot 5\text{H}_2\text{O}$	$P2_1/a$
Gersdorffite- $P2_13$	Gersdorffite	NiAsS	$P2_13$
Gersdorffite- $Pa3$	Paragersdorffite	NiAsS	$Pa3$
Gersdorffite- $Pca2_1$	Orthogersdorffite	NiAsS	$Pca2_1$
Betalomonosovite	Paralomonosovite	$\text{Na}_{5+x}\text{Ti}_4(\text{Si}_2\text{O}_7)_2[\text{PO}_3(\text{OH})]_{2-y}$ $[\text{PO}_2(\text{OH})_2]_y\text{O}_2[(\text{OH},\text{F})_{2-x}\text{O}_2]_z$, with $0 < x < 2$, $0 < y < 1$, $0 < z < 1$	$P\bar{1}$
Lammerite- β	Paralammerite	$\text{Cu}_3(\text{AsO}_4)_2$	$P2_1/c$
Nováčekite-I	Hydronováčekite	$\text{Mg}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 12\text{H}_2\text{O}$	$P\bar{1}$
Nováčekite-II	Nováčekite	$\text{Mg}(\text{UO}_2)_2(\text{AsO}_4)_2 \cdot 10\text{H}_2\text{O}$	$P2_1/n$
Halloysite- 7Å	Halloysite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$	Cm
Halloysite- 10Å	Hydrohalloysite	$\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot 2\text{H}_2\text{O}$	Cm
Metauranocircite-I	Metauranocircite	$\text{Ba}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 6\text{H}_2\text{O}$	$P2_1$
Taimyrite-I	Taimyrite	$(\text{Pd,Pt})_9\text{Cu}_3\text{Sn}_4$	Orthorhombic
Uranocircite-II	Uranocircite	$\text{Ba}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 10\text{H}_2\text{O}$	$P2_1$
Andorite IV	Quatrandorite	$\text{AgPbSb}_3\text{S}_6$	$P2_1/c$
Andorite VI	Senandorite	$\text{AgPbSb}_3\text{S}_6$	$Pn2_1a$

*Due to their close chemical compositions, these minerals are considered as true polymorphs.

- Domeykite is the cubic root-name, and domeykite- β is a trigonal polymorph. Domeykite- β consequently becomes trigodomeykite.
- Fergusonite-(Y) is the oldest tetragonal species, and fergusonite-(Y)- β is a monoclinic polymorph. Consequently, fergusonite-(Y)- β is re-named clinofergusonite-(Y). In the same way, fergusonite-(Ce) is unchanged, fergusonite-(Ce)- β becomes clinofergusonite-(Ce), and fergusonite-(Nd)- β becomes clinofergusonite-(Nd).
- Ice-VII is the cubic polymorph of hexagonal ice. Consequently, ice-VII is renamed cubo-ice (the name is hyphenated to improve readability).
- Roselite was the earlier defined monoclinic species, and the later defined roselite- β is triclinic. Roselite- β is re-named anorthoroselite.
- Sulphur is the older species and is orthorhombic, whereas later defined sulphur- β is monoclinic. Sulphur- β becomes clinosulphur. Another monoclinic polymorph of sulphur is also known, which has been named rosickýite (nomenclature without suffix).

Polymorphs showing different crystal systems, but one polymorph shows a pseudosymmetry

When polymorphs with a different crystal system show a pseudosymmetry, we recommend adding the prefix 'pseudo-' to the secondly described polymorph. This situation occurs between pseudo-hexagonal mertieite-I, and hexagonal mertieite-II.

- Mertieite-II is renamed mertieite, and mertieite-I renamed pseudomertieite.

Other examples of minerals, in which the pseudo- prefix is used to designate a pseudosymmetry, are pseudoboleite, pseudosinhaitite and pseudowollastonite.

Some mineral names have also used the prefix pseudo- to designate strong similarities with existing species (pseudobrookite, pseudocotunnite, pseudograndreefite, pseudojohannite, pseudolyonsite, pseudomalachite, pseudomarkeyite, pseudomeiserite-(NH_4) and pseudorutile) or to designate polymorphic relationships (pseudolaueite).

Polymorphs showing the same crystal system, but different space groups

If two polymorphs show the same crystal system but different space groups, we recommend using the prefix 'para-' to distinguish them.

The prefix 'para-' is used widely in the mineralogical nomenclature to designate polymorphs (paraberrillite, parabrandtite, parabutlerite, paracelsian, paracoquimbite, paracostibite, paradamite, parafransoletite, parageorgobokiite, paraguanajuatite, parahopeite, parakuzmenkoite-Fe, paralabuntsovite-Mg, paralaurionite, paralstonite, paranatisite, pararaisaite, paramammelsbergite, pararealgar, pararobertsite, pararsenolamprite, parascholzite, parascorodite, parasibirskite, parasymphesite, paratellurite, paratsepinite-Ba and paratsepinite-Na).

It has also been used for species with similar chemical compositions and/or structural features (para-alumohydrocalcite, paraershovite, parakeldyshite, paramelaconite, paramendozavilite, paramontroseite, paranatrolite, paraotwayite, parapierrotite, paraschachnerite, paraschoepite, parasterryite, paratacamite, paratacamite-(Mg), paratacamite-(Ni), paraumbite, paravauxite, paravinogradovite and parawulffite), and also for species occurring in close association (paradocrasite), or for resembling other species (paratimroseite).

The nomenclature of the following mineral species can hence be simplified:

- Uranophane- α and uranophane- β are monoclinic, however their space groups are different. As uranophane- α is the first defined species, it becomes uranophane, whereas uranophane- β becomes parauranophane.
- As the gersdorffite group contains two cubic polymorphs and an orthorhombic polymorph, it was very difficult to distinguish these species by prefixes. Consequently, the space group notations were placed as suffixes: gersdorffite- $Pa3$, gersdorffite- $P2_13$, and gersdorffite- $Pca2_1$ are the valid mineral names. As gersdorffite- $P2_13$ has historical priority, it has been renamed as gersdorffite. Gersdorffite- $Pa3$ becomes paragersdorffite, and the orthorhombic polymorph gersdorffite- $Pca2_1$ becomes orthogersdorffite.

If three or more polymorphs show the same crystal system but different space groups, the space group may be added as a suffix. Such examples are not yet known in mineralogy, and such a nomenclature should be avoided, if possible, as it is very cumbersome.

Polymorphs showing the same space group

If two polymorphs show the same space group, then the prefix 'para-' should ideally be used to distinguish them, though in some cases below further investigation is required.

- Baumhauerite was defined before baumhauerite II, which is a questionable species with similar chemistry. Both minerals are triclinic, $P\bar{1}$, therefore baumhauerite II should ideally be renamed parabaumhauerite, however we decided to keep the name of this questionable mineral unchanged as its restudy is required. 'Baumhauerite-2a', which appeared in the first versions of the CNMNC list of minerals, has recently been redefined and renamed argentobaumhauerite (Topa and Makovicky, 2016).
- Betalomonosovite and lomonosovite have close structural relations, however Sokolova *et al.* (2015) showed that their structural formulae are slightly different. These minerals are both triclinic, space group $P\bar{1}$. In order to show the structural relations between these species, and to avoid the use of the prefix 'beta-' which is not used elsewhere in the mineralogical nomenclature, betalomonosovite is renamed as paralomonosovite.
- Lammerite is monoclinic, space group $P2_1/c$, and lammerite- β is a polymorph having the same space group. Consequently, lammerite- β becomes paralammerite.

Unnecessary polymorph suffixes

Several examples occur where polymorph suffixes are unnecessary. Two situations can be distinguished as follows:

Minerals with polymorph suffixes but with different chemical compositions

Some mineral names have a polymorph suffix, but cannot be considered as true polymorphs due to distinct chemical compositions. In those cases, we recommend using the prefix 'meta-', which indicates a close but significantly different chemical composition. This prefix can still be used for a mineral with different (generally lower) hydration degrees, as well as the prefix 'hydro-' which indicates a higher hydration degree, compared to the root species.

The prefix meta- is already widely used in mineral nomenclature, where it generally designates two species with different water contents: meta-aluminite, meta-alunogen, meta-autunite, metacalcicouranoite, metahaiweeite, metaheinrichite, metahewettite, metahohmannite, metakahlerite, metamunirite, metanováčekite, metarauchite, metarossite, metasaléeite, metaschoepite, metasideronatrite, metastudtite, metaswitzerite, metatamboite, metatorbernite, metatyuyamunite, metauramphite, metauranocircite-I, metauranopilitite, metauranospinitite, metauraxite, metavanandriesscheite, metavanmeersscheite, metavanuralite, metavauxite, metavivianite, metazellerite and metazeunerite.

A few examples exist where the prefix designates minerals with chemical compositions significantly different from those of the root species: metadelrioite, metaköttigite and metaschoderite. The prefix meta- is also used for minerals with the same chemical composition as that of the root species, but with a different crystal structure: metacinnabar, metastibnite, metathénardite and metavariscite. Some of these names were given to denote the thermodynamic metastability of these species.

In addition, this prefix still exists in some species where the root-name has been discredited: meta-ankoleite, metaborite, metakirchheimerite, metalodèveite, metanatroautunite and metavoltine.

The following species are now covered by this guideline and are recommended for renaming though some require further study:

- Nováčekite-I contains 12 H₂O molecules per formula unit (pfu), nováčekite-II contains 10 H₂O molecules pfu, and metanováčekite contains 8 H₂O molecules pfu. Consequently, nováčekite-I is renamed hydronováčekite, and nováčekite-II is renamed nováčekite. The name of metanováčekite remains unchanged, as this species is the weakly-hydrated end-member.
- Joséite-A corresponds to Bi₄TeS₂, and joséite-B to Bi₄Te₂S. As joséite-B was the first historically-defined species (Atencio, 2020), it should become joséite, whereas joséite-A should be renamed metajoséite. These minerals were investigated recently by Cook *et al.* (2021), who demonstrated that they are valid species, however their official CNMNC status is still 'questionable'. For that reason, and while waiting for further structural investigations, we decided to keep these names unchanged.
- Rathite-IV is a questionable species, with a chemical composition significantly different from that of rathite. It should ideally become metarathite, but we decided to keep this name unchanged as a structural investigation of this questionable species is necessary.
- Halloysite-10Å and halloysite-7Å are both monoclinic, but due to different hydration degrees, the interlayer distances, $d_{001} = c \cdot \sin\beta$, are different. Bailey (1980) recommended adding the approximate value of $c \cdot \sin\beta$ as a suffix, but this procedure is ill-advised as such suffixes are similar to polytype suffixes. Halloysite-10Å is the most hydrated species, Al₂Si₂O₅(OH)₄·2H₂O, whereas halloysite-7Å is less hydrated, Al₂Si₂O₅(OH)₄. As halloysite-7Å corresponds to the first historically-defined species (Berthier, 1826), halloysite-7Å is renamed halloysite, and halloysite-10Å is renamed hydrohalloysite.

Minerals with polymorph suffixes that are no longer necessary

For some minerals, a polymorph suffix exists, though the original un-suffixed root-name does not exist anymore. In those case, we recommend deleting the unnecessary suffix.

The species affected by this guideline are:

- metauranocircite-I that becomes metauranocircite;
- taimyrite-I that becomes taimyrite; and
- uranocircite-II that becomes uranocircite.

Polysomatic sequences and related phases

Polysomes are mineral species with distinct chemistries, which are produced by the stacking of different structure modules. Polysomatic symbols have to be placed as a suffix, which indicates the number and types of modules which alternate in the structure. In the högbomite supergroup, such suffixes are used in ferrohögbomite-2N2S, ferronigerite-2N1S, ferronigerite-6N6S, ferrotaafeite-2N²2S, ferrotaafeite-6N³3S, magnesiohögbomite-2N2S, magnesiohögbomite-2N3S, magnesiohögbomite-2N4S, magnesiohögbomite-6N6S, magnesionigerite-2N1S, magnesionigerite-6N6S, magnesiotaafeite-2N²2S, magnesiotaafeite-6N³3S, zincohögbomite-2N2S and zincohögbomite-2N6S (Armbruster, 2002). The suffixes explicitly indicate the number of nolanite (N) and spinel (S) modules occurring in these mineral species.

In the sartorite group, the polysomes are produced by the stacking of the same basic unit with an *a* parameter of 4.2 Å (Topa *et al.*, 2017). The polysomes show the same $P2_1/c$ symmetry, and suffixes have been added to indicate the number of basic sartorite motifs involved in the stacking sequences. The crystal structures of heptasartorite, enneasartorite and hendekasartorite are characterised by the stacking of 7, 9 and 11 basic sartorite motifs, respectively.

In order to prevent any confusion, we recommend using different prefixes for crystal systems and for homologous series. For example, tetra- and hexa- prefixes are used to designate tetragonal and hexagonal crystal systems, however the prefixes quadra- and sena- can be used to distinguish minerals in homologous series.

This nomenclature scheme has been applied in the andorite series.

- Andorite VI and andorite IV are sulfosalts showing modular structures, characterised by the stacking of slabs along the *c* axis producing *c* unit-cell parameter values = $n \times 4.3$ Å. These names were given by Donnay and Donnay (1954), to indicate the *n* value of four in andorite IV, and of six in andorite VI. Strictly speaking, these minerals cannot be classified as polytypes, but rather as chemical twins; their observed chemical compositions are slightly different (Nespolo *et al.*, 2012). In the literature the prefixed names quatrandorite and senandorite also appear (Moëlo *et al.*, 1984; Nespolo *et al.*, 2012), and recently, arsenquatrandorite was described as an As-rich analogue of andorite IV (Topa *et al.* 2013). We consequently suggest uniformising the nomenclature of the andorite homologous series, by renaming andorite IV as quatrandorite, and andorite VI as senandorite.

Conclusions

These new guidelines for the nomenclature of polymorphs and polysomes must be followed for new mineral species proposals, when the authors decide to use structural prefixes or suffixes instead of a trivial name, as well as for nomenclature proposals. The guidelines will not be applied systematically to all existing mineral species, as the CNMNC recommends avoiding changing names, especially for grandfathered and well-established species (Hatert *et al.*, 2013). However, a few names have been modified for consistency; the species renamed in this paper are summarised in Table 1. Questionable species joséite-A, joséite-B, rathite-IV

and baumhauerite II have not been renamed at this stage as future studies are necessary to clarify their status.

Acknowledgements. The authors thank the reviewers and Editors for their comments.

Competing interests. The authors declare none.

References

- Arakcheeva A.V., Pushcharovskii D.Y., Rastsvetaeva R.K., Kashaev A.A. and Nadezhina T.N. (1995) Crystal structure of nigerite-6H. *Kristallografiya*, **40**, 639–644.
- Armbruster T. (2002) Revised nomenclature of högbomite, nigerite, and taaffeite minerals. *European Journal of Mineralogy*, **14**, 389–395.
- Armbruster T. and Feenstra A. (2004) Lithium in nigerite-group minerals. *European Journal of Mineralogy*, **16**, 247–254.
- Armbruster T., Bonazzi P., Akasaka M., Bermanec V., Chopin C., Gieré R., Heuss-Assbichler S., Liebscher A., Menchetti S., Pan Y. and Pasero M. (2006) Recommended nomenclature of epidote-group minerals. *European Journal of Mineralogy*, **18**, 551–567.
- Atencio D. (2020) *Type Mineralogy of Brazil: a Book in Progress*. Daniel Atencio editions, Brazil, 661 pp.
- Bailey S.W. (1980) Summary of recommendations of the AIPEA nomenclature committee. *The Canadian Mineralogist*, **18**, 143–150.
- Barresi A.A., Orlandi P. and Pasero M. (2007) History of ardenite and the new mineral ardenite-(V). *European Journal of Mineralogy*, **19**, 581–587.
- Bayliss P. (1986) Subdivision of the pyrite group, and a chemical and X-ray-diffraction investigation of ullmannite. *The Canadian Mineralogist*, **24**, 27–33.
- Berthier P. (1826) Analyse de l'halloysite. *Annales de Chimie et de Physique*, **32**, 332–334.
- Biagioni C., George L.L., Cook N. J., Makovicky E., Moëlo Y., Pasero M., Sejkora J., Stanley C.J., Welch M.D. and Bosi F. (2020) The tetrahedrite group: Nomenclature and classification. *American Mineralogist*, **105**, 109–122.
- Bindi L., Steinhardt P.J., Yao N. and Lu P.J. (2011) Icosahedrite, Al₆₃Cu₂₄Fe₁₃, the first natural quasicrystal. *American Mineralogist*, **96**, 928–931.
- Bindi L., Yao N., Lin C., Hollister L.S., Andronicos C.L., Distler V.V., Eddy M.P., Kostin A., Kryachko V., MacPherson G.J., Steinhardt W.M., Yudovskaya M. and Steinhardt P.J. (2015) Decagonite, Al₇₁Ni₂₄Fe₅, a quasicrystal with decagonal symmetry from the Khatyrka CV3 carbonaceous chondrite. *American Mineralogist*, **100**, 2340–2343.
- Bosi F., Hatert F., Hälenius U., Pasero M., Miyawaki R. and Mills S.J. (2019) On the application of the IMA–CNMNC dominant-valency rule to complex mineral compositions. *Mineralogical Magazine*, **83**, 627–632.
- Chopin C., Oberti R. and Cámara F. (2006) The arrojadite enigma: II. Compositional space, new members and nomenclature of the group. *American Mineralogist*, **91**, 1260–1270.
- Cook N.J., Ciobanu C.L., Wagner T. and Stanley C.J. (2007) Minerals of the system Bi-Te-Se-S related to the tetradymite archetype: review of classification and compositional variation. *The Canadian Mineralogist*, **45**, 665–708.
- Cook N.J., Ciobanu C.L., Slattery, A.D., Wade, B.P. and Ehrig, K. (2021) The mixed-layer structures of ikonolite, laitakarite, joséite-B and joséite-A. *Minerals*, **11**, 920.
- Coombs D.S., Alberti A., Armbruster T., Colella C., Galli E., Grice J.D., Liebau F., Mandarino J.A., Minato H., Nickel E.H., Passaglia E., Peacor D.R., Quartieri S., Rinaldi R., Ross M., Sheppard R.A., Tillmanns E. and Vezzalini G. (1997) Recommended nomenclature for zeolite minerals: report of the Subcommittee on Zeolites of the International Mineralogical Association, Commission on New Minerals and Mineral Names. *The Canadian Mineralogist*, **35**, 1571–1606.
- de Villiers, J.P.R. (1971) Crystal structures of aragonite, strontianite, and witherite. *American Mineralogist*, **56**, 758–767.
- de Villiers J.P.R., Liles D.C. and Becker M. (2009) The crystal structure of a naturally occurring 5C pyrrhotite from Sudbury, its chemistry, and vacancy distribution. *American Mineralogist*, **94**, 1405–1410.
- Donnay J.D.H. and Donnay G. (1954) Syntactic intergrowths in the andorite series. *American Mineralogist*, **39**, 161–171.

- Fronde J.W. and Wickman F.E. (1970) Molybdenite polytypes in theory and occurrence. II. Some naturally-occurring polytypes of molybdenite. *American Mineralogist*, **55**, 1857–1875.
- Graf D.L. (1961). Crystallographic tables for the rhombohedral carbonates. *American Mineralogist*, **46**, 1283–1316.
- Grew E.S., Hälenius U., Pasero M. and Barbier J. (2008) Recommended nomenclature for the sapphirine and surinamite group (sapphirine supergroup). *Mineralogical Magazine*, **72**, 839–876.
- Grey I.E., Elliott P., Mumme W.G., MacRae C.M., Kampf A.R. and Mills S.J. (2022) Redefinition of angastonite, $\text{CaMgAl}_2(\text{PO}_4)_2(\text{OH})_4 \cdot 7\text{H}_2\text{O}$, as an amorphous mineral. *European Journal of Mineralogy*, **34**, 215–221.
- Guinier A., Bokij G.B., Boll-Dornberger K., Cowley J.M., Đurovič S., Jagodzinski H., Krishna P., De Wolff P.M., Zvyagin B.B., Cox D.E. and Goodman P. (1984) Nomenclature of polytype structures. Report of the International Union of Crystallography Ad hoc Committee on the nomenclature of disordered, modulated and polytype structures. *Acta Crystallographica*, **A40**, 399–404.
- Güven N. and Burnham C.W. (1967) The crystal structure of 3T muscovite. *Zeitschrift für Kristallographie*, **125**, 163–183.
- Hatert F. and Burke E.A.J. (2008) The IMA–CNMNC dominant-constituent rule revisited and extended. *The Canadian Mineralogist*, **46**, 717–728.
- Hatert F., Pasero M., Perchiazzi N. and Theye T. (2007) Pumpellyite-(Al), a new mineral from Bertrix, Belgian Ardennes. *European Journal of Mineralogy*, **19**, 247–252.
- Hatert F., Mills S.J., Pasero M. and Williams P.A. (2013) CNMNC guidelines for the use of suffixes and prefixes in mineral nomenclature, and for the preservation of historical names. *European Journal of Mineralogy*, **25**, 113–115.
- Kampf A.R., Adams P.M., Kolitsch U. and Steele I.M. (2009) Meurigite-Na, a new species, and the relationship between phosphofibrite and meurigite. *American Mineralogist*, **94**, 720–727.
- Kampf A.R., Mills S.J., Rumsey M.S., Dini M., Birch W.D., Spratt J., Pluth J.J., Steele I.M., Jenkins R.A. and Pinch W.W. (2012) The heteropolymolybdate family: structural relations, nomenclature scheme and new species. *Mineralogical Magazine*, **76**, 1175–1207.
- Khomyakov A.P., Nechelyustov G.N., Ferraris G., Gula A. and Ivaldi G. (2001) Labuntsovite-Fe and labuntsovite-Mg - two new minerals from the Khibina and Kovdor alkaline massifs, Kola Peninsula. *Zapiski Vserossijskogo Mineralogicheskogo Obshchestva*, **130**, 36–45.
- Kolitsch U., Mills S.J., Miyawaki R. and Blass G. (2012) Ferriallanite-(La), a new member of the epidote supergroup from the Eifel, Germany. *European Journal of Mineralogy*, **24**, 741–747.
- Levinson A.A. (1966) A system of nomenclature for rare-earth minerals. *American Mineralogist*, **51**, 152–158.
- Makovicky E. (1997) Modular crystal chemistry of sulphosalts and other complex sulphides. Pp. 237–271 in: *Modular Aspects of Minerals* (Stefano Merlino, editor). EMU Notes in Mineralogy, vol. 1.
- Mazzi F. and Galli E. (1978) Is each analcime different? *American Mineralogist*, **63**, 448–460.
- Mills S.J., Hatert F., Nickel E.H. and Ferraris G. (2009) The standardisation of mineral group hierarchies: application to recent nomenclature proposals. *European Journal of Mineralogy*, **21**, 1073–1080.
- Miyawaki R., Yokoyama K. and Husdal T. (2013) Bastnäsite-(Nd), a new dominant member of the bastnäsite group from the Stetind pegmatite, Tysfjord, Nordland, Norway. *European Journal of Mineralogy*, **25**, 187–191.
- Moëlo Y., Makovicky E. and Karup-Møller S. (1984) New data on the minerals of the andorite series. *Neues Jahrbuch für Mineralogie, Monatshefte*, **1984**, 175–182.
- Moëlo Y., Makovicky E., Mozgova N.N., Jambor J.L., Cook N., Pring A., Paar W., Nickel E.H., Graeser S., Karup-Møller S., Balic-Žunic T., Mumme W.G., Vurro F., Topa D., Bindi L., Bente K. and Shimizu M. (2008) Sulfosalt systematics: a review. Report of the sulfosalt sub-committee of the IMA Commission on Ore Mineralogy. *European Journal of Mineralogy*, **20**, 7–46.
- Momma K. and Izumi F. (2011) VESTA 3 for the three-dimensional visualization of crystal, volumetric and morphology data. *Journal of Applied Crystallography*, **44**, 1272–1276.
- Nespolo M., Ozawa T., Kawasaki Y. and Sugiyama K. (2012) Structural relations and pseudosymmetries in the andorite homologous series. *Journal of Mineralogical and Petrological Science*, **107**, 226–243.
- Nickel E.H. and Grice J.D. (1998) The IMA commission on new minerals and mineral names: procedures and guidelines on mineral nomenclature. *The Canadian Mineralogist*, **36**, 913–926.
- Pasero M. (2023) *The New IMA List of Minerals*. International Mineralogical Association. Commission on new minerals, nomenclature and classification (IMA–CNMNC) [<http://cnmnc.main.jp/>].
- Pechar F. (1988) The crystal structure of natural monoclinic analcime ($\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$). *Zeitschrift für Kristallographie – Crystalline Materials*, **184**, 63–70.
- Pósfai M. and Dóony I. (1990a) Pyrrhotite superstructures. Part I: Fundamental structures of the NC (N = 2, 3, 4 and 5) type. *European Journal of Mineralogy*, **2**, 525–528.
- Pósfai M. and Dóony I. (1990b) Pyrrhotite superstructures. Part II: A TEM study of 4C and 5C structures. *European Journal of Mineralogy*, **2**, 529–538.
- Powell A.V., Vaqueiro P., Knight K.S., Chapon L.C. and Sanchez R.D. (2004) Structure and magnetism in synthetic pyrrhotite Fe_7S_8 : A powder neutron-diffraction study. *Physical Review*, **B70**, 014415.
- Pratesi G., Cipriani C., Giuli G. and Birch W.D. (2003) Santabarbarite, a new amorphous phosphate mineral. *European Journal of Mineralogy*, **15**, 185–192.
- Schönfeld B., Huang J.J. and Moss S.C. (1983) Anisotropic mean-square displacements (MSD) in single crystals of 2H- and 3R-MoS₂. *Acta Crystallographica*, **B39**, 404–407.
- Schreyer W., Armbruster T., Bernhardt H.-J. and Medenbach O. (2003) Pertsevite, a new silicatian magnesioborate mineral with an end-member composition $\text{Mg}_2\text{BO}_3\text{F}$, in kotoite marble from east of Verkhojansk, Sakha-Yakutia, Russia. *European Journal of Mineralogy*, **15**, 1007–1018.
- Sokolova E., Abdu Y., Hawthorne F.C., Genovese A., Cámara F. and Khomyakov A.P. (2015) From structure topology to chemical composition. XVIII. Titanium silicates: revision of the crystal structure and chemical formula of betalomonosovite, a group-IV TS-block mineral from the Lovozero alkaline massif, Kola Peninsula, Russia. *The Canadian Mineralogist*, **53**, 401–428.
- Takeda H., Haga N. and Sadanaga R. (1971) Structural investigation of polymorphic transition between 2M₂-, 1M-lepidolite and 2M₁ muscovite. *Mineralogical Journal*, **6**, 203–215.
- Topa D. and Makovicky E. (2016) Argentobaumhauerite: name, chemistry, crystal structure, comparison with baumhauerite, and position in the Lengenbach mineralization sequence. *Mineralogical Magazine*, **80**, 819–840.
- Topa D., Makovicky E., Putz H., Zagler G. and Tajjedine H. (2013) Arsenquatranderite, IMA 2012–087. CNMNC Newsletter No. 16, August 2013, page 2696. *Mineralogical Magazine*, **77**, 2695–2709.
- Topa D., Makovicky E., Stoeger B. and Stanley C. (2017) Heptasartorite, $\text{Tl}_7\text{Pb}_{22}\text{As}_{55}\text{S}_{108}$, enneasartorite, $\text{Tl}_6\text{Pb}_{32}\text{As}_{70}\text{S}_{140}$ and hendekasartorite, $\text{Tl}_2\text{Pb}_{48}\text{As}_{82}\text{S}_{172}$, three members of the anion-omission series of ‘sartorites’ from the Lengenbach quarry at Binntal, Wallis, Switzerland. *European Journal of Mineralogy*, **29**, 701–712.
- Trill R.J. (1963) A rhombohedral polytype of molybdenite. *The Canadian Mineralogist*, **7**, 524–526.
- Velde B. (1965) Experimental determination of muscovite polymorph stabilities. *American Mineralogist*, **50**, 436–449.
- Vignola P., Hatert F., Baijot M., Dal Bo F., Andò S., Bersani D., Pavese A., Risplendente A. and Vanini F. (2016) Arrojadite-(BaNa), $\text{BaNa}_3(\text{Na,Ca})\text{Fe}_{13}^{2+}\text{Al}(\text{PO}_4)_{11}(\text{PO}_3\text{OH})(\text{OH})_2$, a new phosphate mineral from the Luna Albite pegmatite, Dorio commune, Lecco province, Italy. *The Canadian Mineralogist*, **54**, 1021–1032.
- Vignola P., Hatert F., Rotiroti N., Nestola F., Risplendente A. and Vanini F. (2019a) Jahnsite-(MnMnFe), $\text{Mn}^{2+}\text{Mn}^{2+}\text{Fe}_2^{2+}\text{Fe}_3^{3+}(\text{PO}_4)_4(\text{OH})_2 \cdot 8\text{H}_2\text{O}$, a new phosphate mineral from the Malpensata pegmatite, Olgiasca, Colico municipality, Lecco province, Italy. *The Canadian Mineralogist*, **57**, 225–233.
- Vignola P., Hatert F., Baijot M., Rotiroti N., Risplendente A. and Varvello S. (2019b) Jahnsite-(MnMnMg), $\text{Mn}^{2+}\text{Mn}^{2+}\text{Mg}_2^{2+}\text{Fe}_3^{3+}(\text{PO}_4)_4(\text{OH})_2 \cdot 8\text{H}_2\text{O}$, a new phosphate mineral species from Sapucaia pegmatite, Sapucaia Do Norte, Galiléia, Minas Gerais, Brazil. *The Canadian Mineralogist*, **57**, 363–370.
- Wickman F.E. and Smith D.K. (1970) Molybdenite polytypes in theory and occurrence. I. Theoretical considerations of polytypism in molybdenite. *American Mineralogist*, **55**, 1843–1856.