Eur. J. Mineral., 35, 1027–1030, 2023
https://doi.org/10.5194/ejm-35-1027-2023

European Journal of Mineralogy
Open Access

Changes to the cerite group nomenclature

Daniel Atencio[1], Andrezza A. Azzi[1], Kai Qu[2,3], Ritsuro Miyawaki[4], Ferdinando Bosi[5], and Koichi Momma[4]

[1]Instituto de Geociências, Universidade de São Paulo, Rua do Lago, 562, 05508-080 São Paulo, SP, Brazil
[2]Tianjin Center, China Geological Survey, Hedong, 300170 Tianjin, China
[3]School of Earth Sciences and Engineering, Nanjing University, Xixia, 210023 Nanjing, China
[4]National Museum of Nature and Sciences, 4-1-1 Amakubo, Tsukuba, Ibaraki 305-0005, Japan
[5]Dipartimento di Scienze della Terra, Sapienza Università di Roma, Piazzale Aldo Moro 5, 00185 Rome, Italy

Correspondence: Daniel Atencio (datencio@usp.br)

Received: 27 July 2023 – Revised: 6 October 2023 – Accepted: 13 October 2023 – Published: 23 November 2023

Abstract. The cerite and merrillite groups belong to the cerite supergroup. Some nomenclature and classification changes have been made to the cerite group, whereas the merrillite group remains unchanged. Minerals of the cerite group have the general formula $A_9XM[T_7O_{24}Ø_4]Z_3$, where T is Si. The cerite group, from now on, is subdivided into two subgroups, cerite and taipingite. The root name will be cerite and taipingite if the Z anions are dominated by (OH) and F, respectively. The prefix ferri- or alumino- will be added if the M cations are dominated by Fe^{3+} or Al, respectively. If the M cation is Mg, there will be no prefix. Taking into account the valency-imposed double site occupancy and the site total charge approach, a double suffix will be used to represent the essential A constituents in the general chemical formula. Cerite-(Ce), aluminocerite-(Ce), ferricerite-(La), and taipingite-(Ce) have been renamed cerite-(CeCa), aluminocerite-(CeCa), ferricerite-(LaCa), and taipingite-(CeCa), respectively. The newly approved mineral aluminotaipingite-(CeCa) also belongs to the taipingite subgroup.

The cerite supergroup (Atencio and Azzi, 2020) consists of two groups of isostructural trigonal $R3c$ (no. 161) minerals, namely, cerite (silicates) and merrillite (phosphates) groups. The merrillite group is subdivided into two subgroups: merrillite (without OH in the Ø site) and whitlockite (with OH in the Ø site). The nomenclature introduced by Atencio and Azzi (2020) is based on the dominant species of the dominant valence at each site.

The recent discoveries of four new members in the cerite group, following the four valid members already approved, make it necessary to revise the nomenclature of this group. One of these new species, aluminotaipingite-(CeCa) IMA2022-126, has already been approved by the CNMNC-IMA (Commission on New Minerals, Nomenclature and Classification of the International Mineralogical Association) and published (Campostrini et al., 2023); two are under review by the CNMNC-IMA; and one is under study.

The crystal structure of these minerals involves three 8- and 9-fold coordinated A sites, one 6-fold coordinated X site, one octahedral M site, and three $[TO_3(Ø)]$ tetrahedral groups. The crystal structure of cerite supergroup minerals consists of $[M(TO_4)_6]$ clusters linked by $\{A_9X(TO_3Ø)\}$ groups.

The general chemical formula of cerite supergroup minerals is $A_9XM[T_7O_{24}Ø_4]Z_3$, where the letters, except for O for oxygen, represent groups of atoms (and not structural sites) on which to apply the dominant constituent and valency rule and the endmember concept. A = REE, Ca, Sr, Na, and □; X = □, Ca, Na, and Fe^{2+}; M = Mg, Fe^{2+}, Fe^{3+}, Al, and Mn; T = Si and P; Ø = O and OH; and Z = □, OH, and F, where REE is rare earth elements of yttrium and lanthanoids (La–Lu) (Atencio and Azzi, 2020). The general structural formula of cerite supergroup minerals is $A1_3A2_3A3_3XM1[T1_3T2_3T3O_{24}Ø1_3Ø10]Z1Z2Z3$. The letter Z represents the set of anions occurring at three nonequivalent $Z1$, $Z2$, and $Z3$ sites; thus, the composition $Z = F_{1.8}(OH)_{1.2}$ is consistent with the endmember composition $Z = F_3$ (as F > OH). Grouping atoms over similar sites,

https://doi.org/10.5194/ejm-35-1027-2023

Table 1. Ideal formula, dominant constituents in the general chemical formula, and unit-cell parameters ($R3c$) for the cerite supergroup minerals.

	Ideal formula	A_9	X	M	T_7	O_{24}	$Ø_4$	Z_3	Unit-cell parameters (a, c, V)			Ref.
Cerite group												
Cerite subgroup												
Cerite-(CeCa)	$(Ce_7Ca_2)Mg(SiO_4)_3(SiO_3OH)_4(OH)_3$	Ce_7Ca_2	□	Mg	Si	O	OH	OH	10.779	38.0610	3829.73	1
Ferricerite-(LaCa)	$(La_6Ca_3)Fe^{3+}(SiO_4)_3(SiO_3OH)_4(OH)_3$	La_6Ca_3	□	Fe^{3+}	Si	O	OH	OH	10.7493	38.318	3834.37	2
Aluminocerite-(CeCa)	$(Ce_6Ca_3)Al(SiO_4)_3(SiO_3OH)_4(OH)_3$	Ce_6Ca_3	□	Al	Si	O	OH	OH	10.6450	38.019	3730.98	3
Taipingite subgroup												
Taipingite-(CeCa)	$(Ce_7Ca_2)Mg(SiO_4)_3(SiO_3OH)_4F_3$	Ce_7Ca_2	□	Mg	Si	O	OH	F	10.7246	37.9528	3780.4	4
Aluminotaipingite-(CeCa)	$(Ce_6Ca_3)Al(SiO_4)_3(SiO_3OH)_4F_3$	Ce_6Ca_3	□	Al	Si	O	OH	F	10.658	37.865	3725	5
Merrillite group												
Merrillite subgroup												
Merrillite	$Ca_9NaMg(PO_4)_7$	Ca_9	Na	Mg	P	O	O	□	10.3444	37.0182	3430.5	6
Ferromerrillite	$Ca_9NaFe^{2+}(PO_4)_7$	Ca_9	Na	Fe^{2+}	P	O	O	□	10.372	37.217	3467	7
Keplerite	$Ca_9(Ca_{0.5}□_{0.5})Mg(PO_4)_7$	Ca_9	$Ca_{0.5}□_{0.5}$	Mg	P	O	O	□	10.3330	37.0668	3427.4	8
Matyhite	$Ca_9(Ca_{0.5}□_{0.5})Fe^{2+}(PO_4)_7$	Ca_9	$Ca_{0.5}□_{0.5}$	Fe^{2+}	P	O	O	□	10.456	37.408	3541.6	9
Deynekoite	$Ca_9Fe^{3+}(PO_4)_7$	Ca_9	□	Fe^{3+}	P	O	O	□	10.372	37.217	3467	10
Changesite-(Y)	$(Ca_8Y)Fe^{2+}(PO_4)_7$	Ca_8Y	□	Fe^{2+}	P	O	O	□	10.3957	37.207	3482.27	11
Whitlockite subgroup												
Whitlockite	$Ca_9Mg(PO_4)_6(PO_3OH)$	Ca_9	□	Mg	P	O	O_3OH	□	10.330	37.103	3428.79	12
Strontiowhitlockite	$Sr_9Mg(PO_4)_6(PO_3OH)$	Sr_9	□	Mg	P	O	O_3OH	□	10.644	39.54	3880	13
Hedegaardite	$(Ca_8Na)(Ca_{0.5}□_{0.5})Mg(PO_4)_6(PO_3OH)$	Ca_8Na	$Ca_{0.5}□_{0.5}$	Mg	P	O	O_3OH	□	10.3519	37.064	3439.7	14
Wopmayite	$(Ca_6Na_3)Mn(PO_4)_3(PO_3OH)_4$	Ca_6Na_3	□	Mn	P	O	OH	□	10.3926	37.1694	37.1694	15

[1] Moore and Shen (1983). [2] Pakhomovsky et al. (2002). [3] Nestola et al. (2009). [4] Qu et al. (2020). [5] Campostrini et al. (2023). [6] Xie et al. (2015). [7] Britvin et al. (2016). [8] Britvin et al. (2021). [9] Hwang et al. (2019). [10] Galuskin et al. (2023). [11] Li et al. (2022). [12] Calvo and Gopal (1975). [13] Britvin et al. (1991). [14] Witzke et al. (2015). [15] Cooper et al. (2013).

such as $A(1,2,3)$, $T(1,2,3)$, and $Z(1,2,3)$, helps prevent the proliferation of mineral species with endmember formulae based on the structural formula, where each structural sites can be used (Nickel and Grice, 1998) to define an endmember formula (Hawthorne, 2002). For example, the three independent anion Z sites may result in an endmember composition like $F_2(OH)$. In this way, cerite nomenclature is based on the chemical formula, and, in principle, only the chemical information is needed for the mineral identification.

The cerite group, from now on, is subdivided into two subgroups, cerite and taipingite.

The root name will be cerite and taipingite if the Z anions are dominated by (OH) and F, respectively. The prefix ferri- or alumino- will be added if the M cations are dominated by Fe^{3+} or Al, respectively. If the M cation is Mg, there will be no prefix. Taking into account the valency-imposed double site occupancy (Hatert and Burke, 2008; Hatert et al., 2013) and the site total charge approach of Bosi et al. (2019), a double suffix will be used to represent the essential A constituents in the general chemical formula. Cerite-(Ce), aluminocerite-(Ce), ferricerite-(La), and taipingite-(Ce) have been renamed cerite-(CeCa), aluminocerite-(CeCa), ferricerite-(LaCa), and taipingite-(CeCa), respectively. The newly approved mineral aluminotaipingite-(CeCa) also belongs to the taipingite subgroup.

The charge balance of cerite group minerals is according to the following substitution mechanism: $^{A}[REE_8\square]^{+24} + {}^{M}(Fe,Al)^{3+} = {}^{A}[REE_6(Ca,Sr)_3]^{+24} + {}^{M}(Fe,Al)^{3+} = {}^{A}[REE_7(Ca,Sr)_2]^{+25} + {}^{M}(Mg,Fe)^{2+}$.

The nomenclature of merrillite group remains as it current is. Table 1 summarizes all the currently valid species in the cerite supergroup.

Data availability. No data sets were used in this article.

Author contributions. All authors contributed to the conception of the project and the writing of the paper.

Competing interests. At least one of the (co-)authors is a guest member of the editorial board of *European Journal of Mineralogy* for the special issue "New minerals, nomenclature, and classification: EJM support". The peer-review process was guided by an independent editor, and the authors also have no other competing interests to declare.

Disclaimer. Publisher's note: Copernicus Publications remains neutral with regard to jurisdictional claims made in the text, published maps, institutional affiliations, or any other geographical representation in this paper. While Copernicus Publications makes every effort to include appropriate place names, the final responsibility lies with the authors.

Special issue statement. This article is part of the special issue "New minerals: EJM support". It is not associated with a conference.

Acknowledgements. We acknowledge Sergey Krivovichev, Anthony Kampf, the anonymous referee, and all members of the IMA Commission on New Minerals, Nomenclature and Classification for their helpful suggestions and comments.

Financial support. This research has been supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo; project 2019/23498-0) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico; project 303431/2019-9).

Review statement. This paper was edited by Sergey Krivovichev and reviewed by Anthony Kampf and one anonymous referee.

References

Atencio, D. and Azzi A. A.: Cerite: a new supergroup of minerals and cerite-(La) renamed ferricerite-(La), Mineral. Mag., 84, 928–931, 2020.

Bosi, F., Hatert, F., Hålenius, U., Pasero, M., Miyawaki, R., and Mills, S. J.: On the application of the IMA–CNMNC dominant-valency rule to complex mineral compositions, Mineral. Mag., 83, 627–632, 2019.

Britvin, S. N., Pakhomovskii, Y. A., Bogdanova, A. N., and Skiba, V. I.: Strontiowhitlockite, $Sr_9Mg(PO_3OH)(PO_4)_6$, a new mineral from the Kovdor deposit Kola Peninsula U.S.S.R, Can. Mineral., 29, 87–93, 1991.

Britvin, S. N., Krivovichev, S. V., and Armbruster, T.: Ferromerrillite, $Ca_9NaFe^{2+}(PO_4)_7$, a new mineral from the Martian meteorites and some insights into merrillite–tuite transformation in shergottites, Eur. J. Mineral., 28, 125–136, 2016.

Britvin, S. N., Galuskina, I. O., Vlasenko, N. S., Vereshchagin, O. S., Bocharov, V. N., Krzhizhanovskaya, M. G., Shilovskikh, V. V., Galuskin, E. V., Vapnik, E. V., and Obolonskaya, E. V.: Keplerite, $Ca_9(Ca_{0.5}\square_{0.5})Mg(PO_4)_7$, a new meteoritic and terrestrial phosphate isomorphous with merrillite, $Ca9NaMg(PO_4)_7$, Am. Mineral., 106, 1917–1927, 2021.

Calvo, C. and Gopal, R.: The crystal structure of whitlockite from the Palermo quarry, Am. Mineral., 60, 120–133, 1975.

Campostrini, I., Demartin, F., Finello, G., and Vignola, P.: Aluminotaipingite-(CeCa), $(Ce_6Ca_3)Al(SiO_4)_3[SiO_3(OH)]_4F_3$, a new member of the cerite-supergroup minerals, Mineral. Mag., 87, 741–747, https://doi.org/10.1180/mgm.2023.51, 2023.

Cooper, M. A., Hawthorne, F. C., Abdu, Y. A., Ball, N. A., Ramik, R. A., and Tait, K. T.: Wopmayite, ideally $Ca_6Na_3Mn(PO_4)_3(PO_3OH)_4$, a new phosphate mineral from the Tanco Mine Bernic Lake Manitoba: description and crystal structure, Can. Mineral., 51, 93–106, 2013.

Galuskin, E. V., Stachowicz, M., Galuskina, I. O., Woźniak, K., Vapnik, Y., Murashko, M. N., and Zieliński, G.: Deynekoite, $Ca_9Fe^{3+}(PO_4)_7$ – a new mineral of the merrillite group from phosphide-bearing contact facies of par-

alava, Hatrurim Complex, Daba-Siwaqa, Jordan. Mineral. Mag., https://doi.org/10.1180/mgm.2023.71, online first, 2023.

Hatert, F. and Burke, E. A. J.: The IMA-CNMNC dominant-constituent rule revisited and extended, Can. Mineral., 46, 717–728, 2008.

Hatert, F., Mills, S. J., Pasero, M., and Williams P. A.: CNMNC guidelines for the use of suffixes and prefixes in mineral nomenclature, and for the preservation of historical names, Eur. J. Mineral., 25, 113–115, https://doi.org/10.1127/0935-1221/2013/0025-2267, 2013.

Hawthorne, F. C.: The use of end-member charge-arrangements in defining new mineral species and heterovalent substitutions in complex minerals, Can. Mineral., 40, 699–710, 2002.

Hwang, S. L., Shen, P., Chu, H. T., Yui, T. F., Varela, M. E., and Iizuka, Y.: New minerals tsangpoite $Ca_5(PO_4)_2(SiO_4)$ and matyhite $Ca_9(Ca_{0.5}\square_{0.5})Fe(PO_4)_7$ from the D'Orbigny angrite, Mineral. Mag., 83, 293–313, 2019.

Li, T., Li, Z., Huang, Z., Zhong, J., Fan, G., Guo, D., Qin, M., Zhang, J., Li, J., Liu, H., Qiu, L., Wang, F., He, S., Yu, A., Liu, R., Wu, Y., Deng, L., Tai, Z., He, Y., and Lin, Y.: Changesite-(Y), IMA 2022-023, in: CNMNC Newsletter 69, Eur. J. Mineral., 34, https://doi.org/10.5194/ejm-34-463-2022, 2022.

Moore, P. B. and Shen, J. C.: Cerite, RE9 $(Fe^{3+},Mg)(SiO_4)_6(SiO_3OH)(OH)_3$: Its crystal structure and relation to whitlockite, Am. Mineral., 68, 996–1003, 1983.

Nestola, F., Guastoni, A., Cámara, F., Secco, L., Dal Negro, A., Pedron, D., and Beran, A.: Aluminocerite-Ce: A new species from Baveno, Italy: Description and crystal-structure determination, Am. Mineral., 94, 487–493, 2009.

Nickel, E. H. and Grice, J. D.: The IMA Commission on New Minerals and Mineral Names: procedures and guidelines on mineral nomenclature, Can. Mineral., 36, 913–926, 1998.

Pakhomovsky, Y. A., Men'Shikov, Y. P., Yakovenchuk, V. N., Ivanyuk, G. Y., Krivovichev, S. V., and Burns, P. C.: Cerite-(La), $(La,Ce,Ca)_9(Fe,Ca,Mg)(SiO_4)_3[SiO_3(OH)]_4(OH)_3$, a new mineral species from the khibina alkaline massif: occurrence and crystal structure, Can. Mineral., 40, 1177–1184, 2002.

Qu, K., Sima, X. Z., Fan, G., Li, G. W., Shen, G. F., Chen, H. K., Liu, X., Yin, Q. Q., Li, T., and Wang, Y. J.: Taipingite-(Ce), $(Ce_7Ca_2)\sum_9 Mg(SiO_4)_3[SiO_3(OH)]_4F_3$, a new mineral from the Taipingzhen REE deposit, North Qinling Orogen, Central China, Geosci. Front., 11, 2339–2346, 2020.

Xie, X., Yang, H., Gu, X., and Downs, R. T.: Chemical composition and crystal structure of merrillite from the Suizhou meteorite, Am. Mineral., 100, 2753–2756, 2015.

Witzke, T., Phillips, B. L., Woerner, W., Coutinho, J. M. V., Färber, G., and Contreira Filho, R. R.: Hedegaardite, IMA 2014-069, in: CNMNC Newsletter 23, Mineral. Mag., 79, 51–58, 2015.