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# THE NOMENCLATURE OF EUDIALYTE-GROUP MINERALS[¶]

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## ABSTRACT

This is the final report on the nomenclature of eudialyte-group minerals by the Eudialyte Nomenclature Subcommittee established by the Commission on New Minerals and Mineral Names of the International Mineralogical Association. This report is an updated and slightly revised version of the one that was formally accepted by the Commission. Eudialyte-group minerals are Na-rich zirconosilicates with varying amounts of the cations Ca, Fe, Mn, *REE*, Sr, Nb, K, Y, Ti, H and W. They are trigonal, $a \approx 14$ Å, $c \approx 30$ Å (rarely 60 Å), crystallizing in *R*3*m*, *R*3*m* or *R*3. In order to encompass most substitutions known thus far, the general formula of eudialyte (*s.l.*) is $[N(1)N(2)N(3)N(4)N(5)]_3[M(1a)M(1b)]_3M(2)_3M(3)M(4)Z_3[Si_{24}O_{72}]O'_4X_2$, $X$ = Cl, F, OH or $CO_3$; Z = 3. Lately, the number of minerals in this group has increased rapidly and is now approaching twenty. Three different principles of naming minerals have been tested: (i) a hierarchical system with root names modified by use of modifiers and Levinson suffixes, (ii) a unique-name system with use of modifiers with or without Levinson suffixes, and (iii) a system based on the Linnean principle used in the biological world. We conclude that a hierarchical nomenclature system does not work for eudialyte-group minerals. Such a system would be either a multi-level system that would become either very complicated and cumbersome, with disproportionately many root names, or a flatter system with fewer root names but monstrously long names with formula-like endings, *e.g.*, eudialyte-NaNaNaNaNaCaMnNbSiF. Conventional unique names with a maximum of one cation prefix are recommended for the eudialyte-group minerals, and this prefix should refer to the *M*(2) site, as in ferrokentbrooksite. One anion prefix is acceptable as well. A Linnean system composed of a genus name with a species suffix, *e.g.*, eudialyte khomyakovite, is evaluated. However, there is no tradition for binary names in mineralogy, and the system is not endorsed.

*Keywords*: eudialyte, eudialyte group, nomenclature report, Commission on New Minerals and Mineral Names.

## SOMMAIRE

Ceci est le rapport final portant sur la nomenclature des minéraux du groupe de l'eudialyte, rédigé par le sous-comité établi par la Commission sur les Nouveaux Minéraux et les Noms de Minéraux de l'Association Minéralogique Internationale. Il s'agit d'une version mise à jour et légèrement révisée du rapport qui a été formellement accepté par la Commission. Les minéraux du groupe de l'eudialyte sont des zirconosilicates riches en sodium, contenant des quantités variables des cations Ca, Fe, Mn, terres

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[¶] Report from the Eudialyte Nomenclature Subcommittee (ENS) of the IMA Commission on New Minerals and Mineral Names (CNMMN).

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rares, Sr, Nb, K, Y, Ti, H et W. Leur structure est trigonale, $a \approx 14$ Å, $c \approx 30$ Å (rarement 60 Å), répondant au groupe spatial $R\bar{3}m$, $R3m$ ou $R3$. Afin d'expliquer la plupart des substitutions connues jusqu'à maintenant, la formule générale de l'eudialyte (*s.l.*) serait $[N(1)N(2)N(3)N(4)N(5)]_3[M(1a)M(1b)]_3M(2)_3M(3)M(4)Z_3[Si_{24}O_{72}]O'_4X_2$, $X$ = Cl, F, OH or $CO_3$; Z = 3. Dernièrement, nous avons vu le nombre de minéraux grandir rapidement; ils sont maintenant presque vingt. Nous avons évalué trois principes distincts de nomenclature: (i) un système hiérarchique ayant une série de racines modifiées par des qualificatifs et des suffixes de Levinson, (ii) un système fondé sur une série de noms uniques, utilisés avec un qualificatif avec ou sans suffixes de Levinson, et (iii) un système linnéen, tel qu'utilisé en biologie. Nous croyons qu'un système hiérarchique de nomenclature ne fonctionnerait pas dans le cas des minéraux du groupe de l'eudialyte. Il serait soit un système à plusieurs niveaux qui deviendrait soit très compliqué et lourd, avec un nombre de noms de racines hors de toute proportion, ou un système plus uniforme avec un nombre restreint de racines, mais avec des noms monstrueusement longs, avec une terminaison semblable à une formule, par exemple eudialyte-NaNaNaNaNaCaMnNbSiF. Nous recommandons les noms uniques conventionnels, ayant un maximum d'un préfixe pour spécifier le cation, et ce préfixe devrait porter sur l'occupant du site *M*(2), par exemple le cas de la ferrokentbrooksite. Un préfixe définissant l'anion prédominant serait aussi acceptable. Nous avons aussi évalué un système linnéen, composé de nom du genre et d'un suffixe pour indiquer l'espèce, par exemple eudialyte khomyakovite. Il n'y a toutefois aucune tradition de noms binaires en minéralogie, et nous ne proposons pas l'adoption d'un tel système.

(Traduit par la Rédaction)

*Keywords*: eudialyte, groupe de l'eudialyte, rapport de nomenclature, Commission des Nouveaux Minéraux et des Noms de Minéraux.

## Introduction

Eudialyte, a Na-rich zirconosilicate with varying amounts of the cations Ca, Fe, Mn, *REE*, Sr, Nb, Ta, K, Y, Ti, W and H, was first described from Kangerdluarssuk, in the Ilímaussaq alkaline complex, South Greenland (Stromeyer 1819). Since then, a very large number of eudialyte samples have been analyzed from this and other localities, and have been found to display a wide variation in chemical composition.

Golyshev *et al.* (1971) and Giuseppetti *et al.* (1971) independently solved the basic structure of eudialyte and showed it to be a cyclosilicate with both nine- and three-membered rings of $[SiO_4]$ tetrahedra. The former authors solved the structure in space group *R*3*m*, the latter in *R*3*m*. Subsequent refinements of the structure, *e.g.*, Rastsvetaeva & Andrianov (1987), Rastsvetaeva & Borutskii (1988), Rastsvetaeva *et al.* (1988, 1990), provided additional structural information on eudialyte-group phases of different compositions, all in *R*3*m*. Still, until recently, some aspects of the crystal chemistry of the group remained obscure. For example, the nature of the principal substitutions, numbers of anions and numbers of Si atoms per formula unit (*apfu*) were still associated with considerable uncertainty.

Johnsen & Gault (1997) studied the chemical variation in eudialyte using results of electron-microprobe analysis. They concluded that a solid-solution series exists between the classic type of eudialyte rich in Si, Ca, Fe and Cl and compositions rich in Nb, *REE*, Mn and F, such as kentbrooksite (Johnsen *et al.* 1998). On the basis of electron-microprobe information alone, the authors of that study could only address certain problems concerning this complex group of minerals. Johnsen & Grice (1999) examined the crystal-chemical properties of samples of eudialyte (*sensu lato*) specifically selected from the material of Johnsen & Gault (1997), a study principally based on single-crystal structure-refinement data. They concluded that a complete formula of a eudialyte-group mineral requires crystal-structure data, whereas an acceptable empirical formula in most cases can be calculated from the crystal-chemical relationships derived in their study. Johnsen & Grice (1999) further discussed aspects of a site-assignment procedure relevant for eudialyte-group minerals and also demonstrated that space group *R*3 (146) is possible in this group, along with *R*3*m* (160) and *R*3*m* (166).

This new insight into the crystal chemistry of eudialyte (*s.l.*) has resulted in the transformation of the mineral eudialyte into a group of minerals, all having the fundamental eudialyte structure-type. A number of proposals have recently been submitted to the Commission on New Minerals and Mineral Names of the International Mineralogical Association (CNMMN), some of which concern minerals with doubling of the *c* axis parameter as in alluaivite (Rastsvetaeva *et al.* 1990). Present members of the eudialyte group, including the recently approved species, are presented in Table 1. More proposals are inevitable, and the CNMMN membership has requested that a nomenclature scheme be developed for the eudialyte group. This report is an attempt to meet that request. In its present form, it is an updated and slightly revised version of the report that was formally accepted by the Commission.

## Overview of the Structure

The site nomenclature adopted here is based on that of Johnsen & Grice (1999), with a minor modification. Site *Si*(7) is relabeled *M*(4), since Si, although usually the predominant element, can be substituted, as indicated by new data. The full notation for members of all three space groups can be read from Table 2.

The most characteristic property of the eudialyte structure is the unique combination of three- and nine-membered rings of $[SiO_4]$ tetrahedra (Golyshev *et al.* 1971, Giuseppetti *et al.* 1971). These $[Si_3O_9]^{6-}$ and $[Si_9O_{27}]^{18-}$ rings are arranged in layers perpendicular to [001] (Figs. 1, 2). Two such layers, related by a center or a pseudocenter of symmetry, embrace a layer of discrete rings of six $[M(1)O_6]$ octahedra linked together by $[M(2)O_n]$ polyhedra forming a 2:1 slab. The 2:1 slabs are cross-linked by Zr in octahedral coordination and related to one another in accordance with rhombohedral symmetry. This open structure is filled with $[Na\phi_n]$ polyhedra in which Na may have various coordinations ($\phi$: unspecified ligand).

TABLE 1. PRESENT MEMBERS OF THE EUDIALYTE GROUP

**alluaivite** $Na_{19}(Ca,Mn)_6(Ti,Nb)_3Si_{26}O_{74}Cl\cdot 2H_2O$
status: approved by CNMMN (Khomyakov *et al.* 1990)

**aqualite** $(H_3O)_8(Na,K,Sr)_3Ca_6Zr_3Si_{26}O_{66}(OH)_9Cl$
status: approved by CNMMN (Khomyakov *et al.*, in prep.)

**carbokentbrooksite** $(Na,\square)_{12}(Na,\mathit{REE})_3Ca_6Mn_3Zr_3Nb(Si_{25}O_{73})(OH)_3(CO_3)\cdot H_2O$
status: approved by CNMMN (Khomyakov *et al.*, in prep.)

**eudialyte** $Na_{15}Ca_6Fe_3Zr_3Si(Si_{25}O_{73})(O,OH,H_2O)_3(Cl,OH)_2$
status: grandfather clause (Stromeyer 1819, Johnsen & Grice 1999)

**feklichevite** $Na_{11}Ca_9(Fe^{3+},Fe^{2+})_2Zr_3Nb[Si_{25}O_{73}](OH,H_2O,Cl,O)_5$
status: approved by CNMMN (Pekov *et al.* 2001)

**ferrokentbrooksite** $Na_{15}Ca_6Fe_3Zr_3Nb(Si_{25}O_{73})(O,OH,H_2O)_3(F,Cl)_2$
status: approved by CNMMN (Johnsen *et al.* 2003)

**georgbarsanovite (previously "barsanovite")**
$Na_{12}(Mn,Sr,\mathit{REE})_3Ca_6Fe^{2+}{}_3Zr_3NbSi_{25}O_{76}Cl_2\cdot H_2O$
status: "barsanovite" was discredited in 1969; a revalidation was proposed in 1999, but rejected. Now, georgbarsanovite is proposed for the same material and approved (Dorfman *et al.* 1963, 1965, Khomyakov *et al.*, in prep.)

**ikranite**
$(Na,H_3O)_{15}(Ca,Mn,REE)_6Fe^{3+}{}_2Zr_3(\square,Zr)(\square,Si)Si_{24}O_{66}(O,OH)_6Cl\cdot nH_2O$ $(2 < n < 3)$
status: approved by CNMMN (Chukanov *et al.*, in press)

**kentbrooksite** $Na_{15}Ca_6Mn_3Zr_3Nb(Si_{25}O_{73})(O,OH,H_2O)_3(F,Cl)_2$
status: approved by CNMMN (Johnsen *et al.* 1998)

**khomyakovite** $Na_{12}Sr_3Ca_6Fe_3Zr_3W(Si_{25}O_{73})(O,OH,H_2O)_3(Cl,OH)_2$
status: approved by CNMMN (Johnsen *et al.* 1999a)

**labyrinthite** $(Na,K,Sr)_{35}Ca_{12}Fe_3Zr_6TiSi_{51}O_{144}(O,OH,H_2O)_6Cl_3$
status: approved by CNMMN (Khomyakov *et al.*, in prep.)

**manganokhomyakovite** $Na_{12}Sr_3Ca_6Mn_3Zr_3W(Si_{25}O_{73})(O,OH,H_2O)_3(Cl,OH)_2$
status: approved by CNMMN (Johnsen *et al.* 1999a)

**oneillite** $Na_{15}Ca_3Mn_3Fe_3Zr_3Nb(Si_{25}O_{73})(O,OH,H_2O)_3(OH,Cl)_2$
status: approved by CNMMN (Johnsen *et al.* 1999b)

**raslakite** $Na_{15}(Ca_3Fe_3)(Na,Zr)_3(Si,Nb)(Si_{25}O_{73})(OH,H_2O)_3(Cl,OH)_2$
status: approved by CNMMN (Chukanov *et al.*, in press)

**rastsvetaevite** $Na_{27}K_8Ca_{12}Fe_3Zr_6Si_{52}O_{144}(O,OH,H_2O)_6Cl_2$
status: approved by CNMMN (Khomyakov *et al.*, in prep.)

**taseqite** $Na_{12}Sr_3Ca_6Fe_3Zr_3NbSi_{25}O_{73}(O,OH,H_2O)_3Cl_2$
status: approved by CNMMN (Petersen *et al.*, in prep.)

**zirsilite-(Ce)** $(Na,\square)_{12}(\mathit{REE},Na)_3Ca_6Mn_3Zr_3Nb(Si_{25}O_{73})(OH)_3(CO_3)\cdot H_2O$
status: approved by CNMMN (Khomyakov *et al.*, in prep.)

In the stacking sequence of the 2:1 slabs and the layers with $[ZrO_6]$ octahedra, twelve levels can be recognized within the repeat distance of the *c* cell dimension ($c \approx 30$ Å). Figure 3 gives a simplified representation of these levels from one six-fold ring of $[M(1)O_6]$ octahedra to the next ring. Oblong cages exist along the triad axes reaching from one constriction made by a $[Si_3O_9]^{6-}$ ring up through the layer sequence to the next $[Si_3O_9]^{6-}$ ring constriction, including nine of the twelve levels. In these cages, the central level comprises a region surrounded by six $[ZrO_6]$ octahedra (only four of them are shown in the figure), and followed on either side by (i) an intra $[Si_9O_{27}]^{18-}$ ring level, (ii) a level with a region surrounded by $[M(1)O_6]$ and $[M(2)O_n]$ polyhedra, (iii) an inter $[Si_9O_{27}]^{18-}$ ring level, and (iv) a level with a region surrounded by three $[ZrO_6]$ octahedra. Na is the dominant cation in the levels of $[ZrO_6]$ octahedra and in other cavities in or at the border of other levels. Cl, F, OH, $H_2O$ or, rarely, $CO_3$ are accommodated in the inter $[Si_9O_{27}]^{18-}$ ring levels, whereas the central parts of the $[Si_9O_{27}]^{18-}$ rings offer space for a cation in tetrahedral or octahedral coordination. Which coordination is present depends on the incorporation or not of *O*(19) which, where present, is shared with the $[M(2)O_5]$ polyhedra. These two sites, $^{[4]}M(4)$ and $^{[6]}M(3)$, are related by the substitution $^{[6]}M(3) + {}^{[4]}M(4) \Leftrightarrow 2{}^{[4]}M(4)$, in which *M*(4) and *M*(3) typically are occupied by Si and Nb, respectively. The elemental contents in the *M*(3) and *M*(4) sites have a primary influence on acentricity of the structure.

Most eudialyte-group minerals, *i.e.*, with a *c* period of ~30 Å and crystallizing in *R*3*m* or *R*$\bar{3}$*m*, comply with the general formula $Na_{12}[Na(4)]_3[M(1)]_6[M(2)]_3$

TABLE 2. NUMBER OF DISTINCT CATION SITES, MULTIPLICITY, AND WYCKOFF NOTATION IN THE NON-SILICATE PART OF EUDIALYTE-GROUP MINERALS IN THE THREE RELEVANT SPACE-GROUPS FOR BOTH CELL SIZES

| S.G. | *c* (Å) | *N* (1) | *N* (2) | *N* (3) | *N* (4) | *N* (5) | *M* (1a) | *M* (1b) | *M* (2) | *M* (3) | *M* (4) | *Z* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 146 | 30 | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(3*a*) | 1(3*a*) | 1(9*b*) |
| 160 | 30 | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | 1(9*b*) | ⇒ | 1(18*c*) | 1(9*b*) | 1(3*a*) | 1(3*a*) | 1(9*b*) |
| 166 | 30 | 1(18*h*) | ⇐ | ⇒ | 1(18*h*) | ½(18*h*) | ⇒ | 1(18*g*) | 1(9d) | 1(6*c*) | ⇐ | 1(9*e*) |
| 146 | 60 | 2(9*b*) | 2(9*b*) | 2(9*h*) | 2(9*b*) | 2(9*b*) | 2(9*b*) | 2(9*b*) | 2(9*b*) | 2(3*a*) | 2(3*a*) | 2(9*b*) |
| 160 | 60 | 2(9*b*) | 2(9*b*) | 2(9*b*) | 2(9*b*) | 2(9*b*) | ⇒ | 2(18*c*) | 2(9*b*) | 2(3*a*) | 2(3*a*) | 2(9*b*) |
| 166 | 60 | 2(18*h*) | ⇐ | ⇒ | 2(18*h*) | 1(18*h*) | ⇒ | 2(18*g*) | 2(9d) | 2(6*c*) | ⇐ | 2(9*e*) |

Space groups are *R*3 (146), *R*3*m* (160) and *R*$\bar{3}$*m* (166).
Split sites such as *M*(2,4) and *M*(2,5) not included, nor are any anion sites.
A site indicated by ⇒ or ⇐ is included in the neighboring site. For example, *M*(1a) and *M*(1b) are distinct sites, each with a multiplicity of 9, in 30-Å *R*3 structures, whereas *M*(1a) is not a distinct site in the 30-Å *R*3*m* structures, but rather is included in the *M*(1b) site, which has a multiplicity of 18.
Examples of information required regarding site-assignment in the non-silicate part and omitting anions and $H_2O$ groups:
30-Å *R*3*m* structures: *N*(1)*N*(4)*N*(5)*M*(1b)*M*(2)*M*(3)*Z*
60-Å *R*3 structures: *N*(1,1)*N*(1,2)*N*(2,1)*N*(2,2)*N*(3,1)*N*(3,2)*N*(4,1)*N*(4,2)*N*(5,1)*N*(5,2) *M*(1a,1)*M*(1a,2)*M*(1b,1)*M*(1b,2)*M*(2,1)*M*(2,2)*M*(3,1)*M*(3,2)*M*(4,1)*M*(4,2)*Z*(1)*Z*(2)

$[M(3)][M(4)]Zr_3(Si_{24}O_{72})$ $(O,OH,H_2O)_4X_2$, $X$= Cl, F, OH or $CO_3$; $Z$ = 3. In this formula, $Na_{12}$ is a condensation of $Na(1)_3Na(2)_3Na(3)_3Na(5)_3$. For example, in *R*3*m* members of the eudialyte group, this formula accounts for 10 cation sites and four anion sites (*O*19, *O*20 and two *X* sites) in addition to the silicate ring system consisting of 6 *Si* and 10 *O* sites. In other eudialyte-group minerals, the situation may be different (regarding cations in the non-silicate part, see Table 2).

Whereas the silicate ring structure is uniform in composition, and Zr in the *Zr* site usually is replaced by Ti or Nb only to a limited extent, extensive substitution can take place in other cation sites. *M*(1) is mainly occupied by Ca, with Mn, Y and *REE* as the major replacing elements. Extensive replacement of Ca by these elements can result in cation order and a reduction of the symmetry to *R*3 [*M*(1) splits up into *M*(1a) and *M*(1b)]. Site *M*(2) is four-, five- or six-fold coordinated, with $^{[4]}$Fe and $^{[5]}$Mn as the most common settings. The *M*(3) and *M*(4) sites typically accommodate Nb and Si, respectively. Of the *Na* sites, *Na*(4) is especially well suited to host heavier elements such as *REE*, Sr, K, Y and Ca. Oxonium substitution for Na is described (Ekimenkova *et al.* 2000).

Alternating layers of Zr and Ti in the *Zr* site, resulting in a doubling of the *c* axis, are also reported (Rastsvetaeva *et al.* 1999). Complete substitution of Ti for Zr is found in alluaivite. In Table 3, we summarize the predominant elements in minerals of the eudialyte group. In order to encompass all substitutions known so far, the general formula of eudialyte (*s.l.*) could be rewritten to $[N(1)N(2)N(3)N(4)N(5)]_3[M(1a)M(1b)]_3$ $M(2)_3M(3)M(4)Z_3[Si_{24}O_{72}]O'_4X_2$.

To conclude, the eudialyte structure is complex. Many sites are able to accommodate more than one cation, and there is a notable variation in the total number of anions. Therefore, an accurate formula can only be constructed from data based on structural information. An empirical formula acceptable in most cases may, however, be derived from results of a chemical analysis, as shown by Johnsen & Grice (1999).

## Schemes of Nomenclature

At present, the eudialyte group accounts for close to twenty species. The potential for many more, however, is enormous. The theoretical number of mineral species, based on the non-silicate cations only, extends far beyond several thousands. In this report, we focus on three different principles of naming minerals: (i) a hierarchical system with root names modified by use of modifiers and Levinson suffixes, (ii) a unique-name system with use of modifiers with or without Levinson suffixes, and (iii) perhaps as a curiosity, a system based on the Linnean principle as used in the biological world.

### *A hierarchical system*

In Table 4, we present an example of a hierarchical system. It has been prepared according to hierarchical principles already becoming traditional in mineralogical nomenclature, with structural sites being subdivided

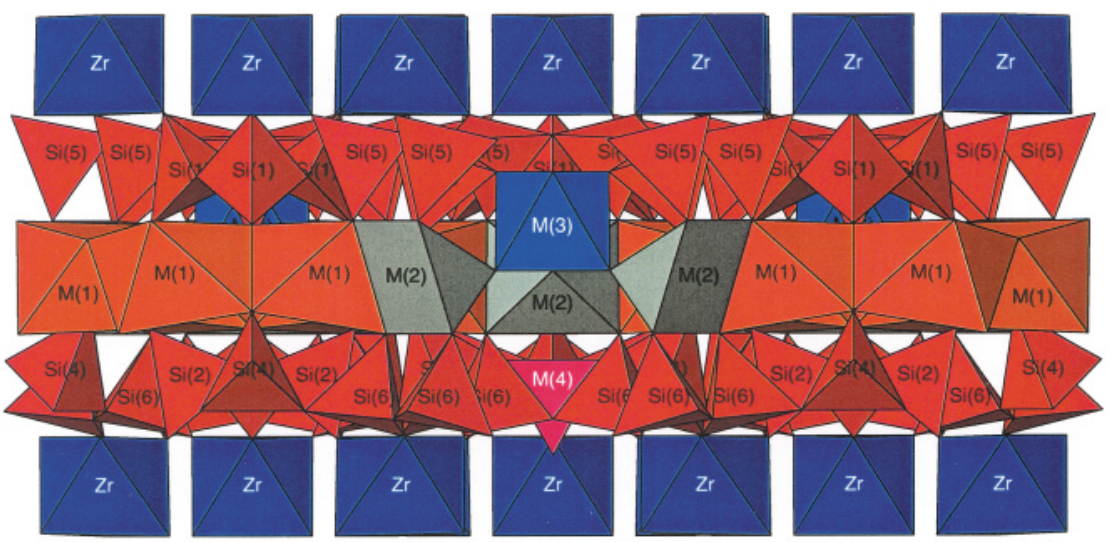


FIG. 1. Polyhedral model of the *R*3*m* eudialyte structure. The structure is projected along [100]; [$Na\phi_n$] polyhedra not shown.

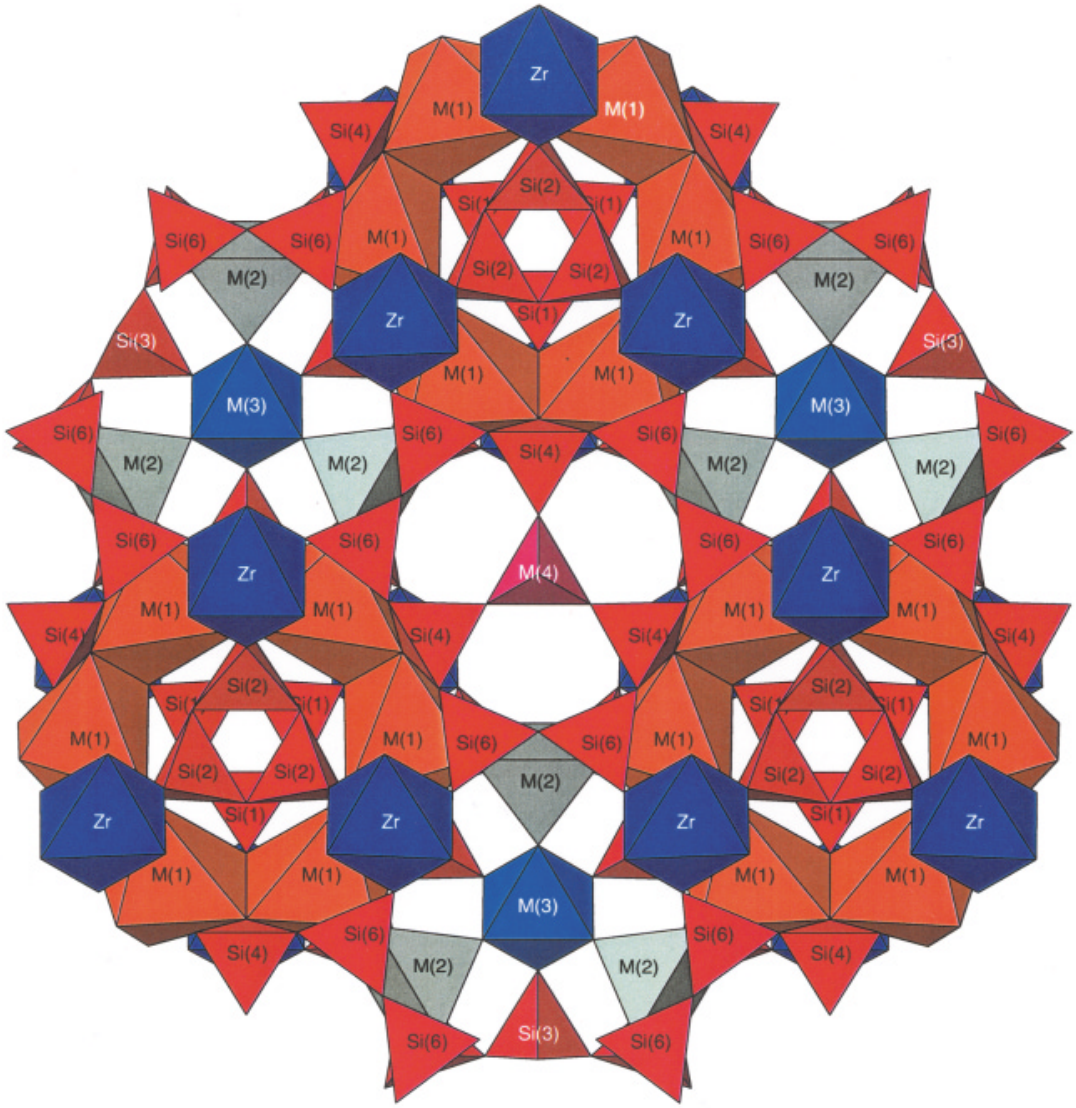


FIG. 2. Polyhedral model of the *R*3*m* eudialyte structure. The structure is projected along [001]; [$Na\phi_n$] polyhedra not shown.

into key sites of descending importance. "Important" sites give names to subgroups and root names or series names, whereas constituents prevailing in "secondary" sites form suffix-modifiers that determine the mineral species. In this example, the order of precedence of the discriminating key sites is *Zr*, *M*(1) and *M*(3). *M*(3) appears to be a good choice for giving root names, as this site represents the greatest elemental diversity (Table 3), but other choices could be made. The individual members are then further characterized by suffixes designating the prevailing element in *M*(2)*M*(4)*N*(4)*X*. The composition of the name is thus: root name-*M*(2)*M*(4)*N*(4)*X*, *i.e.*, eudialyte-FeSiNaCl, kentbrooksite-MnSiNaF, *etc.*

As stated above, the system in Table 4 is just an example, and it is not complete. It serves, however, as an obvious demonstration of the shortcomings observed when a hierarchical system is applied to a group of highly complex minerals, such as those of the eudialyte group.

Despite the fact that the example is incomplete, *e.g.*, by not incorporating 4 *Na* sites in acentric eudialyte-group minerals, it shows the inexpedient ratio between species and root names. At present, we have close to

TABLE 3. PREDOMINANT ELEMENTS IN THE NON-SILICATE PART OF THE STRUCTURE OF SPECIES IN THE EUDIALYTE GROUP#

| | Space group | *c* Å | *Z*, *Z** | *M*(1,1b) | *M*(1a) | *M*(2), *M*(2)* | *M*(3) | *M*(4) | *N*(1) | *N*(2) | *N*(3) | *N*(4), *N*(4)* | *N*(5) | *X* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alluaivite | 166 | 60 | Ti | Ca | | Na? | Si | Si | Na | Na | Na | Na | Na | OH |
| Aqualite | 146 | 30 | Zr | Ca | Ca | $H_3O^+$ | Si | Si | $H_3O^+$ | $Na,H_3O^+$ | $H_3O^-$ | $H_3O^+$ | ? | Cl |
| Carbokentbrooksite | 160 | 30 | Zr | Ca | | Mn | Nb | Si | Na | Na | Na | Na | Na | $CO_3$,OH |
| Eudialyte | 166 | 30 | Zr | Ca | | Fe | Si | Si | Na | Na | Na | Na | Na | Cl |
| Feklichevite | 160 | 30 | Zr | Ca | | $Fe^{3+}$ | Nb | Si | Na | Na | Na | Ca | Na | OH |
| Ferrokentbrooksite | 160 | 30 | Zr | Ca | | $Fe^{2+}$ | Nb | Si | Na | Na | Na | Na | Na | Cl |
| Georgbarsanovite | 160 | 30 | Zr | Ca | | $Fe^{2+}$ | Nb | Si | Na | Na | Na | Mn | Na | Cl |
| Ikranite | 160 | 30 | Zr | Ca | | $Fe^{3+}$ | □ | □ | $Na,H_2O$ | $H_2O$ | $Na,H_2O$ | $Na,H_2O$ | Na | OH,Cl |
| Kentbrooksite | 160 | 30 | Zr | Ca | | Mn | Nb | Si | Na | Na | Na | Na | Na | F |
| Khomyakovite | 160 | 30 | Zr | Ca | | Fe | W | Si | Na | Na | Na | Sr | Na | Cl |
| Labyrinthite | 146 | 60 | Zr | Ca | Ca | Na,Fe | Si,Ti | Si | Na | Na | Na | Na | Na | OH |
| Manganokhomyakovite | 160 | 30 | Zr | Ca | | Mn | W | Si | Na | Na | Na | Sr | Na | Cl |
| Oneillite | 146 | 30 | Zr | Ca | Mn | Fe | Nb | Si | Na | Na | Na | Na | Na | OH |
| Raslakite | 146 | 30 | Zr | Ca | Fe | Na,Zr | Si | Si | Na | Na | Na | Na | Na | Cl |
| Rastsvetaevite | 160 | 60 | Zr | Ca | | K,Na,Fe* | Si | Si | Na | Na | Na | Na,K* | Na | Cl |
| Taseqite | 160 | 30 | Zr | Ca | | Fe | Nb | Si | Na | Na | Na | Sr | Na | Cl |
| Zirsilite-(Ce) | 160 | 30 | Zr | Ca | | Mn | Nb | Si | Na | Na | Na | *REE* | Na | $CO_3$,OH |

# Information is taken from publications or proposals. * Site notation refers to distinct sites in 60-Å members.
Space groups are *R*3 (146), *R*3*m* (160) and $R\bar{3}m$ (166).

TABLE 4. AN INCOMPLETE EXAMPLE OF A HIERARCHICAL SYSTEM OF NOMENCLATURE FOR THE EUDIALYTE GROUP, LEADING TO HYPOTHETICAL NAMES WITH MULTIPLE SUFFIXES

**I. Zr: Eudialyte subgroup**

Ia: greater than 50% Ca in *M*(1)

*M*(3): Si: eudialyte-FeSiNaCl (eudialyte)

*M*(3): Nb: kentbrooksite-MnSiNaF (kentbrooksite)
kentbrooksite-FeSiNaOH (ferrokentbrooksite)
kentbrooksite-FeSiSrCl (taseqite)
kentbrooksite-$Fe^{3+}$SiCaOH (feklichevite)
kentbrooksite-$Fe^{2+}$SiMnCl (georgbarsanovite)

*M*(3): W: khomyakovite-FeSiSrCl (khomyakovite)
khomyakovite-MnSiSrCl (manganokhomyakovite)

*M*(3): □: ikranite-$Fe^{3+}$□?NaOH (ikranite?)

Ib: less than 50% Ca in *M*(1)

*M*(3): Nb: oneillite-FeSiNaOH (oneillite)

**II. Ti: Alluaivite subgroup**

IIa: greater than 50% Ca in *M*(1)

*M*(3): Si: alluaivite-NaSiNaOH (alluaivite)

**III. Nb: not found**

**IV. Modular subgroup**

Zr, with greater than 50% Ca in *M*(1)

*M*(3): Si/Si: rastsvetaevite-FeSiKX /NaK?SiNaX (rastsvetaevite)

*M*(3): Si/Ti: newrootname-NaSiNaX/FeTiNaX (labyrinthite)

Ti/Zr, with greater than 50% Ca in *M*(1)

Ti

twenty species. For all of them, nine root names are necessary, *i.e.*, more than half of the newly discovered mineral species of the eudialyte group form individual subgroups and series. It is easy to predict that such a situation will develop further in the future because these minerals have extensive possibilities for variation: symmetry variations, doubling (only doubling for the present!) of the *c* parameter, polysomatism (only ordered interlayering of eudialyte and alluaivite blocks for the present), cation ordering [only in *M*(1) for the present]. The next problem is the appearance of other different cations or $H_2O$ groups or vacancies not only at *N*(4) but also at other *N* sites. The appearance of such species will undoubtedly entail changes in all systems of suffix-modifiers, including all earlier accepted species. If we accept a multi-level hierarchical system of nomenclature for eudialyte-group minerals, it will be necessary to revise it completely (with total renaming) more than once after the discovery of any unusual member or to enter new subgroups with different hierarchical schemes. In the last case, we lose universality and increase confusion; simultaneously, the number of root names will increase inevitably and quickly.

If we wish to minimize the number of root names, it is necessary to significantly increase the suffix-modifiers, *i.e.*, decrease the number of key sites. For a state of maximum universality, *i.e.*, for a situation where all future mineral species possible in the structural type can be put into prepared frames of reference, we must take into account the totality of all possible variations in all sites. A species name can be constructed according to these principles: root name-*N*(1)*N*(2)*N*(3)*N*(4)*N*(5)

*M*(1)*M*(2)*M*(3)*M*(4)*ZrX* (certainly, for oneillite and other minerals with a different structure, this scheme will be different, and more complicated). If we take out the Zr site from the list of suffixes (for example, by naming all Zr-dominant representatives of this structure type as eudialyte), we would end up with the "full species name" eudialyte-NaNaNaNaNaCaMnNbSiF for kentbrooksite, for example. This would simply be a copy of the simplified (formalized) structural formula without coefficients, which really makes no sense. It would be impossible to remember such names or to communicate such names, verbally. The sequence of the elements would be critical to defining the species, and the probability of error in writing names with such a complicated sequence of suffixes is high.

*A unique-name system*

The conventional unique-name system needs no further presentation. It has worked well for generations. One concern could be the proliferation of names; however, compared to the biological world, mineralogy is fortunate in having a very low number of species names. Unique names are relatively easy to remember, misspelling is usually not a problem, and they can still work well with one modifier and one suffix as well as with ordinary adjectival modifiers. A very important feature of this scheme of nomenclature is its unconstrained character, as opposed to a strict system like a hierarchical system or an amphibole-like system. In the unique-name system, we do not have to predict all sorts of polysomatism, polytypism, cation ordering, doubling of cell dimensions, space- group changes, *etc*. In addition, minerals can be classified and reclassified without laborious renaming.

*A Linnean system*

This system is based on the well-known nomenclature for plants and animals, with a genus name supplemented with a species suffix. Transferred to the eudialyte group, *eudialyte* is the genus and, as an example, *eudialyte taseqite* is the species. In a binary system of nomenclature, the nonspecialist is instantly informed about the type of mineral in question, and the flexibility of the system is simply unsurpassed. The system could be modified in a number of ways, for example in analogy with *schorl tourmaline*, the species designator could be a prefix rather than a suffix, such as *taseqite eudialyte*. However, there is no tradition for binary names in mineralogy, and the system is not endorsed in this report.

## Recommendations

The ENS recommends the continued use of unique names in the eudialyte group. In order to reduce the number of unique names and to underline relationships, these can be modified with prefixes and suffixes. However, for reasons of consistency and clarity, only one site-specific prefix should be used. If the scheme is not site-specific, we end up with names such as manganokhomyakovite and "sodiokhomyakovite", where mangano- pertains to Mn at the *M*(2) site, and sodio-, to Na at the *N*(4) site. According to some of the present proposals, Na can actually be accommodated at *M*(2) (Table 3), so that "sodiokhomyakovite" should be reserved for a khomyakovite-like material with Na the predominant element at *M*(2). A scheme with two prefixes referring to two particular sites, such as *N*(4)–*M*(2)-khomyakovite, gives rise to a new set of problems. In this case all variants of khomyakovite must be specified, *i.e.*, khomyakovite would have to be renamed to "strontioferrokhomyakovite", manganokhomyakovite to "strontiomanganokhomyakovite", *etc*. The long unwieldy names that result actually account for only three cation sites: *N*(4), *M*(2) and W at *M*(3), which is only a fraction of the possible species. In this respect, one should not forget that with the possible exception of eudialyte (*s.s.*), and perhaps a few more eudialyte-group minerals that may be locally abundant, all these minerals are very rare and will only be dealt with by specialists. To conclude, the ENS recommends one prefix referring to one site only; this site should be *M*(2), which will be in line with names already established.

In order to restrict the number of species in this complex group, the ENS recommends that the *X* sites be ignored in nomenclature as a rule. A number of arguments support this recommendation: (i) The total weight % of these anions, most commonly Cl, F and OH, amounts to only approximately 1.4 wt.% (Johnsen & Gault 1997), and pertains to only 2 out of 78 anions per formula unit; (ii) so far, there is no indication of any major crystal-chemical significance of these anions; (iii) analytical reasons. An unequivocal assignment of elemental distribution at the two *X* sites cannot be performed on site-scattering values (electrons per formula unit, *epfu*) from crystal-structure data alone. These *epfu* values are generally derived from a combination of ions with somewhat similar numbers of electrons ($e^-$): 17 $e^-$ (Cl), 9 $e^-$ (F), 9 $e^-$ (OH) and, occasionally, also 10 $e^-$ ($H_2O$). Bond-lengths and bond-valence calculations are not very helpful either in this particular case; quite commonly, the electrons are spread out in a highly disordered way, giving many split *X* sites. Likewise, the degree of order of the elements at the two *X* sites can seldom be determined. In order to reach a reliable site-assignment, a combination of data from high-quality electron-microprobe analyses of the samples for halogens with site-scattering values is necessary. Naturally, a good determination of the $H_2O$ content facilitates site assignment, but such a determination is only rarely obtainable and, besides, the hydrogen atoms can be accommodated elsewhere in the structure. Site assignments in *X* based only on electron-microprobe data can in some cases be specified where Cl, F or OH is clearly domi-

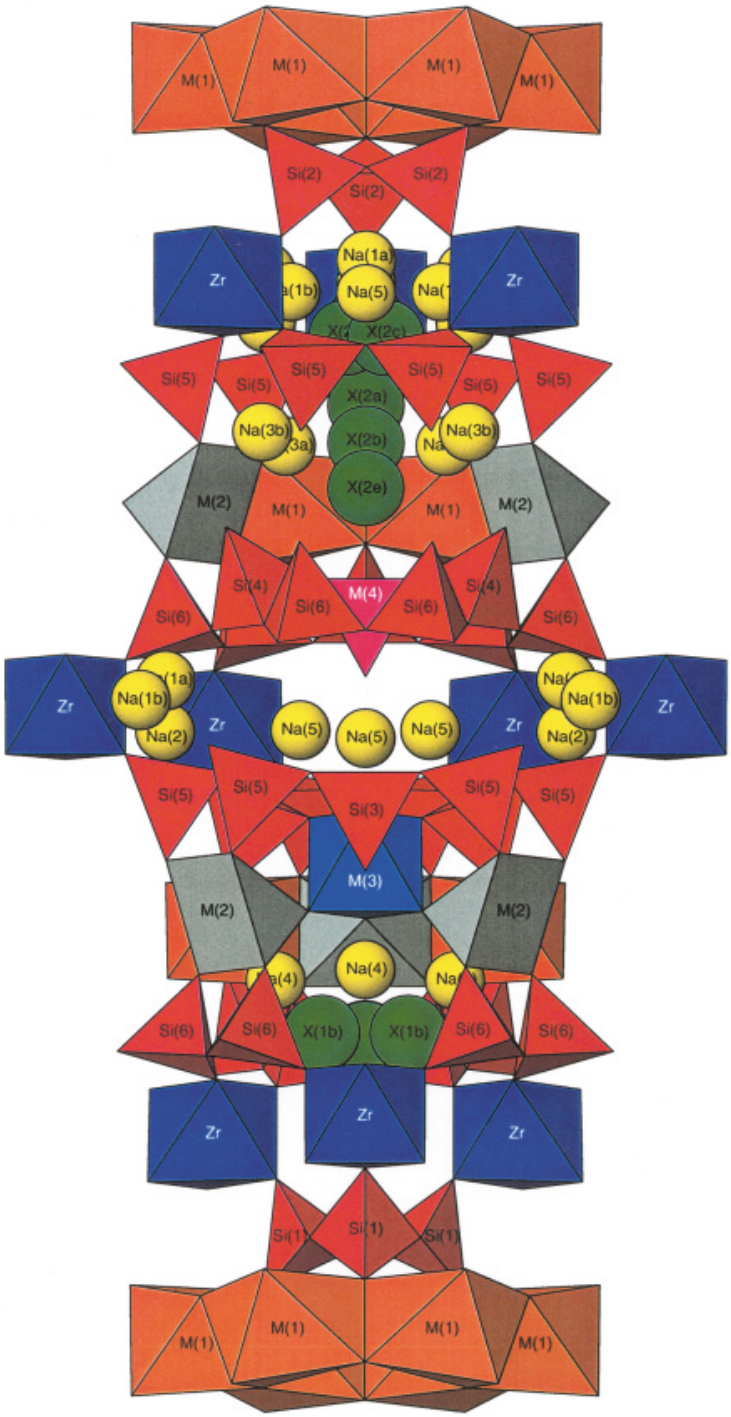


FIG. 3. Polyhedral model of the *R*3*m* eudialyte structure showing the sequence of layers along a triad axis from one ring of $[M(1)O_6]$ octahedra to another. The structure is viewed approximately along [210].

nant. These mono-elemental (or close-to-mono elemental) cases are not frequently encountered, however. Thus, normally the proportion of OH in the *X* sites is stoichiometrically calculated assuming 2(Cl,F,OH) *apfu*, whereas the Cl and F contents are derived from the electron-microprobe data. Usually, the content of Cl is reasonably well defined, whereas that of F is close to the detection limit. These analytical conditions make it problematic to propose a species based on the proportions of three components, one of which is calculated by stoichiometry dependent on the amount of the two other components, one of which in most cases is present in amounts close to the detection limit.

In the event that a eudialyte species is found that has a demonstrated dominance of an unusual anion group, as for example a $CO_3$ group, we can foresee incorporating this in the naming (*i.e.*, "carbonatekentbrooksite"). This would be a special case, in which it may be acceptable that two prefixes could be used, one for a cation at *M*(2) and one for an *X* anion, as these cannot be confused.

If later the CNMMN accepts the proliferation of names within the group by including *X* sites, this could be done by the use of a Levinson suffix, *e.g.*, "eudialyte-OH". As just shown, however, this procedure could be tenuous, and if applied, the CNMMN must insist on solid analytical proof regarding the dominance of a particular anion species. Also, CNMMN will have to decide whether the two *X* sites in an acentric eudialyte should be joined or treated individually. In principle, the latter case gives rise to two anion-prefixes.

As the nomenclature for the eudialyte group is based on crystal chemistry and the overall principle that any new element prevalent in any site gives rise to an independent species, the ENS recommends that for these complicated minerals, the CNMMN request additional data, such as refined scattering values and tables showing complete site-assignments. This would be a prerequisite for a proper evaluation of a proposal on a eudialyte-group mineral. The following two extremes are examples of information required regarding site-assignment in the non-silicate-anion part: for 30-Å *R*3*m* structures: *N*(1)*N*(4)*N*(5)*M*(1b)*M*(2)*M*(3)*Z*; for 60-Å *R*3 structures: *N*(1,1)*N*(1,2)*N*(2,1)*N*(2,2)*N*(3,1)*N*(3,2)*N*(4,1)*N*(4,2)*N*(5,1)*N*(5,2) *M*(1a,1)*M*(1a,2)*M*(1b,1)*M*(1b,2)*M*(2,1)*M*(2,2)*M*(3,1)*M*(3,2)*M*(4,1)*M*(4,2)*Z*(1)*Z*(2).

## Summary

A hierarchical system of nomenclature does not work for eudialyte-group minerals. Such a system would be either a multi-level system that would become either a very complicated and cumbersome system with disproportionately many root names or a flatter system with fewer root names but monstrously long names with formula-like endings. Names with highly extended Levinson modifiers would be very difficult to remember, would have a high risk for misspelling, and complete revisions of the system would frequently become necessary. Most of these eudialyte minerals are very rare in any case, so a highly elaborate scheme of nomenclature would appear to be out of proportion to their importance.

Conventional unique names with a maximum of one cation prefix are recommended for the eudialyte-group minerals, and this prefix should refer to the *M*(2) site. In contrast to root names with complicated suffixes, unique names are relatively easy to remember, and misspelling is usually not critical. This nomenclature scheme is relatively flexible, and future revisions of the group can presumably take place without laborious renaming. In order to restrict the number of species, the ENS recommends ignoring the *X* sites in nomenclature as a rule, but if later the CNMMN decides that *X* sites should be included in the nomenclature scheme, joined or individually, this could be done by the use of a Levinson suffix, alternatively by an anion prefix, and in the extreme case, two anion prefixes.

To assist in the evaluation of future proposals of these complicated eudialyte-group minerals, the ENS recommends that the CNMMN ask for refined site-scattering data and a table of site assignments for all sites relevant to the space group in question.

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