Recommended nomenclature for zeolite minerals: report of the subcommittee on zeolites of the International Mineralogical Association, Commission on New Minerals and Mineral Names

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This report embodies recommendations on zeolite nomenclature approved by the International Mineralogical Association Commission on New Minerals and Mineral Names. In a working definition of a zeolite mineral used for this review, interrupted tetrahedral framework structures are accepted where other zeolitic properties prevail, and complete substitution by elements other than Si and Al is allowed. Separate species are recognized in topologically distinctive compositional series in which different extra-framework cations are the most abundant in atomic proportions. To name these, the appropriate chemical symbol is attached by a hyphen to the series name as a suffix except for the names harmotome, pollucite and wairakite in the phillipsite and analcime series. Differences in space-group symmetry and in order-disorder relationships in zeolites having the same topologically distinctive framework do not in general provide adequate grounds for recognition of separate species. Zeolite species are not to be distinguished solely on Si : Al ratio except for heulandite (Si : Al < 4.0) and clinoptilolite (Si : Al ≥ 4.0). Dehydration, partial hydration, and over-hydration are not sufficient grounds for the recognition of separate species of zeolites. Use of the term ‘ideal formula’ should be avoided in referring to a simplified or averaged formula of a zeolite.

Newly recognized species in compositional series are as follows: brewsterite-Sr, -Ba; chabazite-Ca, -Na, -K; clinoptilolite-K, -Na, -Ca; dachiardite-Ca, -Na; erionite-Na, -K, -Ca; faujasite-Na, -Ca, -Mg; ferrierite-Mg, -K, -Na; gmelinite-Na, -Ca, -K; heulandite-Ca, -Na, -K, -Sr; levyne-Ca, -Na; paulingite-K, -Ca; phillipsite-Na, -Ca, -K; stilbite-Ca, -Na.

Key references, type locality, origin of name, chemical data, IZA structure-type symbols, space-group symmetry, unit-cell dimensions, and comments on structure are listed for 13 compositional series, 82 accepted zeolite mineral species, and three of doubtful status. Herschelite, leonhardite, svetlozarite, and wellsite are discredited as mineral species names. Obsolete and discredited names are listed.

**KEYWORDS:** zeolite nomenclature, herschelite, leonhardite, svetlozarite, wellsite, brewsterite, chabazite, clinoptilolite, dachiardite, erionite, faujasite, ferrierite, gmelinite, heulandite, levyne, paulingite, phillipsite, stilbite.
Introduction

The name ‘zeolite’ was introduced by the Swedish mineralogist Cronstedt in 1756 for certain silicate minerals in allusion to their behaviour on heating in a borax bead (Greek zeo = boil; lithos = stone). Three such minerals were listed by Hauy (1801), namely stilbite, analcime, and harmotome, together with ‘mesotype’, which has not survived. Chabazite and leucite had been named even earlier. Nineteen had been described with their present meaning by 1842. Forty-six zeolites were listed by Gottardi and Galli (1985), and new species continue to be described. The first crystal-structure determination of a zeolite was done on analcime (Taylor, 1930); following this, Hey (1930) concluded that zeolites in general have aluminosilicate frameworks with loosely bonded alkali or alkali-earth cations, or both. Molecules of H₂O occupy extra-framework positions. He pointed out the consequential requirements that the molar ratio Al₂O₃: (Ca,Sr,Ba,Na₂,K₂)O = 1 and that O: (Si + Al) = 2 in the empirical formula.

Zeolites have other highly characteristic features developed to varying degrees, notably the potential for reversible low-temperature dehybridation, the ability of the dehydrated forms to reversibly absorb other molecules, a tendency towards more or less easy low-temperature exchange of extra-framework cations, and a lack of clear-cut, structurally controlled constraints on end-member compositions in terms of Si:Al ratios within the framework. In some cases, observed extra-framework compositions may be artefacts of cation exchange resulting from human activities in the laboratory or elsewhere, and furthermore, the compositions are not conveniently determined by traditional optical methods. Perhaps for a combination of such reasons, separate names have been given to few zeolites on the basis of the dominant extra-framework cation in solid-solution series. This conflicts with standard practice in most mineral groups and with guidelines of the Commission on New Minerals and Mineral Names (CNMMN) (Nickel and Mandarino, 1987).

With intensification of research and the advent of the electron microprobe, a flood of information on compositions has become available, and with automated single-crystal X-ray diffractometers and other developments, many complexities have been investigated, including order–disorder relationships in the frameworks and associated changes in unit-cell parameters and symmetry. Thus in the case of analcime, Mazzi and Galli (1978), Teertstra et al. (1994), and others have demonstrated a wide range of space-group symmetries associated with different patterns of order in the framework and possible displaceable transformations. Sites of extra-framework cations are commonly less well defined in an open, zeolitic structure than in most other minerals, and are variably occupied. Guidelines allowing recognition of separate species depending on the dominant ion occupying each structural site are thus compromised in the case of extra-framework sites in zeolites. Furthermore, changes in the occupancy of such sites can distort the framework to varying degrees, changing the space-group symmetry.

Some minerals meet traditional criteria for zeolites in all respects except that they contain P, Be, or other elements in tetrahedral sites, with consequent departure from the requirement of Hey (1930) that O: (Si + Al) = 2. Other structurally related minerals with zeolitic properties have all tetrahedral sites occupied by elements other than Si and Al. Certain other minerals displaying zeolitic properties depart from traditional requirements for a zeolite in having a framework that is interrupted by some (OH) groups. An example is parthéite, listed by Gottardi and Galli (1985) as a zeolite. Synthesis and structural analysis of materials having zeolitic properties have become major fields of research and have led to a voluminous literature, as has the industrial use of zeolitic materials. The recommendations of an IMA CNMMN subcommittee set up to review zeolite nomenclature are set out below. These recommendations have been adopted by the Commission.

Definition of a zeolite mineral

In arriving at its working definition of a zeolite, the Subcommittee took the view that zeolites in the historical and mineralogical sense are naturally occurring minerals, irrespective of how the term may be applied to synthetic materials and in industry. In the light of advances in mineralogy, the Hey (1930) definition is found to be too restrictive. The Subcommittee gave particular consideration to the following questions. Is more than 50% substitution of elements other than Si and Al permissible in tetrahedral sites? Is the presence of water and of extra-framework cations absolutely essential? Can
‘interrupted’ framework structures qualify as zeolite minerals? These matters are further discussed in Appendix 1.

Definition: A zeolite mineral is a crystalline substance with a structure characterized by a framework of linked tetrahedra, each consisting of four O atoms surrounding a cation. This framework contains open cavities in the form of channels and cages. These are usually occupied by H2O molecules and extra-framework cations that are commonly exchangeable. The channels are large enough to allow the passage of guest species. In the hydrated phases, dehydration occurs at temperatures mostly below about 400°C and is largely reversible. The framework may be interrupted by (OH,F) groups; these occupy a tetrahedron apex that is not shared with adjacent tetrahedra.

Application of the definition (see also Appendix 1): Relatively easy exchange of extra-framework cations at relatively low temperature is a characteristic feature of zeolites and zeolitic behaviour, but varies greatly from species to species. Its extent does not provide a convenient basis for the definition of zeolites. In practice, it appears that channels must have a minimum width greater than that of 6-membered rings (i.e., rings consisting of six tetrahedra) in order to allow zeolitic behaviour at normal temperatures and pressures. Framework structures such as in feldspars, nepheline, sodalites, scapolites, mela- nophlogite, and probably leilithe, in which any channels are too restricted to allow typical zeolitic behaviour such as reversible dehydration, molecular sieving, or cation exchange, are not regarded as zeolites.

Framework density, defined as the number of tetrahedral sites in 1000 Å³, was used as the criterion for inclusion in the Atlas of Zeolite Structure Types (Meier et al., 1996). However, this criterion provides no evidence that the channels necessary for diffusion are present as well as cages, and it has not been adopted in the present definition.

In some minerals with a tetrahedral framework structure and other zeolitic characteristics as described, namely parthéite, roggianite, marico- paite, and chiavenite, one apex of some tetrahedra is occupied by an (OH) group or F atom instead of being occupied by an O atom. This (OH) group or F atom does not form a bridge with an adjacent tetrahedron. The framework is thus interrupted. Such minerals are here accepted as zeolites.

In terms of the definition adopted, minerals of the cancrinite group can arguably be considered as zeolites. This group has long been regarded by many or most mineralogists as distinct from the zeolites, in part, at least, because of the presence of large volatile anions (e.g., Hassan, 1997). They are not reviewed in the present report. Rather similarly, wenkite contains large cages and channels, but these are blocked by SO4, Ca, and Ba ions (Wenk, 1973; Merlino, 1974), inhibiting zeolitic behaviour. In addition, no water is lost below 500°C. Wenkite is not listed in this report as a zeolite.

Leucite has seldom been regarded as a zeolite, as it does not display a full range of zeolitic behaviour. Nevertheless, it has the same framework structure as analcime and conforms to the adopted definition. Ammonioleucite can be regarded as an analcime derivative, can be synthesized from analcime by cation exchange, and may have formed naturally by low-temperature replacement of analcime. Leucite and ammonioleucite are included in the list of zeolites, as is kalborsite, a derivative of the edingtonite structure.

Also conforming to the definition adopted are the beryllophosphates pahasapate and weinebe- neite. These contain neither Si nor Al and can be regarded as end-member examples of Si-free zeolites or zeolite phosphates.

Rules for nomenclature of zeolite minerals

In presenting the following rules for nomenclature of zeolite minerals, the Subcommittee feels strongly that they should be viewed as guidelines rather than as being rigidly prescriptive. As stated by Nickel and Mandarino (1987): “It is probably not desirable to formulate rigid rules to define whether or not a compositional or crystallographic difference is sufficiently large to require a new mineral name, and each new mineral proposal must be considered on its own merits”. Explanatory notes following the proposed rules or guidelines give examples of how the Subcommittee envisages that rule being applied, but like Nickel and Mandarino, the Subcommittee urges that each case be treated on its merits. In some cases, compelling reasons may exist on grounds of historical usage for retaining an existing name, or other grounds may exist for departing from the rules for giving a new name. Cases arising under Rule 2 are particularly difficult, and require individual consideration.
Rule 1
(a) One or more zeolite minerals having a topologically distinctive framework of tetrahedra and a composition that is distinctive for zeolites having that framework, constitute separate species. (b) Zeolites having the same topologically distinctive framework of tetrahedra constitute a series when they display a substantial range in composition in which differing extra-framework cations may be the most abundant in atomic proportions. These cations may occupy different extra-framework sites. Such series consist of two or more species that are distinguished on the basis of the most abundant extra-framework cation.

Application of the rule: Laumontite, for example, has a topologically distinctive framework and a composition which, as far as is currently known, is distinctive in that Ca is always the dominant extra-framework cation. It is a separate zeolite species under Rule 1a. Natrolite, mesolite, and scolecite have the same topologically distinctive framework structure as each other, and have compositions that are distinctive. They also are separate species under Rule 1a.

Zeolites having the topologically distinctive chabazite structure have a range of compositions in which any one of Ca, Na, or K may be the most abundant extra-framework cation. Substantial Sr is in some cases present as well, but so far has never been reported as the most abundant in natural examples. Chabazite is a series consisting of three separate species under Rule 1b. It is known that near-end-member Na, K, Ca, and Sr compositions are readily obtainable by ion exchange from natural Ca-dominant chabazite at 110°C (Alberti et al., 1982a), but this is not the essential criterion for recognition of the natural series.

Mesolite may have either Na or Ca slightly in excess of the other, but the ratio Na:Ca is always close to 1:1. The range of its composition is not regarded as ‘substantial’, and mesolite is not divided into more than one species on grounds of composition.

Several distinct structural sites for extra-framework cations are recognized in many zeolites, but in view of the relatively loose bonding and specialized problems in establishing the individual site-occupancies, only the total population of extraframework cations should in general be used in defining zeolite species.

Rule 2
(a) Differences in space-group symmetry and in order-disorder relationships in zeolite minerals having the same topologically distinctive framework do not in general provide adequate grounds for recognition of separate species, but each case should be treated on its merits. (b) In assessing such cases, other factors, such as relationship to chemical composition, should be taken into consideration.

Application of the rule: The Subcommittee found it to be impracticable to formulate quantified criteria for handling problems arising from this rule. Irrespective of decisions that have been made in the past, care should be taken that departures envisaged in Rule 2b from the principle enunciated in Rule 2a are based on grounds that are truly compelling.

Analclime and certain other zeolites exist with several different space-group symmetries, in some cases occurring on a very fine scale in the same hand specimen and with the same chemistry. Even though this may be related to Si,Al ordering, separate species names in these cases are in general not warranted.

Gismondine and garronite are examples of zeolites that have the same topologically distinctive framework. Both have Ca as the dominant extra-framework cation. Their differing space-group symmetry is associated with disordered Si,Al and the presence of significant Na in garronite. They are accepted as separate species. Goboinosite and amicite have topologically the same framework structure as gismondine, but are alkali-dominant. Their different space-group symmetries appear to be related to Si,Al disorder in goboinosite and possible chemical differences, and they are provisionally retained. Barrerite is topologically similar to stilbite and stellerite, but it has different symmetry correlated with the presence of extra cations which cause rotational displacements within the framework (Galli and Alberti, 1975b); it is similarly retained.

Rule 3
Zeolite mineral species shall not be distinguished solely on the basis of the framework Si:Al ratio. An exception is made in the case of heulandite and clinoptilolite; heulandite is defined as the zeolite mineral series having the distinctive framework topology of heulandite and the ratio Si:Al < 4.0. Clinoptilolite is defined as the series with the same framework topology and Si:Al ≥ 4.0.

Application of the rule: Many zeolites have a widely variable Si:Al ratio, but this, in itself, is
not regarded as providing adequate grounds for recognition of separate species. The exception is based on entrenched usage of the names heulandite and clinoptilolite, and their convenience for recognizing an important chemical feature. The cut-off value adopted (following Boles, 1972) is arbitrary in a continuous range of compositions. The usual 50% compositional rule cannot be applied, as there are no clearly defined Si,Al end-member compositions for heulandite and clinoptilolite. Thermal stability has been used by some investigators to distinguish clinoptilolite from heulandite. This is a derivative property, however, suggested by Mumpton (1960) as an aid to identification, and it is not appropriate as the basis for definition. Alietti (1972) and Boles (1972) have shown that there is no gap in composition either in framework or extra-framework cation contents between heulandite and clinoptilolite, and that samples transitional in composition may show intermediate properties in terms of thermal stability.

**Rule 4**

Dehydration, partial hydration, and over-hydration, whether reversible or irreversible, are not sufficient grounds for the recognition of separate species of zeolite minerals.

Application of the rule: If a new topologically distinctive framework arises from over-hydration or partial dehydration, separate species status would result from application of Rule 1. Leonhardite, a partially and in most cases reversibly dehydrated form of laumontite, is not accepted as a separate mineral species.

**Rule 5**

Individual species in a zeolite mineral series with varying extra-framework cations are named by attaching to the series name a suffix indicating the chemical symbol for the extra-framework element that is most abundant in atomic proportions, e.g. chabazite-Ca.

The following exceptions are made: (a) On grounds of historical precedence and long-established usage, the name harmotome is retained for the Ba-dominant member of the phillipsite series. (b) On grounds of long-established usage, pollucite is retained as the Cs-dominant zeolite of the analcime structure-type. On grounds of established usage and markedly different space-group symmetry and Si,Al order related to the extra-framework cation content (Rule 2b), wairakite is retained as the Ca-dominant zeolite of the analcime structure-type. On the other hand, herschelite is suppressed in favour of chabazite-Na (Appendix 2).

Application of the rule: New species arising from Rule 5 that are well authenticated by published data are set out in Table 1. Future proposals for additional new species under this rule should be dealt with as for any other proposal for a new mineral name.

Adoption of a Levinson-style system of suffixes avoids the proliferation of a large number of new and potentially unrelated species names, and ensures that all members of a topologically identical compositional series are indexed together. It has the great advantage that where adequate chemical data are not required or are not available, a mineral can be referred to correctly by an unambiguous series name. The system adopted here is without the brackets (parentheses) used by Levinson (1966) in suffixes for rare-earth minerals.

Substantial amounts of extra-framework cations other than the dominant one may be indicated, if desired, by the use of adjectives such as calcian and sodian, e.g. calcian clinoptilolite-K. Such adjectival modifiers are not part of the formal name of a species.

Informal use is often made of descriptive terms such as calcium chabazite and Ca chabazite, in which the name or symbol of an element is used adjectivally. In conformity with general IMA guidelines, these should not appear in print as mineral names or in hyphenated form. The correct name for the mineral species in this case is chabazite-Ca. Terms such as sodium-substituted chabazite-Ca are suggested for what in effect would be a synthetic chabazite-Na prepared by cation exchange from chabazite-Ca. Chabazite remains the correct name for a member of the chabazite series that is not specifically identified on compositional grounds.

**Rule 6**

(a) Space-group variants of zeolite mineral species may be indicated by placing the space-group symbol in round brackets (parentheses) after the mineral species name, e.g. analcime (Ibca), heulandite-Ca (C2/m). (b) Levels of order may be indicated by adjectival use of words such as ‘disordered’ or ‘fully ordered’ before the mineral name.
Application of the rule: Modifiers as suggested here are not part of the formal name of the mineral.

Accepted zeolite series and species

Zeolites to be elevated to series status and the consequential new species to be recognized on the basis of the most abundant extra-framework cation (Rule 5) are set out in Table 1.

An annotated list of accepted zeolite series and species follows below. In each entry for series, and for those species that are not members of compositional series, a simplified or generalized formula is given in the first line. This is followed by Z, the number of these formula units per unit cell, as given later in the entry. The simplified or generalized formula should be regarded as representative only and should not be regarded as an ‘ideal’ composition (see next paragraph). Users of the list should bear in mind that the Si : Al ratio, or, more generally, occupancy of tetrahedral sites by Si, Al, P, Be, Zn, and possibly other elements, varies widely in many zeolites. The total extra-framework cation charge varies accordingly. Major variation in more-or-less exchangeable, extra-framework cations is also a feature of many natural zeolites. Contents of H$_2$O tend to decrease with increasing number and size of extra-framework cations, as well as with increasing temperature and decreasing $P_{H_2O}$. Such variations can be vital to petrological, geochemical, environmental, and experimental considerations.

Simplified or generalized formulae of zeolites, e.g. NaAlSi$_2$O$_6$H$_2$O for analcime, are often referred to as ‘ideal’ formulae. However, the supposed ideality may be in writers’ desire for simplicity, rather than in anything fundamental to the zeolites concerned, and can lead to false assumptions. There is much evidence that the composition of naturally occurring analcime is a function of the chemical environment in which it forms (e.g. Coombs and Whetten, 1967). In environments of low Si activity, as in altered...

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The first-named member of each series is the one to which the original type specimen for the series appears to belong.
strongly silica-deficient alkaline rocks, natural analcime approaches an Si:Al ratio of 1.5. The composition in burial metamorphic rocks in equilibrium with quartz appears to be distinctly more Si-rich than the supposed ‘ideal’ Si:Al value of 2. The evidently metastable equilibrium in natural environments containing siliceous volcanic glass or other source of silica yielding higher activity of Si than coexistence with quartz, leads to analcime with Si:Al approaching 3. Analogous observations apply to heulandite and other zeolites. If ‘ideal’ is taken to imply equilibrium, it can therefore be concluded that this is a function of the chemical (and P–T) environment during crystallization, rather than simply being a function of crystal structure. Differing Si:Al ratios may in turn favour different patterns of order in the framework. Application of the term ‘ideal’ to simplified or averaged formulae of zeolites should be avoided.

Also given in the first line of each entry is the structure-type code allocated by the Structure Commission of the International Zeolite Association (IZA) and listed in Meier et al. (1996). The code consists of three capital letters. A preceding hyphen indicates an interrupted framework of tetrahedra.

The second line of each relevant entry starts with the original reference in which the current name of the mineral, or a near variant of that name, is given, followed by the type locality, or, in the case of descriptions that predate the concept of type localities, the general region of origin of the material on which the name and original description are based, where this is known. The locality is followed by a note on the derivation of the name. Further information on these matters is given by Gottardi and Galli (1985), Clark (1993), and Blackburn and Dennen (1997), but in some cases the information is here revised.

Next is given information on the currently known range in composition of the mineral concerned. This includes known values, or range of values, for \( T_{Si} \), the proportion of tetrahedron sites occupied by Si atoms, as reported in acceptable published analyses. For many zeolites \( T_{Si} \) varies widely, and the values reported may not indicate the full range possible, especially in the case of the rarer zeolites.

Much information on zeolite compositions was given by Gottardi and Galli (1985). The present compilation incorporates results of further extensive searches of the literature. A widely used criterion for acceptability of zeolite compositions is that the value of the balance error function of Passaglia (1970)

\[
E_{\%} = 100 \times \frac{(Al + Fe^{3+}) - (Li + Na + K) - 2(Mg + Ca + Sr + Ba)}{(Li + Na + K) + 2(Mg + Ca + Sr + Ba)}
\]

should be less than 10%, a figure that is itself arguably excessive. The calculation of \( E_\% \) may be modified to allow for other suspected cations, such as \( Fe^{2+} \) and \( Cs^+ \). The role of Fe causes problems that may not be resolvable. Some Fe reported in zeolites is undoubtedly a contaminant, but there are reasons to suspect that both \( Fe^{2+} \) and \( Fe^{3+} \) may enter the structures of some zeolites in extra-framework or framework sites, or both.

Space-group symmetry and crystallographic parameters follow. Many accepted zeolite species exist with more than one known space-group symmetry, and these are listed. Variations in space-group symmetry and variations in order–disorder relationships of framework cations are not in themselves adequate evidence for establishing new species (Rule 2). Cell parameters given are as reported for material specified in key references. Cell dimensions of many species vary widely as a result of variable compositions, variable ordering, and differing levels of hydration. Except for a few newly described species, details of structure, including size and orientation of channels, can be obtained for each structure type from Meier et al. (1996) and are discussed in Gottardi and Galli (1985).

The accepted series and species are as follows:

**Amicite**

\[ K_2Na_4[Al_8Si_8O_{32}]·10H_2O \quad Z = 1 \quad GIS \]

Alberti et al. (1979). Type locality: Höwenegg (a Tertiary melilite nephelinite volcano), Hegau, southwestern Germany. Named after Giovan Battista Amici (1786–1863), inventor of the Amici lens and microscope objectives with a hemispherical front lens. Both type amicite and the only other known example (Khomyakov et al., 1982) include minor Ca. \( T_{Si} = 0.51, 0.49 \). Monoclinic, \( I2, a = 10.226(1), b = 10.422(1), c = 9.884(1) \, Å, \beta = 88.32(2) \). The framework is characterized by double crankshaft chains as in gismondine (Alberti and Vezzalini, 1979). Amicite has the same framework topology as gismondine. Si,Al and Na,K distributions are
ordered and lower the symmetry from topological $I4_{1}$/amd to real symmetry $I2$.

Ammonioleucite

$\text{(NH}_{3}\text{)}_{2}\text{[AlSi}_{2}\text{O}_{6}]$  

\[Z = 16\text{ ANA}\]

Hori et al. (1986). Type locality: Tatara-zawa, Fujioka, Gunma Prefecture, Japan. The name reflects composition and relationship to leucite. Material from the only known locality contains significant K. $T_{\text{Si}} = 0.70$.

Tetragonal, $I4_{1}$/a, $a = 13.214(1), c = 13.713(2)$ Å.

Analcime

$\text{Na[AlSi}_{2}\text{O}_{4}]\text{H}_{2}\text{O}$  

\[Z = 16\text{ ANA}\]

Hauy (1797, p. 278). Type locality: near Catanes, Cyclopean Isles, Italy (Hauy, 1801, pp. 180–185). Name from Greek roots meaning ‘without strength’, in allusion to the weak electrical effects induced by friction. In most analyses, Na is the only substantial extra-framework cation, but analcime forms a continuous series with pollucite and possibly with wairakite (Seki and Oki, 1969; Seki, 1971, Cho and Liou, 1987). $T_{\text{Si}}$ varies widely, 0.59–0.73 (e.g. Coombs and Whetten, 1967). As Si increases, NaAl decreases and H$_2$O increases. Topological symmetry is cubic, $Ia3d$. Real symmetry variants include: cubic, $Ia3d$, $a = 13.725$ Å; tetragonal, $I4_{1}$/acd, $a = 13.723(7), c = 13.686(10)$ Å; $a = 13.721(1), c = 13.735(1)$ Å (Mazzi and Galli, 1978); tetragonal, $I4_{1}$/a; orthorhombic, $Ibca$, $a = 13.733(1), b = 13.729(1), c = 13.712(1)$ Å; $a = 13.727(2), b = 113.714(2), c = 13.740(2)$ Å (Mazzi and Galli, 1978); monoclinic with 2-fold axis parallel both to pseudo-cubic [100] and [110]; triclinic, $a = 13.6824(5), b = 13.7044(6), c = 13.7063(5)$ Å, $\alpha = 90.158(3), \beta = 89.543(3), \gamma = 89.569(3)$ (Hazan and Finger, 1979); and probably trigonal; with variable Si,Al order (e.g. Hazen and Finger, 1979; Teerstra et al., 1994)

The name applies to Na-dominant compositions with this framework structure regardless of the degree and patterns of order.

Barrerite

$\text{Na}_{2}\text{Al}_{7}\text{Si}_{7}\text{O}_{18}\text{H}_{2}\text{O}$  

\[Z = 8\text{ STI}\]


Also known from Kuiu Island, Alaska (Di Renzo and Gabelica, 1997). $T_{\text{Si}}$ in the range 0.77–0.78. The type example has composition: $\text{(Na}_{5.45}\text{K}_{1.06}\text{Ca}_{0.84}\text{Mg}_{0.17})\text{[Al}_{8.19}\text{Fe}_{0.01}\text{Si}_{27.72}\text{O}_{72}]\text{H}_{25.78}\text{O}$.

Orthorhombic, $Amma$ or $Ammm$, $a = 13.643(2), b = 18.200(3), c = 17.842(3)$ Å (Passaglia and Pongiluppi, 1974).

The structure is similar to that of stilbite and stellerite, but it has different symmetry as a result of extra cations, which cause rotational displacements within the framework (Galli and Alberti, 1975b).

Bellbergite

$\text{(K, Ba, Sr)}_{2}\text{Sr}_{2}\text{Ca}_{2}\text{(Ca, Na)}_{4}\text{Al}_{18}\text{Si}_{16}\text{O}_{72}\cdot 30\text{H}_{2}\text{O}$  

\[Z = 1\text{ EAB}\]

Rüdinger et al. (1993). Type and only known locality: Bellberg (or Bellerberg) volcano, near Mayen, Eifel, Germany. Named after the locality. Ca is overall the dominant extra-framework cation. The framework structure is as for synthetic zeolite TMA-EAB.

Bikitaite

$\text{Li[AlSi}_{2}\text{O}_{6}]\text{H}_{2}\text{O}$  

\[Z = 2\text{ BIK}\]

Hurlbut (1957). Type locality: Bikita, Zimbabwe. Named after the type locality. Two known localities, the bikitaite having very similar compositions. $T_{\text{Si}} = 0.67$.

Hexagonal, possible space-groups $P6_{3}mmc$, $P62c$, and $P6_{3}mc$, $a = 13.244(1), c = 15.988(2)$ Å. The framework structure is as for synthetic zeolite TMA-EAB.

Boggsite

$\text{Ca}_{8}\text{Na}_{3}\text{[Al}_{19}\text{Si}_{78}\text{O}_{192}]\cdot 70\text{H}_{2}\text{O}$  

\[Z = 1\text{ BOG}\]

Pluth et al. (1989) and Howard et al. (1990). Type locality: Basalt above cliff, Goble Creek, south
side of the Neer Road, 0.2 km north of Goble, Columbia County, Oregon, U.S.A. Named after Robert Maxwell Boggs (father) and Russell Calvin Boggs (son), mineral collectors in the Pacific Northwest.

Type boggsite approximates the above formula, with minor Fe, Mg, and K. Boggsite from Mt. Adamson, Antarctica (Galli et al., 1995) approximates Ca₆Na₂K[Al₁₅Si₇₈O₁₉₂]·7₇H₂O, with minor Fe, Mg, Sr, Ba. Tₚ = 0.81. Orthorhombic, Imma, "a" = 20.236(2), "b" = 23.798(1), "c" = 12.798(1) Å (Pluth and Smith, 1990).

Si, Al highly disordered.

**Brewsterite (series)**

(Sr,Ba)₂[Al₆Si₁₂O₃₂]·10H₂O Z = 1 BRE Brooke (1822). Type locality: Strontian, Argyll, Scotland. Named after Sir David Brewster (1781–1868), Scottish natural philosopher who discovered laws of polarization of light in biaxial crystals.

Monoclinic, P2₁/m, P2₁ or triclinic (Akizuki, 1987a, Akizuki et al., 1996).

The structure is sheet-like parallel to (010) (Perrotta and Smith, 1964).

**Brewsterite-Sr**

New name for the original species of the series; Sr is the most abundant extra-framework cation. Tₚ in the range 0.74–0.75.

Monoclinic, P₂₁/m, "a" = 6.793(2), "b" = 17.573(6), "c" = 7.759(2) Å, β = 94.54(3)°, for composition (Sr₁.₄₂Ba₀.₄₈K₀.₀₂)[Al₁₄.₁₂Si₁₁.₉₅O₃₂]·1₂H₂O (Schlenker et al., 1977a).


Partly ordered Si, Al distribution.

**Brewsterite-Ba**

New name; Ba is the most abundant extra-framework cation.

Proposed type example: the Gouverneur Talc Company’s No. 4 wollastonite mine near Harrisville, Lewis County, New York, U.S.A. (Robinson and Grice, 1993). Also Cerchiara mine, Liguria, Italy (Cabella et al., 1993, including structure refinement) Tₚ in the range 0.73–0.74.

Monoclinic, P₂₁/m or P₂₁, "a" = 6.780(3), "b" = 17.599(9), "c" = 7.733(2) Å, β = 94.47(3)° for type example, containing up to 0.85 Ba per 16 O atoms.

**Chabazite (series)**

(Ca₀.₅-Na,K)₄[Al₁₃Si₈O₂₄]·12H₂O Z = 1 (trigonal)CHA Bosc d’Antic (1792), as ‘chabazie’. The source of the original specimen is unclear. The name is from a word ‘chabazion’ used for an unknown substance in the story of Orpheus. Ca-, Na-, and K-dominant species occur in that order of frequency, with Sr and Mg occasionally significant, Ba more minor. Tₚ varies widely, 0.58–0.81.

Topological symmetry of the framework, trigonal (R₃m) where "a" ≈ 13.2, "c" ≈ 15.1 Å (pseudo-hexagonal cell). Significant deviations to triclinic, P₁, "a" ≈ 9.4, "b" ≈ 9.4, "c" ≈ 9.4 Å, x ≈ 94°, β ≈ 94°, γ ≈ 94° (Smith et al., 1964; Mazzi and Galli, 1983).

Partial order leads to the lower symmetry.

**Chabazite-Ca**

New name for the original and most common species; Ca is the most abundant single extra-framework cation. Other cations vary widely. Tₚ in the range 0.58–0.80.

"a" = 13.790(5), "c" = 15.040(4) Å, for pseudo-hexagonal cell, with composition (Ca₁₈₋₄Na₀.₀₅K₀.₀₂Mg₀.₀₅Si₀.₀₃)·[Al₁₃.₉₄Fe₀.₀₁Si₈.₀₃O₂₄]·1₃.₁₆H₂O, from Col de Lares, Val di Fassa, Italy (Passaglia, 1970, #13).

**Chabazite-Na**

New name; Na is the most abundant single extra-framework cation. Other cations vary widely. Tₚ in the range 0.62–0.79.

Suggested type locality: biggest ‘Faraglione’ facing Acì Trezza, Sicily, Italy (Passaglia, 1970, #1). "a" = 13.863(3), "c" = 15.165(3) Å, for hexagonal cell, with composition (Na₃.₁₁K₁.₀₅Ca₀.₁₉Mg₀.₀₆Sr₀.₀₅)·[Al₄.₅₃Fe₀.₀₁Si₇.₄₀O₂₄]·1.₄₇H₂O.

Although originally described as containing ‘silex, alumina, and potash’ (Levy, 1825), the name herschelite has often been applied to chabazite minerals of tabular habit and high Na content. Herschelite should no longer be used as a species name.
Chabazite-K

New name; K is the most abundant single extra-framework cation. Other cations vary widely. T_{Si} in the range 0.60-0.74.

Suggested type specimen: Tufo Ercolano, Ercolano, Naples, Italy (De Gennaro and Franco, 1976), a = 13.849(3), c = 15.165(3) Å, for hexagonal cell, with composition (K_{2.06}Na_{0.98}Ca_{0.46}Mg_{0.01}Si_{0.01})_2[Fe_{0.08}Al_{4.37}Si_{17.60}O_{24}]·11.42H_2O.

Chiavennite

CaMn[Be_{5}Si_{15}O_{13}(OH)_{2}]·2H_2O Z = 4 CHI Bondi et al. (1983), Raade et al. (1983). Type locality: Chiavenna, Lombardy, Italy. Named after type locality.

Limited available data show up to 0.72 Al and 0.15 B in tetrahedral sites, and significant extra-framework Fe and Na (Raade et al., 1983; Langhof and Holstam, 1994). T_{Si} 0.63 - 0.68.orthorhombic, Pnab, a = 8.729(5), b = 31.326(11), c = 4.903(2) Å (Tazzoli et al., 1995). A Ca,Mn berylliosilicate with an interrupted framework of four-connected [SiO_{4}] and three-connected [BeO_{4}] tetrahedra.

Clinoptilolite (series)

(Na,K,Ca_{0.5}Sr_{0.5}Ba_{0.5}Mg_{0.5})_{6}[Al_{6}Si_{30}O_{72}]·20H_2O Z = 1 HEU Schaller (1923, 1932). Type locality: in decomposed basalt at a high point on ridge running east from Hoodoo Mountain, Wyoming, U.S.A. (‘crystallized mordenite’ of Pirsson, 1890). The name reflects its inclined extinction and supposed similarity in composition to ‘ptilolite’ (mordenite). Ptilo-, from Greek, alludes to the downy, finely fibrous nature of that mineral.

The cation content is highly variable. Ca-, Na-, and K-dominant compositions are known, and Sr, Ba, and Mg are in some cases substantial. Fe^{2+} and Fe^{3+} are possible constituents. In Pirsson’s (1890) analysis, K is the most abundant single cation by a small margin. Clinoptilolite-K is therefore taken as the type species of the series. T_{Si} in the range 0.80-0.84.

Minerals with the same framework topology but with T_{Si} < 0.80, Si/Al < 4.0 are classified as heulandite, with which clinoptilolite forms a continuous series.

Monoclinc, C2/m, or C2, or Cm. Structure refinements by Alberti (1975a) and Armbruster (1993) demonstrate variations in extra-framework cation sites compared with heulandite and as a function of the extent of dehydration.

Clinoptilolite-K

New name for the original species; K is the most abundant single extra-framework cation. A moderately K-rich clinoptilolite-K was referred to as ‘potassium clinoptilolite’ by Minato and Takano (1964). T_{Si} in the range 0.80-0.83.

Monoclinic, C2/m, C2, or Cm, a = 17.688(16), b = 17.902(9), c = 7.490(7) Å, β = 116.50(7)°, for (K_{4.72}Na_{0.85}Ca_{0.04}Sr_{0.37}Mg_{0.19}Fe_{0.03}Mn_{0.01}) [Al_{6.52}Si_{29.38}O_{72}]·nH_2O, from an off-shore borehole, Japan (Ogihara and Iijima, 1990).

Clinoptilolite-Na

New name; Na is the most abundant single extra-framework cation. Other cations vary widely. T_{Si} in the range 0.80-0.84.

Suggested type example: Barstow Formation, about 1.6 km east of mouth of Owl Canyon, San Bernardino County, California, U.S.A., USGS Lab. no. D100594 (Sheppard and Gude, 1969a). Monoclinic, C2/m, C2, or Cm, a = 17.627(4), b = 17.955(4), c = 7.399(4) Å, β = 116.29(2)° (Boles, 1972), for type material of Sheppard and Gude (1969a), (Na_{3.78}K_{1.31}Ca_{0.61}Ba_{0.09}Mg_{0.23}Mn_{0.01}) [Al_{6.61}Fe_{0.18}Si_{29.19}O_{72}]·20.4H_2O.

Clinoptilolite-Ca

New name; Ca is the most abundant single extra-framework cation. Other cations vary widely. T_{Si} in the range 0.80-0.84.

Suggested type specimen: Kuruma Pass, Fukushima Prefecture, Japan (Koyama and Takéuchi, 1977). Monoclinic, C2/m, C2, or Cm, a = 17.660(4), b = 17.963(5), c = 7.400(3) Å, β = 116.47(3)° based on C2/m, (Koyama and Takéuchi, 1977), for Kuruma Pass specimen, (Na_{1.76}K_{1.05}Ca_{1.96}Mg_{0.17}) [Al_{6.72}Si_{29.20}O_{72}]·23.7H_2O.

Cowlesite

Ca[Al_{2}Si_{10}O_{5}]·5.3H_2O Z = 52 (IZA code not assigned) Wise and Tschenrich (1975). Type locality: road cuts 0.6 km northwest of Goble, Columbia County, Oregon, U.S.A. Named after John Cowles of Rainier, Oregon, amateur mineralogist.
Dachiardite (series)

\[(Ca,Na,K)_{4.86}\{Al_{4.54}Si_{22.2}O_{48}\}_1\{H_{2}O\}_{7.56}\]

Monoclinic, \(a = 18.647(7), b = 7.506(4), c = 10.296(4)\) Å, \(\beta = 108.37(3)^\circ\), for 
\[(Na_{2.59}K_{0.71}Ca_{0.53}Mg_{0.04}Ba_{0.01})_{[Fe_{0.11}Al_{4.42}Si_{19.61}O_{48}]_{13.43}}H_{2}O\] from the type locality (Alberti, 1975b).

Diffuse diffraction spots indicate disorder.

Edingtonite

\[Ba[Al_{2}Si_{3}O_{10}]\cdot 4H_{2}O\]

Orthorhombic, \(P2_12_12_1\), \(a = 9.550(10), b = 9.665(10), c = 6.523(5)\) Å (Böhlet Mine, Westergotland, Sweden) (Galli, 1976).

Also tetragonal, \(P4_{2}2_{1}2_{1}\), \(a = 9.584(5), c = 6.524(3)\) Å (Old Kilpatrick, near Glasgow, Scotland) (Mazzi et al., 1984).

From optical evidence, Akizuki (1986) suggested that a triclinic true symmetry is also possible. The structure is similar to that of natrolite, but with a distinctive cross-linking of the chains (Taylor and Jackson, 1933; Mazzi et al., 1984).

Examples of orthorhombic edingtonite have nearly perfect (Si,Al) order. The tetragonal form is disordered, and available analyses show that slightly more Ba has been replaced by other ions.

Epistilbite

\[(Ca,Na_{2})\{Al_{2}Si_{4}O_{12}\}\cdot 4H_{2}O\]

Monoclinic, \(a = 10.226(1)\) Å, \(\beta = 124.66(2)^\circ\) (Teigarhorn, Iceland: Alberti et al., 1985) or:
triclinic, \(C1, a = 9.083(1), b = 17.738(3), c = 10.209(1)\) Å, \(\beta = 98.95(1)^\circ, \gamma = 90.00(1)^\circ\) (Gibelsbach, Valais, Switzerland: Yang and Armbruster, 1996).

The structural framework belongs to the mordenite group (Gottardi and Galli, 1985). Earlier work suggested space-group symmetry \(C2/m\) (Perrotta, 1967). Alberti et al. (1985)
proposed a domain structure involving acentric configurations of tetrahedra and space group C2. Yang and Armbruster (1996) indicated that the proposed domains can be modelled by (010) disorder caused by a local mirror plane, and that increased partial order of Si, Al leads to triclinic symmetry.

**Erionite (series)**

K$_2$(Na, Ca$_{0.5}$)$_8$[Al$_{10}$Si$_{26}$O$_{72}$]$_{\sim}$30H$_2$O  
Z = 1  
ERI

Eakle (1898). Type locality: Durkee, Oregon, U.S.A., in rhyolitic, welded ash-flow tuff. Name from Greek root meaning wool, in reference to its appearance.

Substantial amounts of any or all of Ca, Na, and K, and subordinate Mg may be present, and there is evidence that trace Fe may enter tetrahedral and extra-framework sites. Eakle’s (1898) analysis of type erionite shows Na as the most abundant extra-framework cation; Passaglia _et al._ (in press) found Ca to be the most abundant in a type-locality specimen. T$_{Si}$ in the range 0.68–0.79.

Hexagonal, _P6\_3/mmc_, $a = 13.15$, $c = 15.02$ Å (Kawahara and Curien, 1969). The structure is related to those of offretite, with which it may form intergrowths with stacking faults (Schlenker _et al._, 1977b), and levyne, on which it forms epitactic growths (Passaglia _et al._, 1998). The three minerals have 4-, 6- and 8-membered rings. They differ in the stacking of single and double 6-membered rings, resulting in different $c$ dimensions and differently sized and shaped cages. Si, Al disordered.

**Erionite-Na**

New name; Na is the most abundant extra-framework cation.

Proposed type example: Cady Mountains, California, U.S.A. (Sheppard _et al._, 1965). T$_{Si}$ in the range 0.74–0.79.

For the type specimen, $a = 13.214(3)$, $c = 15.048(4)$ Å, composition (Na$_{5.59}$K$_{2.06}$Ca$_{0.11}$ Mg$_{0.18}$Fe$_{0.02}$)$_2$[Al$_{7.57}$Si$_{28.27}$O$_{72}$]$_{24.60}$H$_2$O (Sheppard and Gude, 1969).

**Erionite-K**

New name; K is the most abundant extra-framework cation.

Proposed type example: Rome, Oregon, U.S.A., in which K makes up 58% of extra-framework cations; significant Na, Ca, and Mg are also present (Eberly, 1964). T$_{Si}$ in the range 0.74–0.79.

For a specimen from Ortenberg, Germany, $a = 13.227(1)$, $c = 15.075(3)$ Å, (K$_{3.32}$Na$_{2.31}$Ca$_{0.09}$ Mg$_{0.08}$Ba$_{0.02}$)[Al$_{8.05}$Si$_{28.01}$O$_{72}$]$_{31.99}$H$_2$O (Passaglia _et al._, 1998).

**Faujasite (series)**

(Na, Ca$_{0.5}$, Mg$_{0.5}$, K)$_x$[Al, Si$_{12-x}$O$_{24}$]$_{16}$H$_2$O  
Z = 16  
FAU

Damour (1842). Type locality: Sasbach, Kaiserstuhl, Germany. Named after Barthélemy Faujas de Saint Fond, noted for his work on extinct volcanoes.

Major amounts of Na, Ca, and Mg are commonly present, and in some cases, K; minor Sr is also reported. The ratio Si: Al ratios also varies; T$_{Si}$ in the range 0.68–0.74, with one record of 0.64. For most analyses, $x$ in the above generalized formula is in the range 3.2–3.8 with one record of 4.4 (Rinaldi _et al._, 1975a; Wise, 1982; Ibrahim and Hall, 1995).

Cubic, _Fd\_3m_. $a = 24.65$ Å (material from Sasbach; Bergerhoff _et al._, 1958).

The framework structure is very open, with complete sodalite-type cages and with very large cavities having 12-membered ring openings. Up to 260 molecules of H$_2$O can be accommodated per unit cell (Bergerhoff _et al._, 1958; Baur, 1964).

**Faujasite-Na**

New name; Na is the most abundant extra-framework cation, as it is in the original (incomplete) and most subsequent analyses of material from the type locality, Sasbach, Kaiserstuhl, and some other localities. T$_{Si}$ in the range 0.70–0.74, with one report of 0.64.

Reported values of $a$ range from 24.638(3) Å (Wise, 1982) to 24.728(2) Å (Ibrahim and Hall, 1995).
**Faujasite-Ca**

New name; Ca is the most abundant extra-framework cation. Reported $T_{Si}$ in the range 0.68–0.73. Proposed type example: drill core from Haselborn near Ilbeshausen, Vogelsberg, Hessen, Germany (Wise, 1982), composition (Ca$_{1.32}$Na$_{0.56}$Mg$_{0.26}$K$_{0.04}$) [Al$_{3.83}$Si$_{8.19}$O$_{24}$]$_n$H$_2$O, $Z = 16$.

Reported values of $a = 24.714(4)$ Å and $24.783(3)$ Å (Jabal Hanoun, Jordan: Ibrahim and Hall, 1995).

**Faujasite-Mg**

New name; Mg is the most abundant extra-framework cation. Proposed type example: Altoona, Washington, U.S.A., composition (Na$_{2.02}$Si$_{2.05}$Ca$_{2.54}$O$_{13.0}$)[Al$_{56}$Si$_{137}$O$_{384}$]$_n$H$_2$O, $Z = 1$.

**Ferrierite (series)**

(K,Na,Mg$_{0.5}$,Ca$_{0.5}$)$_6$[Al$_6$Si$_{30}$O$_{72}$]18H$_2$O $Z = 1$ FER


Substantial amounts of any or all of Mg, K, Na, and Ca may be present, and smaller amounts of Fe, Ba, and Sr. $T_{Si}$ in the range 0.80–0.88.

Statistical symmetry, orthorhombic, Immm; true symmetries orthorhombic, Pnmm, $a = 19.23$, $b = 14.15$, $c = 7.50$ Å (Alberti and Sabelli, 1987). Also monoclinic, $P2_1/n$, $a = 18.89$, $b = 14.18$, $c = 7.47$ Å, $\beta = 90.0^\circ$ (Gramlich-Meier et al., 1985). The structure was first determined by Vaughan (1966). Framework Si,Al partially ordered (Alberti and Sabelli, 1987).

**Ferrierite-Mg**

New name for the original member of the series; Mg is the most abundant single extra-framework cation.

Substantial extra-framework Na, K, and lesser Ca commonly present. $T_{Si}$ in the range 0.80–0.84.

True symmetry orthorhombic, Pnmm, $a = 19.231(2)$, $b = 14.145(2)$, $c = 7.499(1)$ Å for specimen from Monastir, Sardinia, of composition (Mg$_{2.02}$K$_{1.19}$Na$_{0.56}$Ca$_{0.52}$Sr$_{0.14}$Ba$_{0.02}$) [Al$_{6.89}$Si$_{29.03}$O$_{72}$]17.86H$_2$O (Alberti and Sabelli, 1987).

**Ferrierite-K**

New name; K is the most abundant single extra-framework cation.

Proposed type example: Santa Monica Mountains, California, U.S.A., composition (K$_{2.05}$Na$_{0.14}$Mg$_{0.74}$Ca$_{0.14}$) [Al$_{55}$Si$_{51.01}$O$_{172}$]$_n$H$_2$O (Wise and Tschernich, 1976, #3).

$T_{Si}$ in the range 0.81–0.87.

Orthorhombic, $a = 18.973(7)$, $b = 14.140(6)$, $c = 7.478(4)$ Å for type specimen.

**Ferrierite-Na**

New name; Na is the most abundant single extra-framework cation.

Proposed type example: Altoona, Washington, U.S.A., composition (Na$_{3.06}$K$_{0.97}$Mg$_{0.38}$Ca$_{0.05}$Sr$_{0.05}$Ba$_{0.02}$) [Al$_{53}$Si$_{31}$O$_{72}$]18H$_2$O (Wise and Tschernich, 1976, #1).

$T_{Si}$ in the range 0.85–0.88.

Monoclinic, $P2_1/n$, $a = 18.886(9)$, $b = 14.182(6)$, $c = 7.470(5)$ Å, $\beta = 90.0(1)^\circ$ (Gramlich-Meier et al., 1985, for a specimen from Altoona, Washington).

**Garronite**

Na$_{2}$Ca$_{2.51}$[Al$_6$Si$_{10}$O$_{32}$]14H$_2$O $Z = 1$ GIS

Walker (1962). Type locality: slopes of Glenariff Valley, County Antrim, Northern Ireland. Named after the Garron Plateau, where the type locality is sited.

Ca/(Na + K) is variable, but Ca predominates. Type-locality garronite has about 1.3 Na atoms pfu; some others have (Na + K) < 0.2 atoms pfu. H$_2$O 13.0–14.0 molecules pfu. $T_{Si}$ 0.60–0.65.

The crystal structure has been refined in tetragonal symmetry, I4/m2, $a = 9.9266(2)$, $c = 10.3031(3)$ Å, by Artioli (1992), and for a Na-free synthetic garronite, in I4$_1/a$, $a = 9.873(1)$, $c = 10.288(1)$ Å, by Schröpfer and Joswig (1997). Orthorhombic symmetry has been proposed on the basis of X-ray diffraction with twinned crystals (Nawaz, 1983) and crystal morphology (Howard, 1994).

The framework topology is the same as for gismondine, but Si and Al are essentially disordered. The different space-group symmetry...
(Artioli, 1992) is associated with disorder and the presence of significant Na. Gottardi and Alberti (1974) proposed partial ordering subsequent to growth to explain twin domains.

**Gautite**

Na₄[Zn₂Si₇O₁₈]·5H₂O  \( Z = 8 \)  VSV


No other elements detected in the one reported example; \( T_{Si} = 0.78 \).

Orthorhombic, \( F2dd, a = 10.211(3), b = 39.88(2), c = 10.304(4) \) Å.

The zicosilicate framework of tetrahedra is characterized by stacked sheets of edge-sharing 4- and 8-membered rings. The sheets are cross-linked by tetrahedra. Gautite is isostructural with synthetic zeolite VPI-7 and similar in structure to lovdarite (Ercit and Van Velthuizen, 1994).

**Gismondine**

Ca[Al₂Si₂O₈]·4.5H₂O  \( Z = 4 \)  GIS


(K + Na) does not exceed 0.12 atoms \( pfu \), with K less than 0.08 atoms \( pfu \); analyses showing high K result from intergrown phillipsite. Minor Sr may be present. \( T_{Si} \) in the range 0.51–0.54 (Vezzalini and Oberti, 1984). \( H₂O \) is slightly variable (4.4–4.5 molecules \( pfu \)) because of mixed 6- and 7-coordination of Ca (Artioli et al., 1986b). Monoclinic, originally refined in \( P2₁/a \) by Fischer and Schramm (1970); cell converted to standard \( P2₁/c \) second setting is \( a = 10.023(3), b = 10.616(5), c = 9.843(15) \) Å, \( β = 92.42(25) \)°. Also refined (two samples) by Rinaldi and Vezzalini (1985).

The framework topology is based on crankshaft chains of 4-membered rings as in feldspars, connected in UUDD configuration. Si,Al are strictly ordered.

**Gmelinite (series)**

(\( Na₂,Ca,K₂ \))[Al₂Si₁₆O₄₈]·22H₂O  \( Z = 1 \)  GME

Brewster (1825a). Type locality: the name was proposed for minerals occurring both at Little Deer Park, Glenarm, County Antrim, Northern Ireland, and at Montecchio Maggiore, Vicenza, Italy. Named after Christian Gottlob Gmelin, Professor of Chemistry, University of Tübingen.

Na-dominant members are the most common. \( T_{Si} = 0.65–0.72 \).


The structure is similar to that of chabazite, with which it is commonly intergrown (Strunz, 1956), but gmelinite has a different stacking of the double 6-membered rings (Fischer, 1966). Si,Al are disordered.

**Gmelinite-Na**

New name for the most common species of the series. It occurs in at least one of the gmelinite type localities (Montecchio Maggiore). The Ca content is commonly substantial, K is minor, and Sr is significant in a few analysed samples. \( T_{Si} \) in the range 0.65–0.71.

Hexagonal, \( P6₃/mmc, a = 13.756(5), c = 10.048(5) \) Å (Galli et al., 1982), from near-end-member material from Queensland, Australia, of composition \( (Na₇.6₁Ca₀.0₇K₀.1₆)₂Al₇.₄₁Si₁₆.₄₉O₄₈ \) ·21.5₁H₂O (Passaglia et al., 1978a).

**Gmelinite-Ca**

New name for a species that also occurs in at least one of the type localities (Montecchio Maggiore). Ca is the most abundant single extra-framework cation. Significant to substantial Sr and Na, minor K. \( T_{Si} \) in the range 0.68–0.70.

Hexagonal, \( P6₃/mmc, a = 13.800(5), c = 9.964(5) \) Å (Galli et al., 1982), from Montecchio Maggiore, Vicenza, composition \( (Ca₂.₀₆Sr₁.₃₅Na₀.₇₈K₀.₁₁)₂Al₇.₈₂Si₁₆.₂₁O₄₈ \) ·23.₂₃H₂O (Passaglia et al., 1978a).

**Gmelinite-K**

New name; K is the most abundant single extra-framework cation. Proposed type example: Fara Vicentina, Vicenza, Italy, composition \( (K₂₀.₇₂Ca₁.₆₇Sr₀.₃₉Na₀.₂₂Mg₀.₁₃)[Al₇.₇₉Si₁₆.₃₂O₄₈]·2₃.₅₂H₂O \) (Vezzalini et al., 1990). Also known from the Kola Peninsula (Malinovskii, 1984).

Hexagonal, \( P6₃/mmc, a = 13.₆₂₁(3), c = 10.₂₅₄(1) \) Å.
Gobbinsite

$\text{Na}_4\{\text{Al}_3\text{Si}_{11}\text{O}_{32}\}\cdot 12\text{H}_2\text{O}$  \[ \text{Z} = 1 \]  \[ \text{GIS} \]


$\text{Na} : \text{Ca} : \text{Mg} : \text{K}$ variable, with $\text{Na}$ greatly predominant, $\text{Ca} < 0.6$ atoms pfu. High $K$ analyses result from intergrown phillipsite (Artioli and Foy, 1994). $T_{\text{Si}} = 0.62$–0.68, substantially higher than in gismondine.

Orthorhombic, $Pmmn_2$, $a = 10.108(1)$, $b = 9.766(1)$, $c = 10.171(1) \AA$ for the anhydrous composition ($\text{Na}_{2.50}\text{K}_{2.11}\text{Ca}_{0.59}$) $[\text{Al}_{6.17}\text{Si}_{0.93}\text{O}_{32}]$ from Two-Mouth Cave, County Antrim, Northern Ireland (McCusker et al., 1985); $a = 10.1027(5), b = 9.8016(5), c = 10.1682(6) \AA$ for ($\text{Na}_{4.3}\text{Ca}_{0.6})[\text{Al}_{5.6}\text{Si}_{10.4}\text{O}_{32}]\cdot 12\text{H}_2\text{O}$ from Magheramorne quarry, Larne, Northern Ireland (Artioli and Foy, 1994).

The framework topology is the same as for gismondine and is based on crankshaft chains of 4-membered rings, as in feldspars. Distortion from tetragonal topological symmetry results from the arrangement of cations in the channels. $\text{Si},\text{Al}$ in the framework are disordered.

Gonnardite

$\text{(Na, Ca)}_{6–8}\{\text{Al, Si}_{20}\text{O}_{40}\}\cdot 12\text{H}_2\text{O}$  \[ \text{Z} = 1 \]  \[ \text{NAT} \]

Lacroix (1896). Type locality Chaux de Bergonne, Gignat, Puy-de-Dôme, France. Named after Ferdinand Gonnard, who had earlier described the material as ‘mesole’ (= thomsonite).

Forms an extensive substitution series, commonly approximating $\text{Na}_8–3\text{Ca}_2\{\text{Al}_{6+}\text{Si}_{12–}\text{O}_{40}\}\cdot 12\text{H}_2\text{O}$ (after Ross et al., 1992), with minor $\text{Fe}^{3+}, \text{Mg}, \text{Ba}, \text{Sr}$, and $\text{K}$. $T_{\text{Si}}$ in the range 0.52–0.59 (or 0.52–0.62 if tetratrolite = gonnardite).

Tetragonal, $I42d, a = 13.21(1), c = 6.622(4) \AA$ for material from Tvedalen, Langesund, Norway, of composition ($\text{Na}_6.42\text{K}_{0.01}\text{Ca}_{1.50}$) $[\text{Al}_{9.22}\text{Si}_{10.73}\text{O}_{40}]\cdot 12.37\text{H}_2\text{O}$ (Mazzi et al., 1986).

The structure is similar to that of natrolite, but with $\text{Si},\text{Al}$ disordered, and usually with significant to substantial $\text{Ca}$ (Mazzi et al., 1986; Artioli and Torres Salvador, 1991; Alberti et al., 1995).

Goosecreekite

$\text{Ca}[\text{Al}_2\text{Si}_6\text{O}_{16}]\cdot 5\text{H}_2\text{O}$  \[ \text{Z} = 2 \]  \[ \text{GOO} \]

Dunn et al. (1980). Type locality: Goose Creek quarry, Loudoun County, Virginia. Named after the locality.

The single available analysis conforms closely to the formula given, with no other elements detected. $T_{\text{Si}} = 0.75$.

Monoclinic, $P2_1, a = 7.401(3), b = 17.439(6), c = 7.293(3) \AA, \beta = 105.44(4)^\circ$ (Rouse and Peacor, 1986).

The framework consists of 4-, 6-, and 8-membered rings that link to form layers parallel to (010), with some similarities to the breuersterite structure. $\text{Si},\text{Al}$ are nearly perfectly ordered (Rouse and Peacor, 1986).

Gottardite

$\text{Na}_3\text{Mg}_3\text{Ca}_5\{\text{Al}_{19}\text{Si}_{11}\text{O}_{272}\}\cdot 93\text{H}_2\text{O}$  \[ \text{Z} = 1 \]  \[ \text{NES} \]


Known from the type locality only, with composition approximating the above simplified formula; minor $K$, and very high $\text{Si}$. $T_{\text{Si}} = 0.86$.

Orthorhombic, topological symmetry $Fmmm$, real symmetry $Cmca, a = 13.698(2), b = 25.213(3), c = 22.660(2) \AA$ (Alberti et al., 1996).

The framework topology is the same as for the synthetic zeolite NU-87, which, however, has monoclinic symmetry, $P2_1/c$. Some $\text{Si},\text{Al}$ order is probable.

Harmotome

$\text{(Ba}_{0.5}\text{Ca}_{0.5}\text{K, Na})_3\{\text{Al}_{5}\text{Si}_{11}\text{O}_{32}\}\cdot 12\text{H}_2\text{O}$  \[ \text{Z} = 1 \]  \[ \text{PHI} \]

Haüy (1801, p. 191–195), renaming andreasbergolite, also known as andréolite, of Delamétherie (1795, p. 393). Type locality: Andreasberg, Harz, Germany. Named from Greek words for a ‘joint’ and ‘to cut’, in allusion to a tendency to split along junctions (twin planes).

$\text{Ba}$ is the most abundant extra-framework cation. Harmotome forms a continuous series with phillipsite-$\text{Ca}$. The name harmotome predates phillipsite, and on grounds of history and usage both are retained in spite of Rule 1 of the present report. $T_{\text{Si}}$ in the range 0.68–0.71 (e.g. Černý et al., 1977).

Monoclinic, refined in $P2_1/m$, but on piezoelectric
and optical grounds, the true symmetry may be noncentrosymmetric and triclinic, $P1$ (e.g. Akizuki, 1985; Stuckenschmidt et al., 1990), $a = 9.879(2)$, $b = 14.139(2)$, $c = 8.693(2)$ Å, $\beta = 124.81(1)^\circ$ for (Ba$_{1.93}$Ca$_{0.46}$K$_{0.07}$)[Al$_{4.66}$Si$_{11.25}$O$_{32}$]-12H$_2$O from Andreasberg, Harz (Rinaldi et al., 1974). The structure is the same as for phillipsite, with little or no Si,Al order.

**Heulandite (series)**

(Ca$_{0.5}$Sr$_{0.5}$,Ba$_{0.5}$,Mg$_{0.5}$,Na,K)$_9$[Al$_9$Si$_{27}$O$_{72}$]$_x$ -24H$_2$O $Z = 1$ HEU Brooke (1822). Type locality: none; the name was given to the more distinctly monoclinic minerals previously known as stilbite. Named after Henry Heuland, English mineral collector. The cation content is highly variable. Ca-, Na-, K-, and Sr-dominant compositions are known, and Ba and Mg are in some cases substantial. $T_{Si}$ in the range 0.71–0.80. Minerals with the same framework topology but with $T_{Si} \geq 0.80$, Si/Al $\geq 4.0$, are distinguished as clinoptilolite. Monoclinic, with highest possible topological symmetry $C2/m$ ($I2/m$). $Cm$ and $C2$ have also been suggested. The sheet-like structure was solved by Merkle and Slaughter (1968). There is partial order of Si,Al.

**Heulandite-Ca**

New name for the most common species of the series, and that recognized in most older analyses. Ca is the most abundant single extra-framework cation. $T_{Si}$ in the range 0.71–0.80. Monoclinic, $C2/m$, $Cm$, or $C2$, $a = 17.718(7)$, $b = 17.897(5)$, $c = 7.428(2)$ Å, $\beta = 116.42(2)^\circ$ from Faro Islands, composition (Ca$_{3.5}$,Sr$_{0.5}$,Ba$_{0.5}$,Mg$_{0.5}$,Na$_{1.26}$K$_{0.43}$)[Al$_{9.37}$Si$_{26.70}$O$_{72}$]26.02H$_2$O ($T_{Si} 0.74$) (Alberti, 1972).

**Heulandite-Sr**

New name; Sr is the most abundant single extra-framework cation. One known example: Campegli, Eastern Ligurian ophiolites, Italy, of composition (Sr$_{2.10}$Ca$_{1.73}$Ba$_{0.14}$Mg$_{0.02}$Na$_{0.40}$K$_{0.22}$)[Al$_{9.10}$Si$_{26.94}$O$_{72}$]-9H$_2$O, $T_{Si} 0.75$ (Lucchetti et al., 1982). Monoclinic, $C2/m$, $Cm$, or $C2$, $a = 17.655(5)$, $b = 17.877(5)$, $c = 7.396(5)$ Å, $\beta = 116.65^\circ$.

**Heulandite-Na**

New name; Na is the most abundant single extra-framework cation. Proposed type example: Challis, Idaho, U.S.A., U.S. National Museum #94512/3 (Ross and Shannon, 1924; Boles, 1972, #6). Monoclinic, $C2/m$, $Cm$, or $C2$, $a = 17.670(4)$, $b = 17.982(4)$, $c = 7.404(2)$ Å, $\beta = 116.40(2)^\circ$ (Boles, 1972) for the type example, of composition (Na$_{9.98}$Ca$_{1.77}$K$_{0.55}$)[Al$_{7.86}$Si$_{28.00}$O$_{72}$]-21.74H$_2$O, $T_{Si} 0.78$.

**Heulandite-K**

New name; K is the most abundant single extra-framework cation. Proposed type example: Albero Bassi, Vicenza, Italy (Passaglia, 1969)., composition (K$_{2.40}$Na$_{0.96}$Ca$_{1.64}$Mg$_{0.64}$Sr$_{0.56}$Ba$_{0.12}$)[Fe$_{0.56}$Al$_{0.08}$Si$_{26.48}$O$_{72}$]-25.84H$_2$O, $T_{Si} 0.73$. Monoclinic, $C2/m$, $Cm$, or $C2$, $a = 17.498$, $b = 17.816$, $c = 7.529$ Å, $\beta = 116.07^\circ$. A close approach to end-member K$_9$[Al$_9$Si$_{27}$O$_{72}$]-nH$_2$O has been reported by Nørnberg (1990).

**Hsianghudite**

Li$_2$Ca$_3$[Be$_3$Si$_3$O$_{12}$]F$_2$ $Z = 8$ ANA Huang et al. (1958). Type locality unclear, in metamorphosed Devonian limestone, Hunan Province, China. The name is from a Chinese word for fragrant flower. Known from the original locality only. Minor Al, Fe, Mg, Na, and 1.28% loss on ignition reported (Beus, 1960). $T_{Si} 0.48$. Cubic, $I2_3$, $a = 12.864(2)$ Å. Has an analcime-type structure, with tetrahedral sites occupied alternately by Si and Be. Extraframework Ca, Li, and F ions (Rastsvetaeva et al., 1991).

**Kalborsite**

K$_6$[Al$_4$Si$_6$O$_{20}$]B(OH)$_4$Cl $Z = 2$ ?EDI Khomyakov et al. (1980), Malinovskii and Belov (1980) Type locality: rischorrite pegmatite, Mt. Rasvumchorr, Khibina alkaline massif, Kola Peninsula, Russia. The name alludes to the composition. Known from two localities in Khibina massif, both with compositions close to the above.
formula (Pekov and Chukanov, 1996). $T_{Si}$ values are 0.59, 0.61.

Tetragonal, $P4_{2}c_{1}, a = 9.851(5), c = 13.060(5)$ Å. Framework of Si,Al tetrahedra, with channels along $c$ containing $B(OH)_{4}$ tetrahedra and K, Cl (Malinovskii and Belov, 1980). Considered by Smith (1988) to be an anhydrous analogue of the edingtonite structure-type EDI.

Laumontite

$Ca_{4}[Al_{6}Si_{16}O_{48}]_{18}H_{2}O \ Z = 1 \ LAU$

As lecomite, Jameson (1805), who credits the name to Werner without specific reference; spelling changed to laumontite by Haüy (1809), and to laumontite by von Leonhard (1821). Named after Gillet de Laumont, who collected material described as ‘zéolithe efflorescente’ by Haüy (1801, pp. 410–412), from lead mines of Huelgoët, Brittany. The later spellings were applied to this material, and the Huelgoët mines are effectively the type locality. Always Ca-dominant, with minor (K,Na).

Primary leonhardite of Fersman (1908) is laumontite with approximately 1.5 Ca replaced by 3(K,Na) atoms $pfu$ and reduced $H_{2}O$. $T_{Si}$ in the range 0.64–0.70.

Monoclinic, $C2/m$ (although reported to be pyroelectric), $a = 14.845(9), b = 13.167(2), c = 7.5414(8)$ Å, $\beta = 110.34(2)^{\circ}$ (Nasik, India; Artioli and Stähl, 1993). Except where unusually rich in (K,Na), reversibly loses $c \ 4H_{2}O$ at low humidity at room temperature and pressure to form the variety termed ‘leonhardite’ (e.g. Fersman, 1908; Armbruster and Kohler, 1992); structure refined by Bartl (1970) and others. Si,Al in the framework is highly ordered.

Leucite

$K[AlSi_{2}O_{6}] \ Z = 16 \ ANA$

Blumenbachs (1791), who attributes the name to Werner, who had previously described the mineral as ‘white garnet’. Type locality: Vesuvius, Italy. Named from Greek, meaning white, in reference to colour. Minor substitution of Na for K at low temperatures, and Si in excess of that in the simplified formula, are commonly reported, also significant $Fe^{3+}$. $T_{Si}$ in the range 0.66–0.69.

Tetragonal, $I4_{1}/a, a = 13.09, c = 13.75$ Å (Mazzi et al., 1976).

At ordinary temperatures, leucite is invariably finely twinned as a result of a displacive inversion from a cubic polymorph with the structure of analcime, space group $Ia3d$, apparently stable above 630°C (Wyart, 1938; Peacor, 1968). Heaney and Veblen (1990) noted that high leucite inverts to lower symmetry at temperatures between 600° and 750°C depending on the sample, and that there is a tetragonal, metrically cubic form intermediate to high (cubic) and (low) tetragonal forms.

Levyne (series)

$(Ca_{0.5}Na,K)_{6}[Al_{6}Si_{12}O_{36}]_{1} \sim 17H_{2}O \ Z = 3 \ LEV$

Brewster (1825b). Type locality: Dalsnypen, Faeroe Islands. Named after Armand Lévy (1794–1841), mathematician and crystallographer, Université de Paris.

Extra-framework cations range from strongly Ca-dominant to strongly Na-dominant, with minor K and, in some cases, minor Sr or Ba; Si:Al is also variable (Galli et al., 1981). $T_{Si}$ in the range 0.62–0.70.

Trigonal, $R3_{m}, a = 13.32–13.43, c = 22.66–23.01$ Å. The stacking of single and double 6-membered rings differs from that in the related structures of erionite and offretite (Merlino et al., 1975).

Levyne-Ca

New name for the original member of the series; Ca is the most abundant extra-framework cation. Type locality: Dalsnypen, Faeroe Islands. Material closely approaching end-member $Ca_{3}[Al_{6}Si_{12}O_{36}]_{1} \sim 17H_{2}O$ has been reported by England and Ostwald (1979) from near Merriwa, New South Wales, Australia. $T_{Si}$ in the range 0.62–0.70.

Trigonal, $R3_{m}, a = 13.338(4), c = 23.014(9)$ Å for composition $(Ca_{2.73}Na_{0.65}K_{0.20})_{6}[Al_{6.31}Si_{11.69}O_{36}]_{16.66H_{2}O}$ from near the Nurri to Orroli road, Nuora, Sardinia (Passaglia et al., 1974; Merlino et al., 1975).

Levyne-Na

New name; Na is the most abundant extra-framework cation. Proposed type example: Chojabaru, Nagasaki Prefecture, Japan (Mizota et al., 1974). $T_{Si}$ 0.65–0.68.

Trigonal, $R3_{m}, a = 13.380(5), c = 22.684(9)$ Å for $(Na_{3.84}K_{0.38}Ca_{0.89}Mg_{0.08})_{6}[Al_{6.33}Si_{11.71}O_{36}]_{16.66H_{2}O}$ (Mizota et al., 1974).
Lovdarite

K₄Na₁₂[Be₈Si₂₈O₇₂]·18H₂O  Z = 1  LOV


In the type and only known occurrence, approximately 1 Al atom substitutes for Si in the above structure-derived formula, with introduction of additional extra-framework Na and Ca. 

Orthorhombic, Pma2, but contains b-centred domains in which a is doubled; a = 39.576(1), b = 6.9308(2), c = 7.1526(3) Å (Merlino, 1990). The structure consists of a three-dimensional framework of Si (with minor Al) and Be tetrahedra. It contains 3-membered rings, made possible by the presence of Be instead of Si in one of the tetrahedra.

Maricopaite

(Pb₇Ca₂)[Al₁₂Si₃₆(O,OH)₁₀₀]n(H₂O,OH) n ≈ 32  Z = 1

Structure closely related to MOR Peacor et al. (1988). Type locality: Moon Anchor mine, near Tonopah, Maricopa County, Arizona, U.S.A. Named after the locality.

Only one known occurrence. T₆₃ 0.76. Orthorhombic, Cm2m (pseudo-Cmcm), a = 19.434(2), b = 19.702(2), c = 7.538(1) Å (Rouse and Peacor, 1994).

Has an interrupted, mordenite-like framework. Pb atoms form Pb₄(O,OH)₄ clusters with Pb₄ tetrahedra within channels (Rouse and Peacor, 1994).

Mazzite

(Mg₂₀.₅K₂Ca₁₅)[Al₁₀Si₂₆O₇₂]·30H₂O  Z = 1  MAZ

Galli et al. (1974). Type locality: in olivine basalt near top of Mont Somiell, south slope, near Montbrison, Loire, France. Named after Fiorenzo Mazzi, Professor of Mineralogy at the University of Pavia, Italy.

A new chemical analysis from the type and only known locality (G. Vezzalini, personal communication, 1996) gives the above formula (cf. Rinaldi et al., 1975b). T₆₃ 0.72.

Hexagonal, P6₃/mmc, a = 18.392(8), c = 7.646(2) Å. The framework is characterized by stacked gmelinite-type cages (Galli, 1975), with evidence for limited Si,Al order (Alberti and Vezzalini, 1981b).

Merlinoite

K₄Ca₂[Al₃Si₂₃O₆₄]·22H₂O  Z = 1  MER

Passaglia et al. (1977). Type locality: Cupello quarry in kalsilite melilitite, near Santa Rubia, Rieti, Italy. Named after Stefano Merlino, Professor of Crystallography at the University of Pisa.

Available reliable data (Passaglia et al., 1977; Della Ventura et al., 1993) show strongly K- dominant compositions with significant Ca, and less Na and Ba; T₆₃ 0.66, 0.71. Orthorhombic, Immn, a = 14.116(7), b = 14.229(6), c = 9.946(6) Å (Passaglia et al., 1977). The framework is built of double 8-membered rings linked with 4-membered rings (Galli et al., 1979). The structure is related to, but different from, that of phillipsite.

Mesolite

Na₁₅Ca₁₉[Al₄₈Si₇₂O₂₄₀]·64H₂O  Z = 1  NAT

Gehlen and Fuchs (1813), as Mesolith, for some varieties of ‘mesotype’ (mostly natrolite) of Haüy (1801). No type locality was given. Fuchs (1816) clarified the distinctions among natrolite, scolecite, and mesolite, and gave analyses of mesolite from the Faröe Islands, Iceland, and Tyrol. The name recognizes its compositional position between natrolite and scolecite.

(Na + K)/(Mg + Ca + Sr + Ba) varies from 0.45 to 0.52, with K, Mg, Sr, Ba very minor (Alberti et al., 1982b). T₆₃ in the range 0.59– 0.62. Orthorhombic, Fdd2, a = 18.4049(8), b = 56.655(6), c = 6.5443(4) Å, for material from Poona, India (Artioli et al., 1986a).

Ordered Si,Al in the framework, with one natrolite-like layer alternating with two scolecite-like layers parallel to (010) (Artioli et al., 1986a; Ross et al., 1992).

Montesommaite

K₉[Al₉Si₁₅O₆₄]·10H₂O  Z = 1  MON

Rouse et al. (1990). Type locality: Pollena, Monte Somma, Vesuvius, Italy. Named after the locality. Minor Na was detected in the one published analysis. T₆₃ 0.70.

Orthorhombic, Fdd2, a = b = 10.099(1), c = 17.307(3) Å (pseudotetragonal, I₄₁/amd).

The framework can be constructed by linking (100) sheets of 5- and 8-membered rings; it has similarities to those of merlinoite and the gismondine group (Rouse et al., 1990).
Mordenite

\((\text{Na}_2\text{Ca,K}_2)_4\text{[Al}_8\text{Si}_4\text{O}_{96}]\text{28H}_2\text{O})\quad Z = 1\) MOR

How (1864) Type locality: shore of Bay of Fundy, ~3–5 km east of Morden, King’s County, Nova Scotia, Canada. Named after the locality. The cation content is variable, with \(\text{Na}/(\text{Na} + \text{Ca})\) typically in the range 0.50–0.81. Some K, Mg, Fe, Ba, and Sr also may be present (Passaglia, 1975; Passaglia et al., 1995). In some examples, K is reported as the dominant cation (Thugutt, 1933; Lo et al., 1991; Lo and Hsieh, 1991), potentially justifying the recognition of a mordenite series with Na- and K-dominant species. \(\text{Si}\) in the range 0.80–0.86. Orthorhombic, \(\text{Cmcm}\), \(a = 18.052–18.168, b = 20.404–20.527, c = 7.501–7.537\) Å (Passaglia, 1975). Structure determined by Meier (1961). Si,Al disorder in the framework is extensive, but not complete.

Mutinaite

\((\text{Na}_3\text{Ca})_4\text{[Al}_11\text{Si}_8\text{O}_{192}]\text{60H}_2\text{O})\quad Z = 1\) MFI

Galli, et al. (1997b); Vezzalini et al. (1997b). Type locality: Mt. Adamson, Northern Victoria Land, Antarctica. The name is for Mutina, the ancient Latin name for Modena, Italy. Electron microprobe analyses of mutinaite from the type and only known locality show limited departure from the simplified formula, with minor Mg (~ 0.21 atoms pfu) and K (~ 0.11 atoms pfu). Very high Si, \(T_{\text{Si}}\) 0.88. Orthorhombic, \(\text{Pnma}\), \(a = 20.223(7), b = 20.052(8), c = 13.491(5)\) Å. Mutinaite conforms closely in structure to synthetic zeolite ZSM-5.

Natrolite

\((\text{Na}_2\text{Al}_2\text{Si}_3\text{O}_{10})\text{2H}_2\text{O})\quad Z = 8\) NAT

Klaproth (1803). Type locality: Hohentwiel, Hegau, Baden-Württemberg, Germany. Name from \textit{natro-} for sodium-bearing. \((\text{Na} + \text{K})/(\text{Mg} + \text{Ca} + \text{Sr} + \text{Ba})\) varies from 0.97 to 1.00, with K, Mg, Sr, and Ba very minor. \(T_{\text{Si}}\) in the range 0.59–0.62 (Alberti et al., 1982b; Ross et al., 1992).

Orthorhombic, \(\text{Fddd2}\), \(a = 18.272, b = 18.613, c = 6.593\) Å (Si,Al highly ordered, Dutoitspan, South Africa: Artioli et al., 1984); \(a = 18.319(4), b = 18.595(4), c = 6.597(1)\) Å (~70% Si,Al order, \(\text{Si}\),Al partly to highly ordered (Alberti and Vezzalini, 1981a; Ross et al., 1992; Alberti et al., 1995).
Sarp et al. (1979). Type locality: in ophiolitic rocks, 7 km southeast of Doganbaba, Burdur province, Taurus Mountains, southwestern Turkey. Named after Erwin Parthé, professor of structural crystallography, University of Geneva, Switzerland. Minor Na and K. $T_{Si} = 0.52$ and $0.495$ in the only two known occurrences. Monoclinic, $C2/c$, $a = 21.553(3)$ $b = 8.761(1)$, $c = 9.304(2)$ Å, $\beta = 91.55(2)^\circ$ (type locality; Engel and Yvon, 1984). The framework contains various 4-, 6-, 8-, and 10-membered rings, and is interrupted at every second AlO$_4$ tetrahedron by an hydroxyl group. Si and Al are ordered.

**Paulingite (series)**

(K,Ca$_{0.5}$,Na,Ba$_{0.5}$)$_{10}$[Al$_{10}$Si$_{32}$O$_{84}$]$_{27}$$\cdot$$44$H$_2$O

$Z = 16$ PAU


Electron microprobe analyses show K as the most abundant cation at three known localities and Ca at two. Significant Ba and Na are also reported (Tschernich and Wise, 1982, Lengauer et al., 1997). $T_{Si}$ 0.73–0.77.

Cubic, $Im\overline{3}m$, $a = 35.093(2)$ Å (Gordon et al., 1966).

The framework contains several kinds of large polyhedral cages (Gordon et al., 1966). The structure has been refined by Bieniok et al. (1996) and by Lengauer et al. (1997).

**Paulingite-K**

New name; K is the most abundant extra-framework cation.

Average of five analyses, Rock Island Dam, Washington, U.S.A., the suggested type example for paulingite-K:

(K$_{4.44}$Na$_{0.95}$Ca$_{1.88}$Ba$_{0.18}$) [Al$_{9.82}$Si$_{32.21}$O$_{84}$]$_{12}$$\cdot$$44$H$_2$O (Tschernich and Wise, 1982); $a = 35.093(2)$ Å (Gordon et al., 1966).

**Paulingite-Ca**

New name; Ca is the most abundant extra-framework cation. Average of four analyses, Ritter, Oregon, U.S.A., the suggested type locality for paulingite-Ca: (Ca$_{3.70}$K$_{2.67}$Na$_{0.86}$Ba$_{0.10}$)$_{x}$[Al$_{10.78}$Si$_{31.21}$O$_{84}$]$_{34}$$\cdot$$34$H$_2$O; $a = 35.088(6)$ Å (Tschernich and Wise, 1982).

Lengauer et al. (1997) found evidence of reduced H$_2$O content (27 H$_2$O for $Z = 16$) in barian paulingite-Ca from Vinarická Hora, Czech Republic.

**Perlialite**

K$_9$Na(Ca,Sr) [Al$_{12}$Si$_{24}$O$_{72}$]$_{15}$$\cdot$$15$H$_2$O

Z = 1 LTL

Men’shikov (1984). Type locality: Pegmatites of Mt. Eveslogchorr and Mt. Yukspor, Khibina massif, Kola Peninsula, Russia. Named after Lily Alekseevna Perekrest, instructor in mineralogy at Kirov Mining Technical School. Minor substitution by Sr and Ba, but little other compositional variation in the two known occurrences. $T_{Si}$ 0.65, 0.67.

Hexagonal, $P6/mmm$, $a = 18.49(3)$, $c = 7.51(1)$ Å (Men’shikov, 1984).

Perlialite has the same framework topology as synthetic zeolite-L (Artioli and Kvick, 1990). Structural columns have alternating cancrinite-type cages and double 6-membered rings. No Si,Al order has been detected.

**Phillipsite (series)**

(K,Na,Ca$_{0.5}$,Ba$_{0.5}$)$_x$[Al$_x$Si$_{16}$O$_{32}$]$_{12}$$\cdot$$12$H$_2$O

Z = 1 PHI

Lévy (1825). Type locality as recorded by Lévy: Acì Reale, now Acireale, on the slopes of Etna, Sicily, Italy. Contemporary literature (see Di Franco, 1942) and present-day exposures suggest that the occurrence was probably in basaltic lavas at Acì Castello, nearby. Named for William Phillips (1773–1828), author of geological and mineralogical treatises and a founder of the Geological Society of London.

K, Na, Ca, or Ba may be the most abundant extra-framework cation, but the name harmotome is retained for the Ba-dominant member of the series. Minor Mg and Sr may be present. In the generalized formula above, $x$ ranges from about 4 to about 7. $T_{Si}$ varies widely, from approximately 0.56 to 0.77.

Monoclinic, $P2_1$ or $P2_1/m$, $a = 9.865(2)$, $b = 14.300(4)$, $c = 8.668(2)$ Å, $\beta = 124.20(3)^\circ$ (phillipsite-K with substantial Ca from Casal Brunori, Rome, Italy: Rinaldi et al., 1974). A pseudo-orthorhombic cell has a $\approx 9.9$, $b \approx 14.2$, $c \approx 14.2$ Å, $\beta \approx 90.0^\circ$, $Z = 2$.

Two cation sites have been identified, one, with two atoms pfu fully occupied by K in phillipsite-K.
and by Ba in harmotome, is surrounded by eight framework atoms of oxygen and four molecules of H$_2$O; the other is partly occupied by Ca and Na in distorted octahedral coordination with two framework atoms of oxygen and four molecules of H$_2$O (Rinaldi et al., 1974). Framework Si,Al largely disordered.

**Phillipsite-Na**

New name; Na is the most abundant extra-framework cation. Na forms 81% of all extra-framework cations in material from Aci Castello, Sicily, Italy, suspected to be the original locality for phillipsite (#6 of Galli and Loschi Ghittoni, 1972). Known range in T$_{Si}$: 0.64–0.77.


**Phillipsite-K**

New name; K is the most abundant extra-framework cation. Proposed type locality: Capo di Bove, Rome, Italy (Hintze, 1897; #2 of Galli and Loschi Ghittoni, 1972).

Known range in T$_{Si}$: 0.59–0.76.


**Phillipsite-Ca**

New name; Ca is the most abundant extra-framework cation. Proposed type locality: In Lower Salt Lake Tuff, Puuolua Road near Moanalua Road junction, Oahu, Hawaii (Iijima and Harada, 1969).

Known range in T$_{Si}$: 0.57–0.74.


**Pollucite**

(Cs,Na) [Al$_{Si}$O$_6$]$_n$H$_2$O, where (Cs + n) = 1

$Z = 16$ ANA

Breithaupt (1846). Type locality: Elba, Italy. Named ‘pollux’ with coexisting mineral ‘castor’ (a variety of petalite) for twins Castor and Pollux, of Greek mythology; name modified to pollucite by Dana (1868).

Forms a series with analcime (Černý, 1974) reaching end-member compositions (Teertstra and Černý, 1995) T$_{Si}$ in the range 0.67–0.74. Minor Rb and Li may be present. Sodian pollucite commonly contains more Si than the simplified formula. The name pollucite applies where Cs exceeds Na in atomic proportions.

Cubic, $a = 13.69$ Å for (Cs$_{11.7}$Na$_{3.1}$Li$_{0.25}$K$_{0.4}$[Al$_{15}$Si$_{33}$O$_{96.2}$]·4H$_2$O (Beger, 1969); $a$ in the range 13.672(1)–13.674(1) Å for 0.114–0.173 Na atoms pfu, $Z = 16$ (Černý and Simpson, 1978). Si,Al disordered.

**Roggianite**

Ca$_2$[Be(OH)$_2$Al$_2$Si$_4$O$_{13}$]<2.5H$_2$O $Z = 8$ -ROG

Passaglia (1969b). Type locality: in sodium feldspar dike at Alpe Rosso in Val Vigezzo about 1.5 km south of Orcesco, Novara Province, Italy. Named after Aldo G. Roggiani, a teacher of natural sciences, who first found the mineral.

Contains minor Na and K.

Tetragonal, $I4/mcm$, $a = 18.33(1)$, $c = 9.16(1)$ Å (Galli, 1980).

Contains framework tetrahedrally coordinated Be (Passaglia and Vezzalini, 1988) and framework-interrupting (OH) groups (Giuseppetti et al., 1991).

**Scolecite**

Ca[Al$_2$Si$_3$O$_{10}$]·3H$_2$O $Z = 4$ or 8 NAT

Gehlen and Fuchs (1813), as skolezit. Clark (1993) gave the type locality as Berufjord, Iceland, but this is not apparent in the original reference. Fuchs (1816) clarified the distinctions among natrolite, scolecite, and mesolite. He listed occurrences of scolecite as Faröe Islands, Iceland, and Staffa (Western Isles, Scotland), with analytical data for specimens from the Faröe Islands and Staffa. Named from Greek skolex, worm, for a tendency to curl when heated.

(NA + K)/(Mg + Ca) varies from 0 to 0.16, with very little K, Mg, or other elements. T$_{Si}$ in the range 0.60–0.62 (Alberti et al., 1982b). Monoclinic, $Cc$, $a = 6.516(2)$, $b = 18.948(3)$, $c = 9.761(1)$ Å, $\beta = 108.98(1)^\circ$, $Z = 4$ (Bombay, India: Kvik et al., 1985), or, by analogy with natrolite, pseudo-orthorhombic $Fd$, e.g. $a = 18.508(5)$, $b = 18.981(5)$, $c = 6.527(2)$ Å, $\beta = 90.64(1)^\circ$, $Z = 8$ (Berufjord, Iceland: Joswig et al., 1984).
The structure is similar to that of natrolite with a well-ordered Si,Al framework, Ca instead of Na, and an extra molecule of H₂O.

**Stellerite**

\[
\text{Ca}_2\text{Al}_2\text{Si}_3\text{O}_{18}\cdot7\text{H}_2\text{O}
\]

Z = 8  
STI

Morozelewicz (1909). Type locality: Commander Island, Bering Sea. Named after Wilhelm Steller (1709–1746), natural scientist and military doctor who made important observations on Commander Island.

Variations in composition include up to about 0.2 atoms of Na in the range 0.75–0.78. Orthorhombic, \(Fmmm\), \(a\) 13.507–13.605, \(b\) 18.198–18.270, \(c\) 17.823–17.863 Å (Passaglia et al., 1978b).

The framework is topologically the same as for stilbite, but it has higher symmetry, correlated with fewer extra-framework cations. Only one independent extra-framework site is occupied, and the symmetry is \(Fmmm\) (Galli and Alberti, 1975a). Na-exchanged stellerite retains the \(Fmmm\) symmetry, unlike the Na zeolite, barrerite, with which it is isostructural (Passaglia and Sacerdoti, 1982). Villarroel (1983) has suggested the occurrence of Na-dominant stellerite at Roberts Island, South Shetland group.

**Stilbite-Ca**

New name for common stilbite in which Ca is the most abundant extra-framework cation. For the pseudo-orthorhombic cell, \(F2/m\), \(a\) 13.595–13.657, \(b\) 18.201–18.291, \(c\) 17.775–17.842 Å, \(\beta\) 90.06°–90.91° (Passaglia et al., 1978b).

**Stilbite-Na**

New name; Na is the most abundant extra-framework cation. Proposed type locality: Capo Pula, Cagliari, Sardinia, Italy (Passaglia et al., 1978b, #21). Known examples contain significant Ca and K and minor Mg, as well as clearly predominant Na. \(T_{Si}\) in the range 0.73–0.78 (Passaglia et al., 1978b; Ueno and Hanada, 1982; Di Renzo and Gabelica, 1997).

Monoclinic, \(C2/m\). Using the pseudo-orthorhombic \(F2/m\) setting, \(a\) = 13.610, \(b\) = 18.330, \(c\) = 17.820 Å, \(\beta\) = 90.54° for type material of composition \((Na_{8.18}K_{1.94}Ca_{3.45}Mg_{0.08})\cdot[Al_{16.62}Si_{55.25}O_{144}]\cdot53.53\text{H}_2\text{O}\) (Quartieri and Vezzalini, 1987).

In spite of the high Na content, the monoclinic \(C2/m\) symmetry of stilbite is retained, in contrast to stellerite, \(Fmmm\), and barrerite, \(Amma\).

**Terranovaite**

\[
\text{NaCa}_2\text{Al}_3\text{Si}_{17}\text{O}_{40}\cdot>7\text{H}_2\text{O}
\]

Z = 4  
TER

Galli et al. (1997a). Type locality: Mt. Adamson, Northern Victoria Land, Antarctica. Named after the Italian Antarctic station at Terranova Bay. Type material contains minor amounts of K and Mg, \(T_{Si}\) 0.85.

Orthorhombic, \(Cmcm\), \(a\) = 9.747(1), \(b\) = 23.880(2), \(c\) = 20.068(2) Å. The framework topology is not known in other
natural or synthetic zeolites. It contains polyhedral units found in laumontite, heulandite, and boggsite.

**Thomsonite**

\[
\text{Ca}_2\text{Na}_2\text{Al}_5\text{Si}_5\text{O}_{20}\cdot 6\text{H}_2\text{O} \quad Z = 4 \quad \text{THO}
\]

Brooke (1820). Type locality: Old Kilpatrick, near Dumbarton, Scotland. Named after Dr Thomas Thomson (1773–1852), editor of the journal in which the name was published, and who contributed to the improvement of methods of chemical analysis.

Extensive variation in \( \text{Na}:(\text{Ca} + \text{Sr}) \) and \( \text{Si}:\text{Al} \) approximately according to the formula \( \text{Na}_{4+}\times(\text{Ca},\text{Sr})_{8-\times}\cdot[\text{Al}_{20-\times}\cdot\text{Si}_{20+\times}\cdot\text{O}_{20}]\cdot 24\text{H}_2\text{O} \), where \( x \) varies from about 0 to 2; small amounts of Fe, Mg, Ba, and K may also be present (Ross et al., 1992). \( T_{\text{Si}} \) in the range 0.50–0.56. Orthorhombic, \( Pncn \), \( a = 13.1043(14) \), \( b = 13.0569(18) \), \( c = 13.2463(30) \) Å (Stähl et al., 1990). Chains with a repeat unit of five tetrahedra occur as in the NAT structure type, but they are cross-linked in a different way; Si,Al are highly ordered, but disorder increases with increasing Si:Al (Alberti et al., 1981).

**Tschernichite**

\[
\text{Ca}[\text{Al}_2\text{Si}_6\text{O}_{16}]\cdot 8\text{H}_2\text{O} \quad Z = 8 \quad \text{BEA}
\]

Smith et al. (1991), Boggs et al. (1993). Type locality: Goble Creek, 0.2 km north of Goble, Columbia County, Oregon, U.S.A. Named after Rudy W. Tschernich, zeolite investigator of the American Pacific Northwest, who discovered the mineral.

Na, Mg, and K are minor but variable constituents in specimens from the one known locality. \( T_{\text{Si}} \) in the range 0.74–0.78 (0.73, 0.80 in a tschernichite-like mineral from Mt. Adamson, Antarctica: Galli et al., 1995).

Tetragonal, possible space-group \( P4/mmm \), \( a = 12.880(2) \), \( c = 25.020(5) \) Å, but may consist of an intergrowth of a tetragonal enantimorphic pair with space groups \( P4_222 \) and \( P4_322 \) and a triclinic polymorph \( P1 \). See also Galli et al. (1995).

This is a structural analogue of synthetic zeolite beta.

**Tschörntnerite**

\[
\text{Ca}_4(\text{K}_2\text{Ca},\text{Sr},\text{Ba})_3\text{Cu}_3(\text{OH})_8[\text{Al}_{12}\text{Si}_{12}\text{O}_{48}]\cdot n\text{H}_2\text{O}, \quad n \geq 20 \quad Z = 16 \quad \text{IZA code not assigned}
\]


\( T_{\text{Si}} = 0.50 \) for the only known occurrence. Cubic, \( Fm\overline{3}m \), \( a = 31.62(1) \) Å.

Cages in the framework include a large super-cage with 96 tetrahedra and 50 faces. A Cu,(OH)-bearing cluster occupies another cage. The framework density is the lowest known for a zeolite with a non-interrupted framework.

**Wairakite**

\[
\text{Ca}[\text{Al}_2\text{Si}_4\text{O}_{12}]\cdot 2\text{H}_2\text{O} \quad Z = 8 \quad \text{ANA}
\]


Most analysed samples have \( \text{Na}/(\text{Na} + \text{Ca}) \) less than 0.3, but wairakite possibly forms a continuous solid-solution series with analcime (Seki and Oki, 1969; Seki, 1971, Cho and Liou, 1987). Other reported substitutions are very minor. \( T_{\text{Si}} \) in the range 0.65–0.69.

Monoclinic (highly ordered), \( I2/a \), \( a = 13.692(3) \), \( b = 13.643(3) \), \( c = 13.560(3) \) Å, \( \beta = 90.5(1) \) for \( (\text{Ca}_{0.90}\text{Na}_{0.14})_{}[\text{Al}_{1.92}\text{Si}_{4.07}\text{O}_{12}]\cdot 2\text{H}_2\text{O} \) (Takéuchi et al., 1979).

Tetragonal or near-tetragonal, \( I4_1/acd \), \( a = 13.72(4) \), \( c = 13.66(4) \) Å for \( (\text{Ca}_{0.92}\text{Na}_{0.10})_{}[\text{Al}_{1.92}\text{Si}_{4.07}\text{O}_{12}]\cdot 2.11\text{H}_2\text{O} \) (Nakajima, 1983). The framework topology is similar to that of analcime, but Al is preferentially located in a pair of tetrahedral sites associated with Ca, and Ca is in one specific extra-framework site. Smaller departures from cubic symmetry are correlated with decreased Si,Al order. The name applies to zeolites of ANA structural type in which Ca is the most abundant extra-framework cation, irrespective of the degree of order or space-group symmetry.

**Weinebeneite**

\[
\text{Ca}[\text{Be}_3(\text{PO}_4)_2(\text{OH})_2]\cdot 4\text{H}_2\text{O} \quad Z = 4 \quad \text{WEI}
\]


No elements other than those in the given formula were detected in the one known occurrence. Monoclinic, \( Cc \), \( a = 11.897(2) \), \( b = 9.707(1) \), \( c = 9.633(1) \) Å, \( \beta = 95.76(1) \).

A calcium beryllophosphate zeolite with 3-, 4-, 5-, 6-
Zeolites of doubtful status and a possible zeolite

Further work is recommended to clarify the status of paranatrolite and tetranatrolite. Essential data for these minerals and for tvedalite, which is possibly a beryllosilicate zeolite, are as follows.

Paranatrolite

Na$_2$[Al$_3$Si$_3$O$_{10}$].3H$_2$O $Z = 8$ NAT

Chao (1980). Type locality, Mont Saint-Hilaire, Quebec, Canada. The name recognizes its association with and similarity in chemical composition to natrolite. Na$_2$[Al$_3$Si$_3$O$_{10}$].2H$_2$O. Contains additional H$_2$O relative to natrolite, also minor Ca and K. Pseudo-orthorhombic, Fmmm, probably monoclinic. $a = 19.07(1)$, $b = 19.13(1)$, $c = 6.580(3)$ Å. Gives very diffuse diffraction spots, and a powder pattern similar to that of gonnardite (Chao, 1980). Dehydrates to tetranatrolite and could be regarded as over-hydrated natrolite, tetranatrolite, or gonnardite. Without further justification, separate species status is debatable according to Rule 4.

Tetranatrolite

(2Na$_{1-x}$Ca$_x$)[Al$_{16-3x}$Si$_{21-3x}$O$_{80}$].16H$_2$O $Z = 0.5$ NAT

Chen and Chao (1980). Type locality, Mont Saint-Hilaire, Quebec, Canada. The name indicates a tetragonal analogue of natrolite. First described as ‘tetragonal natrolite’, from Ilmaussaq, Greenland, by Krogh Andersen et al. (1969). Extensive solid solution approximating (Na$_{16-}$Ca$_x$)[Al$_{16-3x}$Si$_{24-3x}$O$_{80}$].16H$_2$O, where $x$ varies from about 0.4 to 4, is reported by Ross et al. (1992). Small amounts of Fe$^{3+}$, Sr, Ba, and K may replace Na and Ca. $T_{Si}$ in the range 0.50–0.59. Tetragonal, $I42d$. $a = 13.141$, $c = 6.617$ Å (Mont Saint-Hilaire, Quebec, Canada: Ross et al., 1992). The framework is of disordered natrolite type. Tetranatrolite is considered to be a dehydration product of paranatrolite (Chen and Chao, 1980; Ross et al., 1992). It differs from natrolite in CaAl substitution for NaSi, as well as in space-group symmetry. These, however, are also characteristics of gonnardite, to which its relationship is debatable.

Tvedalite

(Ca,Mn)$_3$Be$_2$Si$_6$O$_{17}$(OH)$_4$.3H$_2$O $Z = 2$

Larsen et al. (1992). Type locality: Vevya quarry, Tvedalen, Vestfold County, Norway. Named after the locality.

**Zeolites of doubtful status and a possible zeolite**

Further work is recommended to clarify the status...
Spot analyses show a range from (Ca$_{3.20}$Mn$_{0.72}$Fe$_{0.08}$)$_4$S$_4$ to (Ca$_{2.00}$Mn$_{1.86}$Fe$_{0.14}$)$_4$S$_4$ for Be$_3$Si$_6$O$_{17}$(OH)$_4$3H$_2$O, with about 0.1 to 0.21 Al and minor Be substituting for Si in the generalized formula.

Orthorhombic (c-centred), $a = 8.724(6)$, $b = 23.14(1), c = 4.923(4) \text{Å}$.

Considered to be structurally related to chiavennite, but in the absence of an adequate determination of its structure, it has not been listed here as an accepted zeolite species.

### Discredited, obsolete, and other non-approved zeolite names

*Herschelite, leonhardite, sveltozarite, and wellsite* are discredited as names of mineral species (Appendix 2).

*Kehoeite* was regarded by McConnell (1964) as a zinc phosphate analogue of analcime, but according to White and Erd (1992), type kehoeite is a heterogeneous mixture of quartz and phalerite with other phases including gypsum and woodhouseite, or a very similar phase. No phase present bears any relationship to analcime. It is not accepted as a valid zeolite species.

*Viséite* is shown by Di Renzo and Gabelica (1995) not to be a zeolite, as had commonly been supposed. They regard it as a defective member of the crandallite group with composition CaAl$_3$(PO$_4$,SiO$_4$)$_2$(OH)$_n$mH$_2$O. Kim and Kirkpatrick (1996) showed that a specimen examined by them is very disordered, with a structure similar to that of crandallite, but contains other phases including opal. Viséite is excluded from the list of accepted zeolites.

Obsolete and discredited names are listed below, followed by the correct names or identifications. The list is based on one compiled by the late G. Gottardi, using the following references: Hintze (1897), Dana (1914), Cocco and Garavelli (1958), Davis (1958), Hey (1960, 1962), Merlino (1972), and Strunz (1978). Numerous additions and amendments have been made in the light of more recently published work and of the notes below, and of listings in Clark (1993), in which much information on the history and usages of these names can be found.

abrazite = gismondine, phillipsite
acadalite = chabazite
achiardite = dachiardite
adipite = chabazite?
aedelforsite = laumontite?, stilbite?
aedelite (of Kirwan), aedilite = natrolite
ameletite = mixtures of sodalite, analcime, phillipsite, and relict nepheline
amphigène = leucite
analcidite = analcime
analcite = analcime
analzim = analcime
andreasbergolite = harmotome
andreolite, andréolithe = harmotome
antédrite = edingtonite
apoanalcite = natrolite
arduinite = mordenite
aricite = gismondine
ashtonite = streetonian mordenite
bagotite = thomsonite
barium-heulandite = barian heulandite
barytkreuzstein = harmotome
beaumontite = heulandite
bergmannite = natrolite
blätterzeolith = heulandite, stilbite
brevicite = natrolite
cabasite = chabazite
caporciandite = laumontite
carhostilbite = thomsonite
chabasie, chabasite = chabazite
christianite (of des Cloizeaux) = phillipsite
cuthalite = analcime
comptonite = thomsonite
crocalite = natrolite
cubicite, cubizit = analcime
cubic zeolite = analcime?, chabazite
cuboite = analcime
cubozite = chabazite
desmine = stilbite
diagonite = brewsterite
dollanite = probably analcime
doranite = analcime with thomsonite, natrolite, and Mg-rich clay minerals (Teerstra and Dyer, 1994)
echellite = natrolite
efflorescing zeolite = laumontite
eisennatrolith = natrolite with other mineral inclusions
ellagite = a ferriferous natrolite or scolecite?
epidesmine = stellerite
epinatrolite = natrolite
ercinite = harmotome
eudnophite = analcime
euthalite, euthallite = analcime
euzeolith = heulandite
falkenstenite = probably plagioclase (Raade, 1996)
fargite = natrolite
faröelite = thomsonite
NOMENCLATURE OF ZEOLITE MINERALS

fassaite (of Dolomieu) = probably stilbite
feugasite = faujasite
flokite, flockit = mordenite
foliated zeolite = heulandite, stilbite
foresite = stilbite + cookeite
galactite = natrolite
gibsonite = thomsonite
ginzburgite (of Voloshin et al.) = roggianite
gismondite = gismondine
glottalite = chabazite
granatite = leucite
grenatite (of Daubenton) = leucite
groddeckite = gmelinite?

Hairzeolite (group name) = natrolite, thomsonite, mordenite
harmotomite = harmotome
harringtonite = thomsonite, mesolite mixture
haydenite = chabazite
hegauit (högauite) = natrolite
hercynite (of Zappe) = harmotome
herschelite = chabazite-Na
högauite = natrolite
hsiang-hua-shih = hsianghualite
hydrocastorite = stilbite, mica, petalite mixture
hydroelite (of Leman) = gmelinite
hydronatrolite = natrolite
hydroenephyelite = a mixture, probably containing natrolite
hypodesmine = stilbite
hypostilbite = stilbite or laumontite
idrocastorite (hydrocastorite) = stilbite, mica, petalite mixture
kali-harmotome, kalkharmotome = phillipsite
kalithomsonite = ashcroftine (not a zeolite)
kalkrezstein = phillipsite
karphostilbite = thomsonite
kehoeite = a mixture including quartz, sphalerite, gypsum, and ?woodhouseite
koodlitite = thomsonite
krokolith = natrolite
kubizit = analcime
kuboite = analcime
laubanite = natrolite
laumonite = laumontite
ledererite, lederite (of Jackson) = gmelinite
lehunite = natrolite
leonhardite = H₂O-poor laumontite
leuzit = leucite
levyine, levynite, levyite = levyine
lime-harmotome = phillipsite
lime-soda mesotype = mesolite
lincolnine, lincolnite = heulandite
lintonite = thomsonite
lomonite = laumontite
marburgite = phillipsite
mesole = thomsonite
mesoline = levyine? chabazite?
mesolitine = thomsonite
mesotype = natrolite, mesolite, scolecite
metachabazite = partially dehydrated chabazite
metadesmine = partially dehydrated stilbite
metaepistolbite = partially dehydrated epistolbite
metaheulandite = partially dehydrated heulandite
metalaumonite = partially dehydrated laumontite
metaleonhardite = dehydrated 'leonhardite' (laumontite)
metaleucite = leucite
metamesolite = mesolite
metanatrolite = partially dehydrated natrolite
metascolecite, metaskolecit, metaskolezit = partially dehydrated scolecite
metathomsonite = partially dehydrated thomsonite
monophane = epistolbite
mooraboolite = natrolite
morvenite = harmotome
natrochabazite = gmelinite
natron-chabasit, natronchabazit (of Naumann) = gmelinite
natronite (in part) = natrolite
needle zeolite, needle stone = natrolite, mesolite, scolecite
normalin = phillipsite
orizite, oryzite = epistolite
ozarkite = thomsonite
parastilbite = epistolite
phacolite, phakolite(ch) = chabazite
picrancalcite = analcime
picrothomsonite = thomsonite
pollux = pollucite
poonahlite, poonalite = mesolite
portite = natrolite (Franzini and Perchiazzi, 1994)
potassium clinoptilolite = clinoptilolite-K
psuedolaumontite = pseudomorphs after laumontite
psuedomesolite = mesolite
psuedonatrolite = mordenite
psuedophillipsite = phillipsite
ptilolite = mordenite
puferite, puflerite = stilbite
punahlite = mesolite
radiolite (of Esmark) = natrolite
ranite = gonnardite (Mason, 1957)
reissite (of Fritsch) = epistolite
reitzite = stilbite?, laumontite?
sarcolite (of Vauquelin) = gmelinite
sasbachite, saspachite = thomsonite?
savite = natrolite
schabasit = chabazite
schneiderite = laumontite (Franzini and
Perchiazzi, 1994)

D.S.C. and H.M. of the present Subcommittee, J.V. Smith, W.M. Meier, R.W. Tschernich, and the late V.A. Frank-Kamenetskii were consultants. Although recommendations in the present report differ significantly from those in the 1987 report, the existence of that report has greatly facilitated our task. We thank J.V. Smith and L.B. McUsker for advice, C.E.S. Arps and W.D. Birch, successive secretaries of CNMMN, for much help, and many other colleagues for contributions of time, advice, and specimens. Staff of the Science Library, University of Otago, and others, helped trace obscure references.

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NOMENCLATURE OF ZEOLITE MINERALS


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Appendix I. Notes on the definition of a zeolite

Is more than 50% substitution of elements other than Si and Al permissible in tetrahedral sites?

There was complete agreement in the Subcommittee that some substitution of elements such as P and Be for Si and Al in tetrahedral sites must be permitted in the definition. Discussion in this context focussed on whether a 50% rule should be applied. The so-called 50% rule (Nickel, 1992) is normally applied to split a binary solid-solution series into two species at the half-way point according to the predominant cations concerned, but not to separate members of a solid-solution series into two separate classes of minerals, as could happen if applied in the present context. Proponents of a 50% rule argued that the definition of zeolites should be on grounds of both structure and composition, zeolites being aluminosilicates or possibly Al-free silicates. The contrary opinion is that where structures are topologically equivalent and other essentially identical zeolitic characteristics prevail, irrespective of Si and Al contents in tetrahedral sites, any restrictions based on specific Si and Al contents would be arbitrary and undesirable. The Subcommittee voted by a substantial majority for this view. The beryllosilicates lovdarite and chiavennite, like the zincosilicate gaultite, have more than 50% tetrahedral sites occupied by Si, and are here accepted as zeolites in spite of having little if any Al. Also included are the beryllophosphates pahasapaite and weinebeneite which have neither Si nor Al, but have typically zeolitic structures and other zeolitic characteristics. They can be regarded as end-member examples of Si-free zeolites or zeolite phosphates.

A compositional factor is included in the adopted definition that the framework consists essentially of oxygen atoms together with cations that enter into tetrahedral co-ordination with oxygen.

Is the presence of H₂O and of extra-framework cations essential?

Reversible dehydration is a characteristic feature of zeolitic behaviour, but how much H₂O must be present for a mineral to be considered a zeolite? Pollucite forms a continuous series with analcime, the H₂O content declining progressively with increasing Cs content such that the Na-free, Cs member is essentially anhydrous. It seems unnecessary, impractical, and illogical to prescribe some arbitrary H₂O content below which pollucite (or other mineral) would be defined as anhydrous, and no longer a zeolite. Furthermore, it is not inconceivable that some typical zeolite might be reversibly dehydrated under natural conditions without essential loss of structure. If so, it has not ceased to be a zeolite. Although zeolites typically are hydrous, it is inexpedient to specify the presence of H₂O in the definition.

Natural zeolites are known with up to 88% of tetrahedral sites occupied by Si, as in mutinaite, and there is no theoretical reason why this figure cannot be exceeded. If the site occupancy of tetrahedra by Si approaches 100%, the extra-framework cation content will approach zero, even though the structure and other characteristics may remain typically zeolitic. It is again considered inexpedient to word the definition so as to exclude such a hypothetical end-member case from the zeolite category. Melanophlogite, a low-density SiO₂ phase with large cages in its framework, would be a possible example, but is otherwise excluded by the adopted definition because it lacks appropriate channels for the passage of guest species.

Reference

Appendix 2. Discreditations

**Herschelite is chabazite-Na**

Herschelite, Na[AlSi$_2$O$_6$]-3H$_2$O, was named by Lévy (1825) from material brought to him by Herschel from "Aci Reale" (now Acireale) on the flanks of Mt. Etna in Sicily. Contemporary literature and present-day exposures suggest that the actual occurrence may have been in basaltic lavas at Aci Castello, nearby. Lévy described herschelite as tabular crystals of hexagonal outline that contain 'silex, alumina, and potash'. It was later identified with chabazite (e.g. Hausmann, 1847) and relegated to synonymy, although shown to be Na-rich, not K-rich. Strunz (1956) confirmed that herschelite and chabazite give essentially identical X-ray powder patterns. Mason (1962) proposed revalidation on the bases of a supposed compositional gap between herschelite and 'normal' Ca-rich chabazite, the distinctive habit, and lower refractive indices.

Passaglia (1970) demonstrated a continuum of compositions from Ca- to Na-dominant types, extending into the field of K-dominance in a ternary series; there is no discernible gap in composition. The lower refractive indices reflect the Na-rich composition. Variant crystal habit is not an accepted basis for species status for minerals, and some examples of strongly Na-dominant chabazite have rhombohedral, not tabular habit, as in the case of micrometre-scale crystals aggregated into thin ragged plates illustrated by Sheppard et al. (1978).

In view of its chequered history and the above considerations, the name herschelite is suppressed and the name chabazite-Na is to be applied to those members of the chabazite series in which Na is the most abundant extra-framework cation. Herschelite may retain some use as a term for a distinctive habit.

**Leonhardite is H$_2$O-poor laumontite**

Leonhardite Ca$_4$[Al$_8$Si$_{16}$O$_{48}$]-14H$_2$O was described by Blum (1843) for a mineral closely related to laumontite Ca$_4$[Al$_8$Si$_{16}$O$_{48}$]-18H$_2$O, but with different morphology. The type locality was near Schemnitz, nowadays Banska Stiavnica, then in Hungary, now in Slovakia. Delffs (1843) showed that type locality leonhardtite has less H$_2$O (c. 13 molecules of H$_2$O pfu) than laumontite. Doelter (1921) agreed that leonhardtite is identical in composition to laumontite apart from its lower content of H$_2$O. The name has continued to be used widely for a material that forms rapidly and reversibly by partial dehydration of laumontite under ambient conditions. This happens upon exposure in the field and in the laboratory as a function of H$_2$O vapour pressure or by soaking in water, giving a readily observable change in extinction angle and cell dimensions (e.g. Coombs, 1952; Armbruster and Kohler, 1992).

Fersman (1908) introduced the term ‘primary leonhardtite’ for a variety from Kurtsy (nowadays Ukrainka), Crimea, with 14 molecules of H$_2$O, which neither dehydrates nor rehydrates under ambient conditions. In it, (Na,K)$_2$ substitutes for Ca, although Ca is still dominant (Pipping, 1966).

Type leonhardtite of Blum from Schemnitz catalogued in the Museum of Natural History, Vienna, in 1843 and type ‘primary leonhardtite’ of Fersman obtained from the Fersman Mineralogical Museum in Moscow are shown by Wuest and Armbruster (1997) and Stolz and Armbruster (1997, respectively, to have the same Si,Al ordered framework of tetrahedra as laumontite. The low H$_2$O content of ‘primary leonhardtite’ is attributed to space limitations resulting from the introduction of additional cations of larger size.

In conformity with Rule 4, leonhardtite is discredited as the name of a separate species. It is an H$_2$O-poor variety of laumontite. ‘Primary leonhardtite’ is H$_2$O-poor sodian potassian laumontite.

**Svetlozarite is dachiardite-Ca**

Svetlozarite was described by Maleev (1976) as a high-silica zeolite occurring as spherulites in chalcedony veinlets in brecciated andesites west of Zvesdel, eastern Rhodopes, Bulgaria. Analysis showed Ca > Na > K, and minor Fe and Mg. From X-ray powder diffraction studies, Maleev suggested an orthorhombic symmetry, with a c-axis repeat of 7.5 Å, which is characteristic of the
mordenite group, to which he attributed the mineral.

Gellens et al. (1982) concluded from powder and single-crystal X-ray and transmission electron microscopy (TEM) studies, that svetlozarite, space group \( \text{Ccma} \) (?), is related to the ideal dachiardite structure by irregular periodic twinning and stacking faults, and that it is not a topologically distinct member of the mordenite family. Its composition is within the range of other samples of dachiardite. It is regarded as a multiply twinned and highly faulted dachiardite (dachiardite-Ca), and is discredited as a separate species.

**Wellsite is barian phillipsite-Ca and calcian harmotome**

The mineral named *wellsite* by Pratt and Foote (1897) has been shown by Galli (1972) and Galli and Loschi Ghittoni (1972) to be isostructural with phillipsite and harmotome, and Černý et al. (1977) have shown that zoning in crystals of wellsite covers most of the range from Ca-rich phillipsite to potassian calcian harmotome. Wellsite is discredited. Most examples of wellsite are barian phillipsite-Ca, and others are calcian harmotome.

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