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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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ABSTRACT

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 ($Si : Al \geqslant 4.0$). 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 Haüy (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 H_2O occupy extra-framework positions. He pointed out the consequential requirements that the molar ratio $Al_2O_3:(Ca,Sr,Ba,Na_2,K_2)O = 1$ 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 dehydration, 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 displacive 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 H_2O 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, melanophlogite, and probably leifite, 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 $Å^3$, 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, maricopaite, and chiavennite, 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 SO_4, 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 pahasapaite and weinebeneite. 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.*, 1982*a*), 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.

Analcime 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. Gobbinsite 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 gobbinsite 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, 1975*b*); 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 $\geqslant 4.0$.

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 (*C*2/*m*). (b) Levels of order may be indicated by adjectival use of words such as ‘disordered’ or ‘fully ordered’ before the mineral name.

TABLE 1. Newly proposed zeolite species within compositional series

Series	Species name	Series	Species name
brewsterite	brewsterite-Sr brewsterite-Ba	gmelinite	gmelinite-Na gmelinite-Ca gmelinite-K
chabazite	chabazite-Ca chabazite-Na chabazite-K	heulandite	heulandite-Ca heulandite-Na heulandite-K heulandite-Sr
clinoptilolite	clinoptilolite-K clinoptilolite-Na clinoptilolite-Ca	levyne	levyne-Ca levyne-Na
dachiardite	dachiardite-Ca dachiardite-Na	paulingite	paulingite-K paulingite-Ca
erionite	erionite-Na erionite-K erionite-Ca	phillipsite	phillipsite-Na phillipsite-Ca phillipsite-K
faujasite	faujasite-Na faujasite-Ca faujasite-Mg	stilbite	stilbite-Ca stilbite-Na
ferrierite	ferrierite-Mg ferrierite-K ferrierite-Na		

The first-named member of each series is the one to which the original type specimen for the series appears to belong.

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_2O 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. $NaAlSi_2O_6{\cdot}H_2O$ 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 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

$K_4Na_4[Al_8Si_8O_{32}]\cdot 10H_2O$ Z = 1 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, β = 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

$(NH_4)[AlSi_2O_6]$ Z = 16 ANA

Hori *et al.* (1986). Type locality: Tatarazawa, Fujioka, Gumma Prefecture, Japan. The name reflects composition and relationship to leucite.

Material from the only known locality contains significant K. T_{Si} = 0.70.

Tetragonal, $I4_1/a$, a = 13.214(1), c = 13.713(2) Å.

Analcime

$Na[AlSi_2O_6]\cdot H_2O$ Z = 16 ANA

Haüy (1797, p. 278). Type locality: near Catanes, Cyclopean Isles, Italy (Haüy, 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_{Si} varies widely, 0.59–0.73 (e.g. Coombs and Whetten, 1967). As Si increases, NaAl decreases and H_2O 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, α = 90.158(3), β = 89.569(3), γ = 89.543(3)° (Hazen and Finger, 1979);

and probably trigonal; with variable Si,Al order (e.g. Hazen and Finger, 1979; Teertstra *et al.*, 1994).

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

Barrerite

$Na_2[Al_2Si_7O_{18}]\cdot 6H_2O$ Z = 8 STI

Passaglia and Pongiluppi (1974, 1975). Type locality: Capo Pula, Sardinia, Italy. Named after Professor Richard M. Barrer (1910–1996) of Imperial College, London, for contributions to the chemistry of molecular sieves.

Also known from Kuiu Island, Alaska (Di Renzo and Gabelica, 1997). T_{Si} in the range 0.77–0.78. The type example has composition:

$(Na_{5.45}K_{1.06}Ca_{0.84}Mg_{0.17})[Al_{8.19}Fe_{0.01}Si_{27.72}O_{72}]\cdot 25.78H_2O$.

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, 1975*b*).

Bellbergite

$(K,Ba,Sr)_2Sr_2Ca_2(Ca,Na)_4[Al_{18}Si_{18}O_{72}]\cdot 30H_2O$ Z = 1 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. T_{Si} = 0.51.

Hexagonal, possible space-groups $P6_3/mmc$, $P\bar{6}2c$, and $P6_3mc$, a = 13.244(1), c = 15.988(2) Å.

The framework structure is as for synthetic zeolite TMA-EAB.

Bikitaite

$Li[AlSi_2O_6]\cdot H_2O$ Z = 2 BIK

Hurlbut (1957). Type locality: Bikita, Zimbabwe. Named after the type locality.

Two known localities, the bikitaite having very similar compositions. T_{Si} = 0.67.

Monoclinic, $P2_1$, a = 8.613(4), b = 4.962(2), c = 7.600(4) Å, β = 114.45(1)° (Kocman *et al.*, 1974). Also triclinic, $P1$, a = 8.606(1), b = 4.953(1), c = 7.599(1) Å, α = 89.89(2)°, β = 114.42(2)°, γ = 89.96(2)° (Bissert and Liebau, 1986).

The framework structure consists of 5-membered rings linked by additional tetrahedra. Its topological symmetry is $P2_1$. The monoclinic $P2_1$ variant of Kocman *et al.* has partly ordered Si,Al distribution; the triclinic $P1$ variant of Bissert and Liebau is highly ordered.

Boggsite

$Ca_8Na_3[Al_{19}Si_{77}O_{192}]\cdot 70H_2O$ Z = 1 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 $Ca_6Na_5K[Al_{18}Si_{78}O_{192}]\cdot 70H_2O$, with minor Fe, Mg, Sr, Ba. T_{Si} = 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)

$(Sr,Ba)_2[Al_4Si_{12}O_{32}]\cdot 10H_2O$ 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, $P2_1/m$, $P2_1$, or triclinic (Akizuki, 1987*a*, 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. T_{Si} in the range 0.74–0.75.

Monoclinic, $P2_1/m$, a = 6.793(2), b = 17.573(6), c = 7.759(2) Å, β = 94.54(3)°, for composition $(Sr_{1.42}Ba_{0.48}K_{0.02})[Al_{4.12}Si_{11.95}O_{32}]\cdot nH_2O$ (Schlenker *et al.*, 1977*a*).

On optical grounds, possibly triclinic (Akizuki, 1987*a*). Refined as triclinic in three separate growth sectors by Akizuki *et al.* (1996).

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). T_{Si} in the range 0.73–0.74.

Monoclinic, $P2_1/m$ or $P2_1$, 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)

$(Ca_{0.5},Na,K)_4[Al_4Si_8O_{24}]\cdot 12H_2O$

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. T_{Si} varies widely, 0.58–0.81.

Topological symmetry of the framework, trigonal ($R\bar{3}m$) where $a \approx 13.2$, $c \approx 15.1$ Å (pseudo-hexagonal cell). Significant deviations to triclinic, $P\bar{1}$, $a \approx 9.4$, $b \approx 9.4$, $c \approx 9.4$ Å, $\alpha \approx 94°$, $\beta \approx 94°$, $\gamma \approx 94°$ (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. T_{Si} in the range 0.58–0.80.

a = 13.790(5), c = 15.040(4) Å, for pseudo-hexagonal cell, with composition
$(Ca_{1.86}Na_{0.03}K_{0.20}Mg_{0.02}Sr_{0.03})$-
$[Al_{3.94}Fe_{0.01}Si_{8.03}O_{24}]\cdot 13.16H_2O$, 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. T_{Si} in the range 0.62–0.79.

Suggested type locality: biggest 'Faraglione' facing Aci Trezza, Sicily, Italy (Passaglia, 1970, #1). a = 13.863(3), c = 15.165(3) Å, for hexagonal cell, with composition
$(Na_{3.11}K_{1.05}Ca_{0.19}Mg_{0.06}Sr_{0.05})$-
$[Al_{4.53}Fe_{0.01}Si_{7.40}O_{24}]\cdot 11.47H_2O$.

Although originally described as containing 'silex, alumina, and potash' (Lévy, 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 $(K_{2.06}Na_{0.98}Ca_{0.46}Mg_{0.10}Sr_{0.01})$-$[Fe_{0.08}Al_{4.37}Si_{7.60}O_{24}]\cdot 11.42H_2O$.

Chiavennite

$CaMn[Be_2Si_5O_{13}(OH)_2]\cdot 2H_2O$ 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 beryllosilicate with an interrupted framework of four-connected $[SiO_4]$ and three-connected $[BeO_4]$ tetrahedra.

Clinoptilolite (series)

$(Na,K,Ca_{0.5},Sr_{0.5},Ba_{0.5},Mg_{0.5})_6[Al_6Si_{30}O_{72}]\cdot\sim 20H_2O$ 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.

Monoclinic, *C2/m*, or C2, or *Cm*.

Structure refinements by Alberti (1975*a*) 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* = 7.409(7) Å, β = 116.50(7)°, for $(K_{4.72}Na_{0.85}Ca_{0.04}Sr_{0.37}Mg_{0.19}Fe_{0.03}Mn_{0.01})$ $[Al_{6.52}Si_{29.38}O_{72}]\cdot nH_2O$, from an off-shore bore-hole, 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, 1969*a*).

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 (1969*a*), $(Na_{3.78}K_{1.31}Ca_{0.61}Ba_{0.09}Mg_{0.23}Mn_{0.01})$ $[Al_{6.61}Fe_{0.16}Si_{29.19}O_{72}]\cdot 20.4H_2O$.

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, $(Na_{1.76}K_{1.05}Ca_{1.90}Mg_{0.17})$ $[Al_{6.72}Si_{29.20}O_{72}]\cdot 23.7H_2O$.

Cowlesite

$Ca[Al_2Si_3O_{10}]\cdot 5.3H_2O$

Z = 52 (IZA code not assigned)

Wise and Tschernich (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.

Minor substitution for Ca by Na and lesser K, Mg, Sr, Ba, Fe. T_{Si} in the range 0.60– 0.62 (Vezzalini *et al.*, 1992).

Orthorhombic, $P222_1$ or *Pmmm*, *Pmm*2, *P*2*mm*, *P*222 (Nawaz, 1984), *a* = 23.249(5) *b* = 30.629(3) *c* = 24.964(4) Å (Artioli *et al.*, 1987).

Structure and degree of order of framework cations have not been determined.

Dachiardite (series)

$(Ca_{0.5},Na,K)_{4-5}[Al_{4-5}Si_{20-19}O_{48}]\cdot{\sim}13H_2O$ Z = 1 DAC

D'Achiardi (1906). Type locality: San Piero in Campo, Elba, Italy. Named by the author in memory of his father, Antonio D'Achiardi (1839–1902), first full professor of mineralogy at the University of Pisa.

May contain minor Cs and Sr. T_{Si} in the range 0.78–0.86.

Monoclinic, topological symmetry *C*2/*m*, real symmetry *Cm*.

The structure consists of complex chains of 5-membered rings cross-linked by 4-membered rings (Gottardi and Meier, 1963), but with complexities that commonly result in diffuse and streaked X-ray diffraction maxima (Quartieri *et al.*, 1990).

Dachiardite-Ca

New name for the original species of the series; Ca is the most abundant extra-framework cation. Dachiardite from the type locality contains 0.12 Cs atoms per formula unit (atoms *pfu*) (Bonardi, 1979). T_{Si} in the range 0.78–0.83.

Monoclinic, topological symmetry *C*2/*m*, real symmetry *Cm*, *a* = 18.676, *b* = 7.518, *c* = 10.246 Å, β = 107.87°, for composition $(Ca_{1.54}Na_{0.42}K_{0.92}Cs_{0.11}Sr_{0.12}Ba_{0.01})[Al_{4.86}Fe_{0.02}Si_{18.96}O_{48}]\cdot 12.56H_2O$ from the type locality (Vezzalini, 1984).

Partly ordered distribution of Si,Al.

Dachiardite-Na

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

Suggested type example: Alpe di Siusi, Bolzano, Italy (Alberti, 1975*b*).

Available analyses of material from seven localities, e.g. Bonardi et al., (1981), show considerable variation in Na : K : Ca proportions. T_{Si} in the range 0.81–0.86.

Monoclinic, *a* = 18.647(7), *b* = 7.506(4), *c* = 10.296(4) Å, β = 108.37(3)°, for $(Na_{2.59}K_{0.71}Ca_{0.53}Mg_{0.04}Ba_{0.01})[Fe_{0.11}Al_{4.27}Si_{19.61}O_{48}]\cdot 13.43H_2O$ from the type locality (Alberti, 1975*b*).

Diffuse diffraction spots indicate disorder.

Edingtonite

$Ba[Al_2Si_3O_{10}]\cdot 4H_2O$ Z = 2 EDI

Haidinger (1825). Type locality: Kilpatrick Hills, near Glasgow, Scotland. Named after a Mr Edington of Glasgow, in whose collection Haidinger found the mineral.

Small amounts of K, Na, and Ca may replace Ba. T_{Si} in the range 0.59–0.61.

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, $P\bar{4}2_1m$, *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

$(Ca,Na_2)\ [Al_2Si_4O_{12}]\cdot 4H_2O$ Z = 4 EPI

Rose (1826). Type localities: 'Iceland' and 'Faröe Islands'. Named from Greek *epi* in the sense of near, and stilbite, from its supposed similarity to the latter.

Na/(Na + Ca) varies from about 0.1 to 0.3, with minor K and Ba (e.g. Galli and Rinaldi, 1974). T_{Si} in the range 0.72–0.77.

Monoclinic, *C*2, *a* = 9.101(2), *b* = 17.741(1), *c* = 10.226(1) Å, β = 124.66(2)° (Teigarhorn, Iceland: Alberti *et al.*, 1985) or:

triclinic, *C*1, *a* = 9.083(1), *b* = 17.738(3), *c* = 10.209(1) Å, α = 89.95(1)°, β = 124.58(1)°, γ = 90.00(1)° (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 *C*2/*m* (Perrotta, 1967). Alberti *et al.* (1985)

proposed a domain structure involving acentric configurations of tetrahedra and space group *C*2. 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)

$K_2(Na,Ca_{0.5})_8[Al_{10}Si_{26}O_{72}]\cdot{\sim}30H_2O$
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, *P*6₃/*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.*, 1977*b*), 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 $(Na_{5.59}K_{2.00}Ca_{0.11}Mg_{0.18}Fe_{0.02})[Al_{7.57}Si_{28.27}O_{72}]\cdot 24.60H_2O$ (Sheppard and Gude, 1969*b*).

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, $(K_{3.32}Na_{2.31}Ca_{0.99}Mg_{0.06}Ba_{0.02})[Al_{8.05}Si_{28.01}O_{72}]\cdot 31.99H_2O$ (Passaglia *et al.*, 1998).

Erionite-Ca

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

Proposed type example: Mazé, Niigata Prefecture, Japan (Harada *et al.*, 1967). T_{Si} in the range 0.68–0.79.

For the type example: *a* = 13.333(1), *c* = 15.091(2) Å; $(Ca_{2.28}K_{1.54}Na_{0.95}Mg_{0.86})[Al_{8.83}Si_{26.90}O_{72}]\cdot 31.35H_2O$ (Harada *et al.*, 1967).

Faujasite (series)

$(Na,Ca_{0.5},Mg_{0.5},K)_x[Al_xSi_{12-x}O_{24}]\cdot 16H_2O$
Z = 16 FAU

Damour (1842). Type locality: Sasbach, Kaiserstuhl, Germany. Named after Barthélémy 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.*, 1975*a*; Wise, 1982; Ibrahim and Hall, 1995).

Cubic, $Fd\bar{3}m$. *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_2O 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 $(Ca_{1.32}Na_{0.56}Mg_{0.26}K_{0.04})\ [Al_{3.83}Si_{8.19}O_{24}]{\cdot}nH_2O$, 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 (and only) example: 'Old (museum) sample' (# 32, Genth Collection, Pennsylvania State University) from Sasbach, Kaiserstuhl, Germany (anal. #15, Rinaldi *et al.*, 1975*a*), composition $(Mg_{15.3}Ca_{4.0}Na_{7.0}K_{6.4})[Al_{56}Si_{137}O_{384}]{\cdot}nH_2O$, Z = 1.

Ferrierite (series)

$(K,Na,Mg_{0.5},Ca_{0.5})_6[Al_6Si_{30}O_{72}]{\cdot}18H_2O$ Z = 1 FER

Graham (1918). Type locality: Kamloops Lake, British Columbia, Canada. Named after Dr Walter F. Ferrier, mineralogist, mining engineer, and one-time member of the Geological Survey of Canada, who first collected it.

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, *Pnnm*, 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, β = 90.0° (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, *Pnnm*, a = 19.231(2), b = 14.145(2), c = 7.499(1) Å for specimen from Monastir, Sardinia, of composition $(Mg_{2.02}K_{1.19}Na_{0.56}Ca_{0.52}Sr_{0.14}Ba_{0.02})[Al_{6.89}Si_{29.04}O_{72}]{\cdot}17.86H_2O$ (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 $(K_{2.05}Na_{1.14}Mg_{0.74}Ca_{0.14})\ [Al_{5.00}Si_{31.01}O_{72}]{\cdot}nH_2O$ (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 $(Na_{3.06}K_{0.97}Mg_{0.38}Ca_{0.05}Sr_{0.03}Ba_{0.02})[Al_5Si_{31}O_{72}]{\cdot}18H_2O$ (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, β = 90.0(1)° (Gramlich-Meier *et al.*, 1985, for a specimen from Altoona, Washington).

Garronite

$NaCa_{2.5}[Al_6Si_{10}O_{32}]{\cdot}14H_2O$ 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_2O 13.0–14.0 molecules *pfu.* T_{Si} 0.60–0.65.

The crystal structure has been refined in tetragonal symmetry, $I\bar{4}m2$, 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.

Gaultite

$Na_4[Zn_2Si_7O_{18}]\cdot 5H_2O$ Z = 8 VSV

Ercit and Van Velthuizen (1994). Type locality: Mont Saint Hilaire, Quebec, Canada. Named after Robert A. Gault (b. 1943), mineralogist at the Canadian Museum of Nature, Ottawa, Ontario, Canada.

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

Orthorhombic, *F*2*dd*, $a = 10.211(3)$, $b = 39.88(2)$, $c = 10.304(4)$ Å.

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

Gismondine

$Ca[Al_2Si_2O_8]\cdot 4.5H_2O$ Z = 4 GIS

von Leonhard (in footnote, 1817), renaming 'zeagonite' of Gismondi (1817). Type locality: Capo di Bove, near Rome, Italy. Named after Carlo Giuseppe Gismondi (1762–1824), lecturer in mineralogy in Rome.

(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). H_2O is slightly variable (4.4–4.5 molecules *pfu*) because of mixed 6- and 7-coordination of Ca (Artioli *et al.*, 1986*b*).

Monoclinic, originally refined in $P2_1/a$ by Fischer and Schramm (1970); cell converted to standard $P2_1/c$ second setting is $a = 10.023(3)$, $b = 10.616(5)$, $c = 9.843(15)$ Å, $\beta = 92.42(25)^\circ$. 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)

$(Na_2,Ca,K_2)_4[Al_8Si_{16}O_{48}]\cdot 22H_2O$ Z = 1 GME

Brewster (1825*a*). 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.

Hexagonal, $P6_3/mmc$, *a* 13.62–13.88, *c* 9.97–10.25 Å.

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, $P6_3/mmc$, $a = 13.756(5)$, $c = 10.048(5)$ Å (Galli *et al.*, 1982), for near-end-member material from Queensland, Australia, of composition $(Na_{7.61}Ca_{0.03}K_{0.16})[Al_{7.41}Si_{16.49}O_{48}]\cdot 21.51H_2O$ (Passaglia *et al.*, 1978*a*).

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, $P6_3/mmc$, $a = 13.800(5)$, $c = 9.964(5)$ Å (Galli *et al.*, 1982), from Montecchio Maggiore, Vicenza, composition $(Ca_{2.06}Sr_{1.35}Na_{0.78}K_{0.11})[Al_{7.82}Si_{16.21}O_{48}]\cdot 23.23H_2O$ (Passaglia *et al.*, 1978*a*).

Gmelinite-K

New name; K is the most abundant single extra-framework cation. Proposed type example: Fara Vicentina, Vicenza, Italy, composition $(K_{2.72}Ca_{1.67}Sr_{0.39}Na_{0.22}Mg_{0.13})[Al_{7.79}Si_{16.32}O_{48}]\cdot 23.52H_2O$ (Vezzalini *et al.*, 1990). Also known from the Kola Peninsula (Malinovskii, 1984).

Hexagonal, $P6_3/mmc$, $a = 13.621(3)$, $c = 10.254(1)$ Å.

Gobbinsite

$Na_5[Al_5Si_{11}O_{32}]\cdot 12H_2O$ Z = 1 GIS

Nawaz and Malone (1982). Type locality: basalt cliffs near Hills Port, south of the Gobbins area, County Antrim, Northern Ireland. Named after the locality.

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

Orthorhombic, $Pmn2_1$, a = 10.108(1), b = 9.766(1), c = 10.171(1) Å for the anhydrous composition $(Na_{2.50}K_{2.11}Ca_{0.59})$ $[Al_{6.17}Si_{9.93}O_{32}]$ from Two-Mouth Cave, County Antrim, Northern Ireland (McCusker *et al.*, 1985); a = 10.1027(5), b = 9.8016(5), c = 10.1682(6) Å for $(Na_{4.3}Ca_{0.6})[Al_{5.6}Si_{10.4}O_{32}]\cdot 12H_2O$ 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. Si,Al in the framework are disordered.

Gonnardite

$(Na,Ca)_{6-8}[(Al,Si)_{20}O_{40}]\cdot 12H_2O$ Z = 1 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 $Na_{8-3x}Ca_{2x}[Al_{8+x}Si_{12-x}O_{40}]\cdot 12H_2O$ (after Ross *et al.*, 1992), with minor Fe^{3+}, Mg, Ba, Sr, and K. T_{Si} in the range 0.52–0.59 (or 0.52–0.62 if tetranatrolite = gonnardite).

Tetragonal, $I\bar{4}2d$, a = 13.21(1), c = 6.622(4) Å for material from Tvedalen, Langesund, Norway, of composition $(Na_{6.42}K_{0.01}Ca_{1.50})$ $[Al_{9.22}Si_{10.73}O_{40}]\cdot 12.37H_2O$ (Mazzi *et al.*, 1986).

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

Goosecreekite

$Ca[Al_2Si_6O_{16}]\cdot 5H_2O$ Z = 2 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_{Si} = 0.75.

Monoclinic, $P2_1$, a = 7.401(3), b = 17.439(6), c = 7.293(3) Å, β = 105.44(4)° (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 brewsterite structure. Si,Al are nearly perfectly ordered (Rouse and Peacor, 1986).

Gottardiite

$Na_3Mg_3Ca_5[Al_{19}Si_{117}O_{272}]\cdot 93H_2O$ Z = 1 NES

Alberti *et al.* (1996), Galli *et al.* (1996). Mt. Adamson, Victoria Land, Antarctica. Named after Professor Glauco Gottardi (1928–1988), University of Modena, in recognition of his pioneering work on the structure and crystal chemistry of natural zeolites.

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

Orthorhombic, topological symmetry *Fmmm*, real symmetry *Cmca*, a = 13.698(2), b = 25.213(3), c = 22.660(2) Å (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 Si,Al order is probable.

Harmotome

$(Ba_{0.5},Ca_{0.5},K,Na)_5[Al_5Si_{11}O_{32}]\cdot 12H_2O$ Z = 1 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).

Ba is the most abundant extra-framework cation. Harmotome forms a continuous series with phillipsite-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_{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, β = 124.81(1)° for $(Ba_{1.93}Ca_{0.46}K_{0.07})[Al_{4.66}Si_{11.29}O_{32}]\cdot 12H_2O$ from Andreasberg, Harz (Rinaldi *et al.*, 1974).

The structure is the same as for phillipsite, with little or no Si,Al order.

Heulandite (series)

$(Ca_{0.5},Sr_{0.5},Ba_{0.5},Mg_{0.5},Na,K,)_9[Al_9Si_{27}O_{72}]\cdot\sim 24H_2O$ 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 $T_{Si} \geqslant 0.80$, Si/Al $\geqslant 4.0$, 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, β = 116.42(2)° from Faröe Islands, composition $(Ca_{3.57}Sr_{0.05}Ba_{0.06}Mg_{0.01}Na_{1.26}K_{0.43})[Al_{9.37}Si_{26.70}O_{72}]\cdot 26.02H_2O$ (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 $(Sr_{2.10}Ca_{1.76}Ba_{0.14}Mg_{0.02}Na_{0.40}K_{0.22})[Al_{9.19}Si_{26.94}O_{72}]\cdot nH_2O$, 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, β = 116.65°.

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, β = 116.40(2)° (Boles, 1972) for the type example, of composition $(Na_{3.98}Ca_{1.77}K_{0.55})[Al_{7.84}Si_{28.00}O_{72}]\cdot 21.74H_2O$, 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*a*), composition $(K_{2.40}Na_{0.96}Ca_{1.64}Mg_{0.64}Sr_{0.56}Ba_{0.12})[Fe_{0.56}Al_{9.08}Si_{26.48}O_{72}]\cdot 25.84H_2O$, T_{Si} 0.73.

Monoclinic, $C2/m$, Cm, or $C2$, a = 17.498, b = 17.816, c = 7.529 Å, β = 116.07°.

A close approach to end-member $K_9[Al_9Si_{27}O_{72}]\cdot nH_2O$ has been reported by Nørnberg (1990).

Hsianghualite

$Li_2Ca_3[Be_3Si_3O_{12}]F_2$ 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, $I2_13$, a = 12.864(2) Å.

Has an analcime-type structure, with tetrahedral sites occupied alternately by Si and Be. Extra-framework Ca, Li, and F ions (Rastsvetaeva *et al.*, 1991).

Kalborsite

$K_6[Al_4Si_6O_{20}]B(OH)_4Cl$ 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, $P\bar{4}2_1c$, $a = 9.851(5)$, $c = 13.060(5)$ 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

$Ca_4[Al_8Si_{16}O_{48}]\cdot 18H_2O$ Z = 1 LAU

As lomonite, Jameson (1805), who credits the name to Werner without specific reference; spelling changed to laumonite 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_2O. 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, $\beta = 110.34(2)°$ (Nasik, India; Artioli and Ståhl, 1993).

Except where unusually rich in (K,Na), reversibly loses *c.* $4H_2O$ 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

$K[AlSi_2O_6]$ 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)

$(Ca_{0.5},Na,K)_6[Al_6Si_{12}O_{36}]\cdot \sim 17H_2O$ Z = 3 LEV

Brewster (1825*b*). Type locality: Dalsnypen, Faröe 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, $R\bar{3}m$, 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, Faröe Islands. Material closely approaching end-member $Ca_3[Al_6Si_{12}O_{36}]\cdot 17H_2O$ 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, $R\bar{3}m$, $a = 13.338(4)$, $c = 23.014(9)$ Å for composition $(Ca_{2.73}Na_{0.65}K_{0.20})[Al_{6.31}Si_{11.69}O_{36}]\cdot 16.66H_2O$ 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, $R\bar{3}m$, $a = 13.380(5)$, $c = 22.684(9)$ Å for $(Na_{3.84}K_{0.38}Ca_{0.89}Mg_{0.08})$ $[Al_{6.33}Si_{11.71}O_{36}]$ (Mizota *et al.*, 1974).

Lovdarite

$K_4Na_{12}[Be_8Si_{28}O_{72}]\cdot 18H_2O$ Z = 1 LOV

Men'shikov *et al.* (1973). Type locality: alkaline pegmatites on Mt. Karnasurt, Lovozero massif, Kola Peninsula, Russia. Name means 'a gift of Lovozero'.

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. T_{Si} 0.75.

Orthorhombic, *Pma*2, 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

$(Pb_7Ca_2)\ [Al_{12}Si_{36}(O,OH)_{100}]\cdot n(H_2O,OH)$ $n \simeq 32$ 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. T_{Si} 0.76.

Orthorhombic, *Cm*2*m* (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 $Pb_4(O,OH)_4$ clusters with Pb_4 tetrahedra within channels (Rouse and Peacor, 1994).

Mazzite

$(Mg_{2.5}K_2Ca_{1.5})\ [Al_{10}Si_{26}O_{72}]\cdot 30H_2O$ Z = 1 MAZ

Galli *et al.* (1974). Type locality: in olivine basalt near top of Mont Semiol, 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.*, 1975*b*). T_{Si} 0.72.

Hexagonal, $P6_3/mmc$, *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, 1981*b*).

Merlinoite

$K_5Ca_2[Al_9Si_{23}O_{64}]\cdot 22H_2O$ Z = 1 MER

Passaglia *et al.* (1977). Type locality: Cupaello quarry in kalsilite melilitite, near Santa Rufina, 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; T_{Si} 0.66, 0.71.

Orthorhombic, *Immm*, *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

$Na_{16}Ca_{16}[Al_{48}Si_{72}O_{240}]\cdot 64H_2O$ 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.*, 1982*b*). T_{Si} in the range 0.59– 0.62.

Orthorhombic, *Fdd*2, *a* = 18.4049(8), *b* = 56.655(6), *c* = 6.5443(4) Å, for material from Poona, India (Artioli *et al.*, 1986*a*).

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

Montesommaite

$K_9[Al_9Si_{23}O_{64}]\cdot 10H_2O$ 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. T_{Si} = 0.70.

Orthorhombic, *Fdd*2, *a* = *b* = 10.099(1), *c* = 17.307(3) Å (pseudotetragonal, $I4_1/amd$).

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

$(Na_2,Ca,K_2)_4[Al_8Si_{40}O_{96}]\cdot 28H_2O$
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 Na/(Na + 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. T_{Si} in the range 0.80–0.86.

Orthorhombic, *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

$Na_3Ca_4[Al_{11}Si_{85}O_{192}]\cdot 60H_2O$ Z = 1 MFI

Galli, *et al.* (1997*b*); Vezzalini *et al.* (1997*b*). 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_{Si} 0.88.

Orthorhombic, *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

$Na_2[Al_2Si_3O_{10}]\cdot 2H_2O$ Z = 8 NAT

Klaproth (1803). Type locality: Hohentwiel, Hegau, Baden-Württemberg, Germany. Name from *natro-* for sodium-bearing.

(Na + K)/(Mg + Ca + Sr + Ba) varies from 0.97 to 1.00, with K, Mg, Sr, and Ba very minor. T_{Si} in the range 0.59–0.62 (Alberti *et al.*, 1982*b*; Ross *et al.*, 1992).

Orthorhombic, *Fdd*2, *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, Zeilberg, Germany: Hesse, 1983).

Si,Al partly to highly ordered (Alberti and Vezzalini, 1981*a*; Ross *et al.*, 1992; Alberti *et al.*, 1995).

Offretite

$CaKMg[Al_5Si_{13}O_{36}]\cdot 16H_2O$ Z = 1 OFF

Gonnard (1890), as offrétite. Type locality: Mont Simionse (Mont Semiol), Loire, France. Named after Albert J. J. Offret, professor in the Faculty of Sciences, Lyon, France.

Ca, Mg, and K substantial, commonly in proportions approaching 1 : 1 : 1; Na commonly trace or minor. Passaglia *et al.* (1998) and W.D. Birch (personal communication, 1997) show that earlier published analytical data pertaining to apparently Ca- and Na-dominant variants are compromised by identification problems, including possible mixtures. T_{Si} in the range 0.69–0.74.

Hexagonal, $P\bar{6}m2$, *a* = 13.307(2), *c* = 7.592(2) Å for composition $(Mg_{1.06}Ca_{0.97}K_{0.88}Sr_{0.01}Ba_{0.01})[Al_{5.26}Si_{12.81}O_{36}]\cdot 16.85H_2O$ from the type locality (Passaglia and Tagliavini, 1994).

The framework is related to those of erionite and levyne, but differs in the stacking of sheets of 6-membered rings, resulting in different values for *c* and differently sized and shaped cages (Gard and Tait, 1972). A high degree of Si,Al order is inferred. Offretite may contain intergrown macro- or crypto-domains of erionite (e.g. Rinaldi, 1976). It forms epitactic intergrowths with chabazite, but epitactic associations with levyne are questionable (Passaglia *et al.*, 1998).

Pahasapaite

$(Ca_{5.5}Li_{3.6}K_{1.2}Na_{0.2}\square_{13.5})Li_8[Be_{24}P_{24}O_{96}]\cdot 38H_2O$
Z = 1 RHO

Rouse *et al.* (1987). Type locality: Tip Top mine, Black Hills, South Dakota, U.S.A. Named after Pahasapa, a Sioux Indian name for the Black Hills.

Known from the type locality only. T_{Si} = 0.

Cubic, *I*23, *a* = 13.781(4) Å.

A beryllophosphate zeolite with ordered BeO_4 and PO_4 tetrahedra and a distorted synthetic zeolite RHO-type framework, structurally related to the faujasite series (Rouse *et al.*, 1989).

Partheite

$Ca_2[Al_4Si_4O_{15}(OH)_2]\cdot 4H_2O$ Z = 4 -PAR

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, β = 91.55(2)° (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)

$(K,Ca_{0.5},Na,Ba_{0.5})_{10}[Al_{10}Si_{32}O_{84}]\cdot 27-44H_2O$

Z = 16 PAU

Kamb and Oke (1960). Type locality: Rock Island Dam, Columbia River, Wenatchee, Washington, U.S.A. Named after Linus C. Pauling, Nobel Prize winner and Professor of Chemistry, California Institute of Technology.

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, $Im\bar{3}m$, 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:

$(K_{4.44}Na_{0.95}Ca_{1.88}Ba_{0.18})$ $[Al_{9.82}Si_{32.21}O_{84}]\cdot 44H_2O$ (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: $(Ca_{3.70}K_{2.67}Na_{0.86}Ba_{0.10})$ $[Al_{10.78}Si_{31.21}O_{84}]\cdot 34H_2O$; a = 35.088(6) Å (Tschernich and Wise, 1982).

Lengauer *et al.* (1997) found evidence of reduced H_2O content (27 H_2O for Z = 16) in barian paulingite-Ca from Vinarická Hora, Czech Republic.

Perlialite

$K_9Na(Ca,Sr)$ $[Al_{12}Si_{24}O_{72}]\cdot 15H_2O$

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)

$(K,Na,Ca_{0.5},Ba_{0.5})_x[Al_xSi_{16-x}O_{32}]\cdot 12H_2O$

Z = 1 PHI

Lévy (1825). Type locality as recorded by Lévy: Aci 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 Aci 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, β = 124.20(3)° (phillipsite-K with substantial Ca from Casal Brunori, Rome, Italy: Rinaldi *et al.*, 1974). A pseudo-orthorhombic cell has a $\simeq$ 9.9, $b \simeq$ 14.2, $c \simeq$ 14.2 Å, β $\simeq$ 90.0°, 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_2O; the other is partly occupied by Ca and Na in distorted octahedral coordination with two framework atoms of oxygen and four molecules of H_2O (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.

For pseudocell, *a* 9.931–10.003, *b* 14.142–14.286, *c* 14.159–14.338 Å, $\beta = 90°$, Z = 2 (e.g. Galli and Loschi Ghittoni, 1972; Sheppard and Fitzpatrick, 1989).

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.

For the pseudocell, *a* 9.871–10.007, *b* 14.124–14.332, *c* 14.198–14.415 Å, $\beta = 90°$, Z = 2 (e.g. Galli and Loschi Ghittoni, 1972; Sheppard *et al.*, 1970).

Phillipsite-Ca

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

Known range in T_{Si}: 0.57–0.74.

For the pseudocell, *a* 9.859–9.960, *b* 14.224–14.340, *c* 14.297–14.362 Å, $\beta = 90°$, Z = 2 (e.g. Galli and Loschi Ghittoni, 1972; Passaglia *et al.*, 1990).

Pollucite

(Cs,Na) $[AlSi_2O_6]\cdot nH_2O$, 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, $Ia3d$, *a* = 13.69 Å for $(Cs_{11.7}Na_{3.1}Li_{0.25}K_{0.4})[Al_{15}Si_{33}O_{96.2}]\cdot 4H_2O$ (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

$Ca_2[Be(OH)_2Al_2Si_4O_{13}]\cdot <2.5H_2O$
Z = 8 -ROG

Passaglia (1969*b*). 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

$Ca[Al_2Si_3O_{10}]\cdot 3H_2O$ 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.*, 1982*b*).

Monoclinic, *Cc*, *a* = 6.516(2), *b* = 18.948(3), *c* = 9.761(1) Å, $\beta = 108.98(1)°$, Z = 4 (Bombay, India: Kvick *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, $\beta = 90.64(1)°$, 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_2, and an extra molecule of H_2O.

Stellerite

$Ca[Al_2Si_7O_{18}]\cdot 7H_2O$ Z = 8 STI

Morozewicz (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 *pfu* and minor K, Mg, Fe. T_{Si} 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.*, 1978*b*).

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, 1975*a*). 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 *Fmmm* stellerite at Roberts Island, South Shetland group.

Stilbite (series)

$(Ca_{0.5},Na,K)_9[Al_9Si_{27}O_{72}]\cdot 28H_2O$ Z = 1 STI

Haüy (1801, p. 161–6), for minerals, apparently including heulandite, that had previously been described with informal names. He mentioned occurrences in volcanic terranes, and named Iceland, Andreasberg in Harz, Alpes Dauphinoises, and Norway, but there is no clear type locality. Named from Greek word for mirror, in allusion to its lustre ('un certain éclat').

Ca is almost always the dominant extra-framework cation, accompanied by subordinate Na and minor K and Mg, approximating $Ca_4(Na,K)$ *pfu*, but Na-rich members are also known. T_{Si} in the range 0.71–0.78.

Monoclinic, *C2/m*, *a* = 13.64(3), *b* = 18.24(4), *c* = 11.27(2) Å, β = 128.00(25)° (Galli and Gottardi, 1966; Galli, 1971); an alternative setting is pseudo-orthorhombic, *F2/m*, Z = 2.

Increasing departure from the topological symmetry of the orthorhombic framework, *Fmmm*, tends to correlate with increasing content of monovalent cations (Passaglia *et al.*, 1978*b*), which causes the framework to rotate (Galli and Alberti, 1975*a,b*). However, {001} growth sectors with appreciable Na and orthorhombic *Fmmm* symmetry have been observed in crystals in which other isochemical sectors are monoclinic, *C2/m* (Akizuki and Konno, 1985; Akizuki *et al.*, 1993). The centrosymmetric space group depends on statistically complete Si,Al disorder, and the true space group may be noncentrosymmetric (Galli, 1971).

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, β 90.06–90.91° (Passaglia *et al.*, 1978*b*).

Stilbite-Na

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

Proposed type locality: Capo Pula, Cagliari, Sardinia, Italy (Passaglia *et al.*, 1978*b*, #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.*, 1978*b*; 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, β = 90.54° for type material of composition $(Na_{8.18}K_{1.94}Ca_{3.45}Mg_{0.08})[Al_{16.62}Si_{55.25}O_{144}]\cdot 53.53H_2O$ (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

$NaCa[Al_3Si_{17}O_{40}]\cdot >7H_2O$ Z = 4 TER

Galli *et al.* (1997*a*). 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

$Ca_2Na[Al_5Si_5O_{20}]\cdot 6H_20$ Z = 4 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 Na:(Ca + Sr) and Si:Al approximately according to the formula $Na_{4+x}(Ca,Sr)_{8-x}[Al_{20-x}Si_{20+x}O_{80}]\cdot 24H_2O$, 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_{Si} in the range 0.50–0.56.

Orthorhombic, *Pncn*, a = 13.1043(14), b = 13.0569(18), c = 13.2463(30) Å (Ståhl *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

$Ca[Al_2Si_6O_{16}]\cdot \sim 8H_2O$ Z = 8 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_{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 *P*4/*mmm*, a = 12.880(2), c = 25.020(5) Å, but may consist of an intergrowth of a tetragonal enantiomorphic pair with space groups $P4_122$ and $P4_322$ and a triclinic polymorph $P\bar{1}$. See also Galli *et al.* (1995).

This is a structural analogue of synthetic zeolite beta.

Tschörtnerite

$Ca_4(K_2,Ca,Sr,Ba)_3Cu_3(OH)_8[Al_{12}Si_{12}O_{48}]\cdot nH_2O$, $n \geqslant 20$ Z = 16 (IZA code not assigned)

Krause *et al.* (1997), Effenberger *et al.* (1998). Bellberg volcano, near Mayen, Eifel, Germany. Named after Jochen Tschörtner, mineral collector and discoverer of the mineral.

T_{Si} = 0.50 for the only known occurrence.

Cubic, $Fm\bar{3}m$, a = 31.62(1) Å.

Cages in the framework include a large supercage 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

$Ca[Al_2Si_4O_{12}]\cdot 2H_2O$ Z = 8 ANA

Steiner (1955), Coombs (1955). Wairakei, Taupo Volcanic Zone, New Zealand. Named after the locality.

Most analysed samples have Na/(Na + 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_{Si} in the range 0.65–0.69.

Monoclinic (highly ordered), *I*2/*a*, a = 13.692(3), b = 13.643(3), c = 13.560(3) Å, β = 90.5(1)° for $(Ca_{0.90}Na_{0.14})$ $[Al_{1.92}Si_{4.07}O_{12}]\cdot 2H_2O$ (Takéuchi *et al.*, 1979).

Tetragonal or near-tetragonal, $I4_1/acd$, a = 13.72(4), c = 13.66(4) Å for $(Ca_{0.92}Na_{0.10})$ $[Al_{1.92}Si_{4.07}O_{12}]\cdot 2.11H_2O$ (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

$Ca[Be_3(PO_4)_2(OH)_2]\cdot 4H_2O$ Z = 4 WEI

Walter (1992). Type locality: spodumene-bearing pegmatite, 2 km west of Weinebene Pass, Koralpe, Carinthia, Austria. Named after the locality.

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, β = 95.76(1)°.

A calcium beryllophosphate zeolite with 3-, 4-, and 8-membered rings in the framework (Walter, 1992).

Willhendersonite

$K_xCa_{(1.5-0.5x)}[Al_3Si_3O_{12}]\cdot 5H_2O$ where $x = 0-1$ Z = 2 CHA

Peacor *et al.* (1984). Type locality: San Venanzo quarry, Terni, Umbria, Italy. Named after Dr William A. Henderson, of Stamford, Connecticut, U.S.A., who noted this as an unusual mineral and provided it for study.

Type willhendersonite conforms closely to $KCa[Al_3Si_3O_{12}]\cdot 5H_2O$. End-member $Ca_{1.5}[Al_3Si_3O_{12}]\cdot 5H_2O$ and intermediate compositions are now known (Vezzalini *et al.*, 1997*a*). $T_{Si} = 0.50, 0.51$.

Triclinic, $P\bar{1}$, $a = 9.206(2)$, $b = 9.216(2)$, $c = 9.500(4)$ Å, $\alpha = 92.34(3)^\circ$, $\beta = 92.70(3)^\circ$, $\gamma = 90.12(3)^\circ$ (Ettringer Bellerberg near Mayen, Eifel, Germany: Tillmanns *et al.*, 1984).

The framework is the same as for chabazite, which has idealized framework topological symmetry $R\bar{3}m$ but with much lower Si and with Si,Al fully ordered. This reduces the topochemical framework symmetry to $R\bar{3}$, and the nature and ordering of the extra-framework cations further reduce the framework symmetry to $P\bar{1}$. The low-K variants also have fully ordered Si,Al, but are less markedly triclinic (Vezzalini *et al.*, 1996).

Yugawaralite

$Ca[Al_2Si_6O_{16}]\cdot 4H_2O$ Z = 2 YUG

Sakurai and Hayashi (1952). Type locality: Yugawara Hot Springs, Kanagawa Prefecture, Honshu, Japan. Named after the locality.

Reported compositions are close to the ideal stoichiometry with up to 0.2 atoms *pfu* of Na,K,Sr. T_{Si} in the range 0.74–0.76.

Monoclinic, Pc, $a = 6.700(1)$, $b = 13.972(2)$, $c = 10.039(5)$ Å, $\beta = 111.07^\circ$ (Kvick *et al.*, 1986).

Triclinic, $P1$, by symmetry reduction ascribed to local Si,Al order, has been reported on the basis of optical measurements (Akizuki, 1987*b*).

Si,Al are strictly ordered in samples from Iceland (Kerr and Williams, 1969; Kvick *et al.*, 1986). The partial order reported for the Yugawara sample (Leimer and Slaughter, 1969) is doubtful (Gottardi and Galli, 1985).

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

$Na_2[Al_2Si_3O_{10}]\cdot 3H_2O$ 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, $Na_2[Al_2Si_3O_{10}]\cdot 2H_2O$.

Contains additional H_2O relative to natrolite, also minor Ca and K.

Pseudo-orthorhombic, F***, 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

$(Na,Ca)_{16}[Al_{19}Si_{21}O_{80}]\cdot 16H_2O$ 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 Ilímaussaq, Greenland, by Krogh Andersen *et al.* (1969).

Extensive solid solution approximating $(Na_{16-x}Ca_x)[Al_{16+x}Si_{24-x}O_{80}]\cdot 16H_2O$, 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, $I\bar{4}2d$. $a = 13.141$, $c = 6.617$ 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

$(Ca,Mn)_4Be_3Si_6O_{17}(OH)_4\cdot 3H_2O$ Z = 2

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

Spot analyses show a range from $(Ca_{3.20}Mn_{0.72}Fe_{0.08})_{\Sigma 4}$ to $(Ca_{2.00}Mn_{1.86}Fe_{0.14})_{\Sigma 4}$ for $Be_3Si_6O_{17}(OH)_4{\cdot}3H_2O$, 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) 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, svetlozarite, 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 sphalerite 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 $CaAl_3(PO_4,SiO_4)_2(OH)_n{\cdot}mH_2O$. 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
acadialite = 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
antiëdrite = edingtonite
apoanalcite = natrolite
arduinite = mordenite
aricite = gismondine
ashtonite = strontian mordenite
bagotite = thomsonite
barium-heulandite = barian heulandite
barytkreuzstein = harmotome
beaumontite = heulandite
bergmannite = natrolite
blätterzeolith = heulandite, stilbite
brevicite = natrolite
cabasite = chabazite
caporcianite = laumontite
carphostilbite = thomsonite
chabasie, chabasite = chabazite
christianite (of des Cloizeaux) = phillipsite
cluthalite = analcime
comptonite = thomsonite
crocalite = natrolite
cubicite, cubizit = analcime
cubic zeolite = analcime?, chabazite
cuboite = analcime
cuboizite = chabazite
desmine = stilbite
diagonite = brewsterite
dollanite = probably analcime
doranite = analcime with thomsonite, natrolite, and Mg-rich clay minerals (Teertstra 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

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
hydrolite (of Leman) = gmelinite
hydronatrolite = natrolite
hydronephelite = 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)
kalkkreuzstein = phillipsite
karphostilbite = thomsonite
kehoeite = a mixture including quartz, sphalerite, gypsum, and ?woodhouseite
koodilite = thomsonite
krokalith = natrolite
kubizit = analcime
kuboite = analcime
laubanite = natrolite
laumonite = laumontite
ledererite, lederite (of Jackson) = gmelinite
lehuntite = natrolite
leonhardite = H_2O-poor laumontite
leuzit = leucite
levyine, levynite, levyite = levyne
lime-harmotome = phillipsite
lime-soda mesotype = mesolite
lincolnine, lincolnite = heulandite
lintonite = thomsonite
lomonite = laumontite
marburgite = phillipsite
mesole = thomsonite
mesoline = levyne? chabazite?
mesolitine = thomsonite
mesotype = natrolite, mesolite, scolecite
metachabazite = partially dehydrated chabazite
metadesmine = partially dehydrated stilbite
metaepistilbite = partially dehydrated epistilbite
metaheulandite = partially dehydrated heulandite
metalaumontite = 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 = epistilbite
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 = epistilbite
ozarkite = thomsonite
parastilbite = epistilbite
phacolite, phakolit(e) = chabazite
picranalcime = analcime
picrothomsonite = thomsonite
pollux = pollucite
poonahlite, poonalite = mesolite
portite = natrolite (Franzini and Perchiazzi, 1994)
potassium clinoptilolite = clinoptilolite-K
pseudolaumontite = pseudomorphs after laumontite
pseudomesolite = mesolite
pseudonatrolite = mordenite
pseudophillipsite = phillipsite
ptilolite = mordenite
puflerite, pufflerite = stilbite
punahlite = mesolite
radiolite (of Esmark) = natrolite
ranite = gonnardite (Mason, 1957)
reissite (of Fritsch) = epistilbite
retzite = stilbite?, laumontite?
sarcolite (of Vauquelin) = gmelinite
sasbachite, saspachite = phillipsite?
savite = natrolite
schabasit = chabazite
schneiderite = laumontite (Franzini and

Perchiazzi, 1994)
schol blanc = leucite
scolesite, scolezit = scolecite
scoulerite = thomsonite
seebachite = chabazite
skolezit = scolecite
sloanite = laumontite?
snaiderite (schneiderite) = laumontite
soda-chabazite = gmelinite
soda mesotype = natrolite
sodium dachiardite = dachiardite-Na
sommaite = leucite
spangite = phillipsite
sphaerodesmine, sphaerostilbite = thomsonite
spreustein = natrolite (mostly)
staurobaryte = harmotome
steeleite, steelit = mordenite
stellerycie = stellerite
stilbite anamorphique = heulandite
stilbite (of many German authors) = heulandite
strontium-heulandite = strontian heulandite and heulandite-Sr
svetlozarite = dachiardite-Ca
syanhualite, syankhualite = hsianghualite
syhadrite, syhedrite = impure stilbite?
tetraedingtonite = edingtonite
tonsonite = thomsonite
triploclase, triploklase = thomsonite
vanadio-laumontite = vanadian laumontite
verrucite = mesolite
Vesuvian garnet = leucite
Vesuvian (of Kirwan) = leucite
viséite = disordered crandallite and other phases
weissian = scolecite
wellsite = barian phillipsite-Ca and calcian harmotome
white garnet = leucite
winchellite = thomsonite
Würfelzeolith = analcime, chabazite
zeagonite = gismondine, phillipsite
zeolite mimetica = dachiardite
zéolithe efflorescente = laumontite

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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 in that the framework consists essentially of oxygen atoms together with cations that enter into tetrahedral co-ordination with oxygen.

Is the presence of H_2O and of extra-framework cations essential?

Reversible dehydration is a characteristic feature of zeolitic behaviour, but how much H_2O must be present for a mineral to be considered a zeolite? Pollucite forms a continuous series with analcime, the H_2O 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 H_2O 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 H_2O 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 SiO_2 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.

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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_2O-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 leonhardite has less H$_2$O (*c.* 13 molecules of H$_2$O *pfu*) than laumontite. Doelter (1921) agreed that leonhardite 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 leonhardite' 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 leonhardite of Blum from Schemnitz catalogued in the Museum of Natural History, Vienna, in 1843 and type 'primary leonhardite' 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 leonhardite' is attributed to space limitations resulting from the introduction of additional cations of larger size.

In conformity with Rule 4, leonhardite is discredited as the name of a separate species. It is an H$_2$O-poor variety of laumontite. 'Primary leonhardite' 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 *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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