The following tables give the composition of the natural silicates thus far determined by x-ray investigations. The species are arranged according to the classification proposed in the preceding part of the discussion.

The complex silicates are indicated by printing their names in italics. The roman figures beneath the names indicate their constituent types, thus *Vesuvianite* I-II signifies a complex silicate of types I and II. The complex silicates are placed in the table with the simplest type entering into the composition of each.

A few species have been included in the tables whose structures are not adequately known. Such species (or families) are indicated by an asterisk * following their names. The figures enclosed in brackets after the names refer to the literature citations at the end.

**Classification of the Natural Silicates**

**I. SiO₄ Groups Uncombined. Orthosilicates, R₂SiO₄.**

1. **Bivalent Silicates, R₂SiO₄.**

   a. Anhydrous.

   1. Olivine family (1). Orthorhombic
      a. Mg, Fe section
         Fosterite Mg₃SiO₄
         Olivine (1) (Mg, Fe)₂SiO₄
         Fayalite Fe₃SiO₄
      b. Ca section
         Monticellite (2) CaMgSiO₄

   2. Phenacite family. Trigonal
      Phenacite (3) Be₂SiO₄
      Willemite (4) Zn₂SiO₄
      Troostite (Zn, Mn)₃SiO₄

   b. Hydrous.

   1. Chondrodite series (5), n Mg₃SiO₄ + Mg(OH, F)₃, n even monoclinic, n odd orthorhombic
      Norbergite (6) Mg₃SiO₄, Mg(OH, F)₃. Orthorhombic

---

1 A Mn, Fe section may, possibly, be added here. It embraces the minerals Tephroite Mn₃SiO₄, Knebellite (Fe, Mn)₃SiO₄.
Chondrodite 2 Mg$_2$SiO$_4$·Mg(OH, F)$_2$. Monoclinic
Humite 3 Mg$_2$SiO$_4$·Mg(OH, F)$_2$. Orthorhombic
Clinohumite 4 Mg$_2$SiO$_4$·Mg(OH, F)$_2$. Monoclinic

2. Complex division

\[
\text{Bertrandite (7) Be}_2(\text{BeOH})_3 \quad \begin{array}{c}
\text{SiO}_4 \\
\text{SiO}_2,
\end{array}
\quad \text{Orthorhombic}
\]

2. Trivalent Silicates, R'''4(SiO$_4$)$_3$.

- a. Anhydrous.

1. Garnet family (8) R''''4(R'''4(SiO$_4$)$_3$). Isometric

2. Cyanite series (9) Al$_2$O$_3$SiO$_4$
   - Sillimanite (10) Coordination $\frac{1}{3}$Al = 4, $\frac{2}{3}$Al = 6. Orthorhombic
   - Andalusite (11) Coordination $\frac{1}{3}$Al = 5?, $\frac{2}{3}$Al = 6. Orthorhombic
   - Cyanite (12) Coordination Al = 6. Triclinic

3. Eulytite series Bi$_4$(SiO$_4$)$_3$
   - Eulytite (13) Isometric
   - Agricolite *Monoclinic

4. Complex division.

\[
\text{Mullite (14)*} (\text{Al}_2\text{O}_3)_6 \quad \begin{array}{c}
(\text{SiO}_4)_6 \\
\text{Al}_4\text{O}_7 \\
\text{Orthorhombic}
\end{array}
\]

- b. Hydrous.

1. Staurolite (15) 2 cyanite+Fe(OH)$_2$. Orthorhombic

2. Topaz (16) Al$_2$(OH, F)$_2$SiO$_4$. Orthorhombic

3. Euclase (17) Al(BeOH)SiO$_4$. Monoclinic

4. Complex division

\[
\text{Vesuvianite (18) Ca}_{19}\text{Al}_4 \quad \begin{array}{c}
(\text{SiO}_4)_4 \\
(\text{Si}_2\text{O}_7)_3 \\
2\text{Mg(OH)}_2 \\
\text{Tetragonal}
\end{array}
\]


- a. Anhydrous.

1. Zircon family R''''SiO$_4$. Tetragonal
   - Zircon (19) ZrSiO$_4$
   - Thorite* ThSiO$_4$

2. Titanite (20) Ca(TiO)SiO$_4$. Monoclinic

II. SiO$_4$ groups combined by one solid angle. Orthosilicates. R''''SiO$_7$. Pairs


- b. Hydrous.

Calamine (21) Zn$_2$(ZnOH)$_2$Si$_2$O$_7$·H$_2$O. Orthorhombic

2. Trivalent Silicates, R'''4Si$_2$O$_7$.

- a. Anhydrous.

1. Thortveitite (22) Sc$_2$Si$_2$O$_7$. Monoclinic

\^{2} The empirical formula of mullite is 3Al$_2$O$_3$·2SiO$_2$. Taylor showed that the x-ray patterns of mullite and sillimanite are similar and suggests that their structures are analogous. He derives mullite from 8 molecules of sillimanite by removing one atom of O and replacing two Si by two Al. The result suggests a formula of the above type, but the true structure of mullite is unknown.

\^{3} For danburite see type V.
2. Aenigmatite (23)\( X_4Y_{12}(SiO_4)_6 \). \( X = (Na, Ca, K) \). \( Y = (Fe^{+++}, Ti, Fe^{+++}, Mg, Al) \).

Triclinic

3. Bivalent to Quadrivalent Silicates.

a. Anhydrous.

1. Melilite family (24)\( X_2Y(Si, Al)_2O_7 \). \( X = (Ca, Na) \). \( Y = (Mg, Fe, Zn, Si, Al) \).

Tetragonal

a. Bivalent section \( Ca_2(Mg, Zn) \)

Akermanite (24) \( Ca_2MgSi_2O_7 \)

Hardystonite (25) \( Ca_2ZnSi_2O_7 \)

b. Trivalent section

Melilite (24) \( Ca_2Na(Mg, Al) (Si, Al)_2O_7 \)

b. Quadrivalent section

Na-melilite (26) \( Na_4Si_2O_7 \)

Gehlenite (26) \( Ca_2SiAl_2O_7 \)

b. Hydrous.

1. Meliphanite family (27) \( (Ca, Na)_2Be(Si, Al)_2(O, OH, F)_7 \)

Leucophanite (27) \( (Ca, Na)_2BeSi_2(O, OH, F)_7 \) Orthorhombic

Leucophanite (27) \( (Ca, Na)_2Be(Si, Al)_2(O, OH, F)_7 \) Tetragonal

2. Complex division

\[
\begin{array}{c|c|c}
\text{Zunyite (28)} & \text{Al}_{12} \text{SiO}_4 & \text{SiO}_3 \\
\text{II-V} & \text{AlO}_4 & \text{OH}, F \text{Cl} \text{Isometric}
\end{array}
\]

M. Fleischer gives the above formula for aenigmatite, basing it upon chemical analyses and the dimensions and density of the unit cell. The structure has not been adequately determined.

The members of the melilite family can be referred, for classification, with almost equal propriety to two different types. If the \( Y(Mg, Fe, Zn, Si, Al) \) atoms be viewed as kations, the \( (Al, Si)_2O_7 \) groups being considered the only anions, the formula becomes \( X_2Y(Si, Al)_2O_7 \), as written above, and the family is a member of the orthodisilicates of type II. If, however, both the paired \( (Si, Al)_2O_7 \) and the \( YO_4 \) tetrahedra (see Figure 3), are considered anions, then, since they are united by their solid angles, they form sheet-like structures and the formula becomes \( X_2 \) \( Si_2O_5 \). In the latter case the melilites may be viewed as complex silicates related structurally to epididymite \( Na(BeOH) \) \( Si_2O_3 \) \( SiO_2 \).

The original investigators of the structures wrote their formula in the first way, as we do. C. Hermann and his associates, in the second volume of the Structurebericht (1936, pp. 541-543) classify them as forming two-dimensional sheets.

The constitution of the meliphanite family has been studied by W. H. Zachariasen, who derives the formula given above from chemical analyses, the dimensions and densities of the unit cells and the similarity of their x-ray patterns to those of the melilites. The structure suggested, though not determined, is interesting in that it seems to place \( O, OH \) and \( F \), interchangeably, upon the solid angles of the \( SiO_4 \) tetrahedra, a condition seemingly not recognized, hitherto, in other adequately studied silicates.

Zunyite may also be regarded as combining types I, II, V, if the \( AlO_4 \) tetrahedra be regarded as replacing \( SiO_4 \).
III. SiO₄ GROUPS COMBINING BY TWO SOLID ANGLES. METASILICATES, R₄SiO₈.

RINGS AND CHAINS.

A. Rings

1. Three-fold rings, R₄(SiO₄)₄
   a. Anhydrous.

1. Wollastonite family
   a. Monoclinic section
      Wollastonite (29) Ca₄(SiO₄)₄
   2. Benitoite (30) BaTi(SiO₄)₂ Hexagonal
      b. Hydrous.

1. Pectolite family (31) Triclinic-Pseudomonoclinic
   a. Anhydrous.
      1. Orthorhombic system (35) Mg, Fe series
         Enstatite MgSiO₃
         Bronzite (36) (Mg, Fe)SiO₃
         Hypersthene (Fe, Mg) SiO₃
      b. Monoclinic system (37)
         1. Bivalent section
            a. Mg, Fe series
               Clinoenstatite Mg₂Si₂O₆
            b. Ca, Mg series Ca(Mg, Fe)Si₂O₆
               Diopside (38) CaMg
               Hedenbergite CaFe

b. Hydrous.

1. Tourmaline family (32) XY₃B₃Si₆O₁₈(O, OH, F) Hexagonal
   2. Six-fold rings, R₄'₈(SiO₄)₄.
      a. Anhydrous.

1. Beryl (33) Be₃Al₂(SiO₄)₄. Hexagonal
   2. Cordierite (34) (Mg, Fe)₂Al₄(Si₄Al)O₁₆₊H₂O. Orthorhombic

B. Chains.

1. Chains unilateral, R₄SiO₈.

1. Pyroxene family (X, Y)₄(Si, Al)₄O₆
   X = (Ca, Na, K, Mn) Y = (Mg, Fe, Al, Ti, Li, Mn)
   a. Orthorhombic system (35) Mg, Fe series
      Enstatite MgSiO₃
      Bronzite (36) (Mg, Fe)SiO₃
      Hypersthene (Fe, Mg) SiO₃
   b. Monoclinic system (37)
      1. Bivalent section
         a. Mg, Fe series
            Clinoenstatite Mg₂Si₂O₆
         b. Ca, Mg series Ca(Mg, Fe)Si₂O₆
            Diopside (38) CaMg
            Hedenbergite CaFe

8 The wollastonite family occurs in both monoclinic and triclinic sections. M. Barnick, who has determined the ring structure of monoclinic wollastonite, suggests that the triclinic form may have a similar structure, but differs in the lesser symmetry of its cells. Vogtite is a Mn bearing variety (Ca, Mn)SiO₃ of the monoclinic section.

9 The work of M. A. Peacock has shown so close a relation between the triclinic wollastonite and pectolite families as to suggest similarity of structures. As stated above, M. Barnick has established the ring structure of monoclinic wollastonite and suggests a similar structure for the triclinic form. The true structure of the pectolite family, however, is not definitely known.

10 F. Machatschki gives the above formula for tourmaline, save that he unites the (O, OH, F)₄ group with the O, the latter thus becoming (O, OH, F)₄. He derives the formula from chemical analyses and the dimensions and density of the unit cells. The formula suggests a possible position of tourmaline in this division, but its structure and place in the classification are unknown. The work of Machatschki is interesting as an effort to unravel somewhat of the complexity of this difficult family.
2. Trivalent section\textsuperscript{11} (Ca, Na) (Mg, Fe, Al) (Si, Al)\textsubscript{2}O\textsubscript{6}
   a. Ca, Mg series
   Augite\textsuperscript{12} \(X_m Y_{2-m}(Si, Al)\textsubscript{2}O_6\)
   \(X = (Ca, Na, Al, Mn)\), \(Y = (Mg, Fe, Al, Ti, Mn)\).
   b. Ca, Na, Li series \(R'\textsubscript{2}Si_2O_6\)
   Acmite NaFe\textsuperscript{+++}
   Jadeite NaAl
   Spodumene LiAl

2. Complex division. Bilateral chains, \(R'\textsubscript{2}Si_2O_6\)

b. Hydrous.

1. Serpentine family
   Chrysotile (39) \((MgOH)_6Si_2O_6, \text{SiO}_2 \cdot \text{H}_2\text{O}\) Monoclinic

2. Amphibole family \(R'\textsubscript{2}Si_2O_6(OH, F)_2\)
   a. Orthorhombic system
   1. Mg, Fe series
      Anthophyllite (40) \((Mg, Fe)_2Si_4O_12, \text{Si}_2O_6(OH)_2\)
   b. Monoclinic system (41)
   1. Bivalent section
      a. Mg, Fe series \((Mg, Fe)_2Si_4O_12, \text{Si}_2O_6(OH)_2\)
         Kupferite Mg\textsuperscript{7}
         Cummingonite (42) \((Mg, Fe)_2\)
         Grunerite Fe\textsuperscript{+++}
      b. Ca, Mg series \(Ca_2(Mg, Fe)_5Si_2O_6(OH)_2\)
         Tremolite (43) \(Ca_2Mg_5\)
         Actinolite \(Ca_2(Mg, Fe)_5\)
   2. Trivalent section (42) \(X_{2-3}Y_3(Si, Al)\textsubscript{4}O_12, \text{Si}_2O_6(OH, F)_2\)
      \(X = (Ca, Na, K, Mn), \ Y = (Mg, Fe, Al, Mn, Ti)\)
      a. Na rich series\textsuperscript{13} \(R'\textsubscript{16}Si_2O_6(OH)_2\)
         Glaucophane\textsuperscript{*} \(Na_2(Mg, Fe')\textsubscript{2}(Al, Fe')\textsubscript{2}\)
         Riebeckite\textsuperscript{*} \(Na_2Fe\textsubscript{16}Fe'\textsubscript{16}\)
         Arfvedsonite\textsuperscript{*} \(Na_2Fe'\textsubscript{16}Fe''\textsubscript{16}\)
      b. Na poor series \(R'\textsubscript{16}Si_2O_6(OH, F)_2\)
         Hornblende\textsuperscript{14} \(X_{2-3}Y_3\)

11 Formulae have been proposed for various other members of the pyroxene family but the results seem too insecure to render it desirable to present them at this place.
12 B. E. Warren and J. Biscoe cite the presence of \text{H}_2\text{O} in some augites and write the formula \(X_m Y_{2-m}(Si, Al)\textsubscript{2}O_6(OH, F)_2\).
13 The species here listed have had formulae assigned to them by Winchell, Bragg and others, based upon their analogies to the studied amphiboles, but their structures are not adequately known. The formulae here given are those of Winchell. (A. N. Winchell, \textit{Elements of Optical Mineralogy}, pt. II, p. 239, 1933, W. L. Bragg, \textit{Atomic Structure of Minerals}, p. 185, 1937.) See also B. Gossner, F. Spielberg, \textit{Zeits. Krist.}, 72, 111, 1929, B. Gossner, F. Mussgnug, \textit{N. Jb. Min.}, A. \textit{Beit. Bd.}, 58, 213, 1928.
14 Osannite (44) is a variety of hornblende with abnormally high O content and high Na.
Additional varieties of hornblende have been examined by B. Gossner and F. Spielberg (\textit{Zeits. Krist.}, 72, 111, 1929) who derived their formulae from chemical analyses and measurements of the unit cells. The formulae they propose may be written as follows—
Barkevikite \((Ca, Na)_2Mg_6(Fe, Al)\textsubscript{4}(SiO_4)_8\)
Kärsutite \((Ca, Na)_2(Mg, Al, Fe)\textsubscript{6}[(Si, Ti)O_4]_8\)
IV. SiO₄ groups combined by three solid angles. Metadisilicates, R₂Si₂O₆ Sheets


A. Si₂O₅ series

1. Apophyllite (45) 4CaSi₂O₅ · KF · 8H₂O. Tetragonal
2. Kaolin family (46) Al₂Si₂O₅(OH)₄. Monoclinic
   - Kaolinite (47) Al₂Si₂O₅(OH)₄ · β = 101°30'
     - var. Anauxite (48) Al₂Si₂O₅(OH)₄ · β = 96°50'
     - Dickite (49) Al₂Si₂O₅(OH)₄ · β = 91°43'
     - Nacrite (50) Al₂Si₂O₅(OH)₄ · β = 91°43'
3. Halloysite (51) Al₂Si₂O₅(OH)₄ · 2H₂O Monoclinic

B. SiO₆ series

a. R̅₄a(Si, Al)₄O₁₀(OH)₈ division

1. Montmorillonite family (52) (Mg, Al, Fe)₂₋₄(Si, Al, Fe)₂₋₄O₁₀(OH)₈ · nH₂O. Orthorhombic
   - Montmorillonite (Mg, Al)₂₋₄O₁₀(OH)₈. Little or no Si replaced by (Al, Fe)
   - Nontronite (Mg, Al, Fe)₂₋₄O₁₀(OH)₈. Up to 1 Si replaced by (Al, Fe)
2. Talc—Pyrophyllite group (53) (Mg, Al)₂₋₄(Si₂O₅)(OH)₈. Monoclinic
   - Talc Mg₃
   - Pyrophyllite Al₃
3. Mica families (54) R̅₇₋₄(Si, Al)₄O₁₀(OH)₈. Monoclinic
   a. Elastic micas18. One Al replacing Si. R̅₇₋₄(Al₂Si₄O₁₀(OH)₈, F)₂
      - Muscovite (55) KAl₃(Al₂Si₄O₁₀(OH, F))₂
      - Phengite. Muscovite+KAl(Mg, Fe)₂Si₂O₁₀(OH, F)₂
      - Paragonite NaAl₃(Al₂Si₄O₁₀(OH, F)₂

---


17 Anauxite forms an isomorphous series with kaolinite. It may be considered derived from kaolinite by the removal of either Al(OH)₄ or AlO(OH) from kaolinite. In the latter case an OH group is substituted for one O atom in a Si₂O₅ group. (S. B. Hendricks, Zeits. Krist., 95, 247, 1936).

18 Allophane is an amorphous body with approximately the composition of kaolinite. (C. S. Ross, P. F. Kerr, U. S. G. S., Prof. Paper 185 G, 1934.)

18 J. W. Gruner makes the formula of this family (Al, Fe)₈ (Al, Fe)₆Si₈₋₄nO₄₆(OH)₈ · nH₂O and regards montmorillonite, beidellite and nontronite as a continuous isomorphous series with n varying in value from 0 to 4. In montmorillonite n = 0 or < 1, in nontronite n = 2 to 4. In beidellite and other varieties n lies between these limits.

19 The species of elastic micas are subject to wide variation in composition. The following replacements occur in them according to J. Holzner (Zeits. Krist., 95, 435, 1936), R̅₇₋₄X₄Y₂₋₄ where X = (K, Na, Ca), Y = (Mg, Fe, Al, Mn, Li). Fe²⁺ may replace Al in (Al₂Si₄O₁₀. Holzner also suggests certain other replacements that seem less assured, i.e. (X, Y') and (Ti, Si) in some micas and (Na, Li) in lepidolite and zinnwaldite.

Holzner recognizes two structural types of elastic micas, muscovite Y₂ and phlogopite Y₃, and regards biotite as an intergrowth of sheets of both.
Phlogopite $K\text{Mg}_3(\text{Al}_4\text{Si}_3)\text{O}_{12}(\text{OH}, \text{F})_2$
Biotite (56) $K(\text{Mg}, \text{Fe}, \text{Al})_2-3(\text{Al}, \text{Si})\text{O}_{10}(\text{OH}, \text{F})_2$

b. Brittle micas. Two Al replacing Si. $R'_8(\text{Al}_8\text{Si}_6)\text{O}_{16}(\text{OH})_2$
Margarite $\text{CaAl}_2(\text{Al}_4\text{Si}_3)\text{O}_{10}(\text{OH})_2$

4. Vermiculites (57) $(\text{Mg}, \text{Fe})\text{O}_{13-19}(\text{Si}, \text{Al}, \text{Fe}''')_4\text{O}_{10}(\text{OH})_2 \cdot 4\text{H}_2\text{O}$. Monoclinic

b. $R''_{13-14}(\text{Si}, \text{Al})\text{O}_{10}(\text{OH})_2$ division

1. Chlorite group (58) $R''_{13-14}(\text{Si}, \text{Al})\text{O}_{10}(\text{OH})_2$ Monoclinic
a. Clinochlore family. One Al replacing Si
$R''_8(\text{Al}_8\text{Si}_6)\text{O}_{16}(\text{OH})_2$. $R''_8=(\text{Mg}, \text{Fe}'', \text{Mn})_4(\text{Al}, \text{Fe}''')$
b. Amesite family. Two Al replacing Si
$R''_{14}(\text{Al}_8\text{Si}_6)\text{O}_{16}(\text{OH})_2$. $R''_{14}=(\text{Mg}, \text{Fe}'', \text{Mn}''')_4(\text{Al}, \text{Fe}''')_2$

2. Complex division

1. Epididymite (59) $Na(\text{BeOH})\text{Si}_2\text{O}_3$ Orthorhombic

V. SiO$_4$ GROUPS COMBINED BY FOUR SOLID ANGLES. DIOXIDE TYPE, SiO$_2$. NET-WORKS

A. $R'''$ free. SiO$_2$

1. Three-fold. Quartz (60) (SiO$_2$)$_3$ Trigonal
2. Six-fold. (SiO$_2$)$_6$
   Cristobalite (61) Cubic packing. Orthorhombic? Isometric
   Tridymite (62) Hexagonal packing. Orthorhombic, Hexagonal

B. TRIVALENT SILICATES

1. Anhydrous.
   a. Silicates without other anions. Monanionic.
   
1. Feldspar family (63) $R''_{1-2}(\text{Si}, \text{Al})_4\text{O}_8$
   a. Monoclinic system
      Orthoclase (64) $\text{KAlSi}_3\text{O}_8$
      Hyalophane $\text{KAlSi}_3\text{O}_8 \cdot \text{BaAl}_2\text{Si}_2\text{O}_8$
      Celsian $\text{BaAl}_2\text{Si}_2\text{O}_8$
   b. Triclinic system
      Microcline $\text{KAlSi}_3\text{O}_8$
      Albite (65) $\text{NaAlSi}_3\text{O}_8$
      Anorthite $\text{CaAl}_2\text{Si}_2\text{O}_8$

2. Danburite (66) $\text{CaB}_2\text{Si}_2\text{O}_8$. Orthorhombic

---

20 The above formula is that of J. Holzner. A. N. Winchell writes $K(\text{Mg}, \text{Fe}, \text{Al})_8(\text{Al}, \text{Si})\text{O}_{16}(\text{OH})_2$ (Am. Mineral., 20, 773, 1935).
21 Danburite consists of pairs of SiO$_4$ tetrahedra joined by one solid angle, with the formula Si$_2$O$_7$ and similarly joined pairs of BO$_4$ tetrahedra with the formula B$_2$O$_7$. Both the SiO$_4$ and B$_2$O$_7$ pairs are further united by their solid angles to form a net-work. If the Si$_2$O$_7$ pairs alone be viewed as anions, danburite is clearly an orthodisilicate, CaB$_2$OSi$_2$O$_7$. If boron is viewed as replacing Si, in a manner analogous to the replacement of Si by Al, the structure is of the dioxide type and the formula becomes CaB$_2$Si$_2$O$_7$ as here written. The small size and trivalent valency of the B atom has led us to treat the subject in the latter way.
3. Leucite family (67)* Twenty R'AlSiO₄ Tetragonal—Pseudo-isometric
   Leucite KAlSiO₄
   Na-Leucite (K, Na)AlSiO₄
4. Nepheline family (68) R'AlSiO₄ Hexagonal
   Nepheline (α carnegeite) NaAlSiO₄
   Kaliophilite KAlSiO₄

b. Silicates with other anions. Poly-anionic.

1. Scapolite family (69) 3 (Na, Ca) (Al, Si)₂O₆+[NaCl, Ca(CO₃, SO₄)]
   Tetragonal
   Marialite. 3 albite+NaCl
   Wernerite | Marialite+Meionite
   Mizzonite | Meionite. 3 Anorthite+Ca(CO₃, SO₄)
2. Sodalite family (70) (Na, Ca)₆₋₇(AlSiO₄)₄+2X. Isometric
   Sodalite Na₆(AlSiO₄)₆NaCl₂
   Noselite (71) Na₆(AlSiO₄)₈Na₄SO₄
   Haüynite (71) (Ca, Na)₆₋₇(AlSiO₄)₆(CaSO₄)₁₋₂
3. Cancrinite family (72) 3NaAlSiO₄+Ca(Cl, CO₃, SO₄)₂±H₂O. Hexagonal
   Cancrinite 3NaAlSiO₄+CaCO₃±H₂O
   Davynite 3NaAlSiO₄+Ca(Cl₂, SO₄)
4. Helvite—Danalite group (73). Isometric
   Helvite 3(Mn, Fe)(Be, Si)O₄+(Mn, Fe, Zn)S
   Danalite 3(Zn, Fe, Mn)(Be, Si)O₄+(Zn, Fe)S

2. Hydrous.

1. Epidote family (74)* Twenty Ca₃(Al, Fe, R")₃Si₆O₁₈(OH)
2. Zeolites (75)* Twenty Rₙₖ(Al₆Si₆O₂₄)·xH₂O

* No adequate study has been made of the structure of leucite but its composition and relations are such as to suggest its position in this group. Recent studies of J. Wyart show its true tetragonal character.

* The structure of the epidote family is not adequately known. D. J. Bujor studied epidote and clinohumite and published his roentgenographic data in 1931, in the first of two articles. The second part, embracing his interpretation of the data, has not yet appeared. A. N. Winchell has referred the family to the division of three-dimensional lattices. This has a certain plausibility because of the relation of epidote to feldspar. Waldbauer and McCann have shown that orthorhombic zoisite is probably formed by the submicroscopic twinning of clinohumite.

* Different views have been held concerning the composition of the zeolites due to their complexity, variable hydration, isomorphic intergrowths and replacements seemingly taking place after their crystallization. One view, widely held, assigns to most of them two Al atoms (or some multiple of two), a fixed Al:Si ratio, the isomorphic replacement of Ca by Na₂ in many, and a resulting variable number of kations. A second view, suggested by A. N. Winchell, is that CaAl and NaSi mutually replace each other resulting in isomorphic intergrowths, a variable Al:Si ratio and a constant number of kations in each species. Winchell denies the primary replacement of Ca by Na₂ though he believes it may occur subsequent to crystallization. M. H. Hey and J. Wyart believe, on the contrary, that both types of replacement occur.
a. Al₂ section. R'zAl₂Si₄O₁₂(2+6) • xH₂O

1. Si₂O₃ series

Thomsonite (76)²⁸ Na₃Ca₄(Al₃Si₅O₁₆)₆. 12H₂O. Orthorhombic

2. Si₂O₁₉ series

Natrolite (77) Na₆Al₂Si₅O₁₆. 2H₂O. Orthorhombic
Scolecite (78) CaAl₄Si₅O₁₆. 3H₂O. Monoclinic
Mesolite (79)²⁹ Na₃Ca₃Si₅O₁₆. 8H₂O. Monoclinic
Gonnardite (80)³⁰ Na₆Ca(Al₃Si₅O₁₆)₂. 7H₂O. Orthorhombic or Tetragonal
Edingtonite (81) Ba₆Al₂Si₅O₁₀. 4H₂O. Tetragonal

3. Si₂O₁₂ series

Analcite (82) Na₆Al₂Si₄O₁₂. 2H₂O. Tetragonal? pseudo-isometric

Chabazite (83)³³ CaAl₄Si₄O₁₂. 6H₂O. Orthorhombic
Pollucite (84)³³ Ca₆Al₂Si₅O₁₂. 1H₂O. Isometric

4. Si₂O₁₈ series

Heulandite (85)³³ CaAl₄Si₄O₁₂. 6H₂O. Monoclinic

5. Si₂O₂₅ series

Mordenite (86)³³ Na₆Ca(Al₃Si₅O₁₆)₂. 12H₂O. Monoclinic

b. Al₆ section

Ashcroftine (87)³³ NaK(Ca, Mn, Mg)Al₆Si₆O₁₈. 8H₂O. Tetragonal

²⁸ Subject to replacements of CaAl ≡ NaSi and Ca ≡ Na₆, according to M. H. Hey.
²⁹ Composition doubtful, perhaps Na₃Ca₄(Al₃Si₅O₁₆)₆. 21H₂O, (W. H. Taylor et al., Zeits. Krist., 84, 384, 1933, footnote.)
³⁰ M. H. Hey gives the above formula and states that CaAl and NaSi replace each other, more rarely Ca and Na₆.
³³ The structure of chabazite was determined by J. Wyart who gives the above formula, subject to various replacements of Ca ≡ Na₆, CaAl ≡ NaSi, etc. A. N. Winchell's formula is (Na, K, Ca)₆(Al, Si)₆O₁₈. 40H₂O.
³⁴ The composition of heulandite varies widely. J. Wyart studied its structure but did not determine the parameters. He gives the above formula subject to various replacements of Ca, Al, Si, especially Si ≡ NaAl. M. H. Hey gives the formula Na₆Ca₆Al₁₈Si₉O₇₈. 24H₂O.
³⁵ The above formula is by A. N. Winchell, who bases it upon chemical analyses.
³⁶ A. N. Winchell adds the following formula of additional species of zeolites, basing them upon selected chemical analyses (Am. Mineral., 10, 170, 1925. See also ib. 22, 85, 1937). His kation number ("alkali number") is recalculated for 80 oxygen atoms.

1. Al:Si ratio and composition constant

Levynite NaCa₄Al₅Si₉O₉₀. 25H₂O Kation number 8
Stilbite NaCa₃Al₅Si₉O₉₀. 60H₂O Kation number 6
Epistilbite Na₂Ca₃Al₅Si₉O₉₀. 25H₂O Kation number 6
Brewsterite Na₂(Al₅Sr₅Ba₅)Si₉O₉₀. 25H₂O Kation number 6
Harmatome K₆Ba₄Al₅Si₉O₉₀. 25H₂O Kation number 6
Ptilotite Na₃Ca₃Al₅Si₉O₉₀. 25? H₂O Kation number 5?

2. Al:Si ratio and composition variable. Isomorphous intergrowths

Gmelinite (Na, Ca)₁₂(Al, Si)₄O₉₀. 40H₂O Kation number 12 (11½?)
Gismondite (K, Ca)₁₁(Al, Si)₄O₉₀. 36–40H₂O Kation number 11
Phillipsite (K, Ca)₁₁(Al, Si)₄O₉₀. 30–40H₂O Kation number 11
Laumontite (Na, Ca)₁₁(Al, Si)₄O₉₀. 25H₂O Kation number 7
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**References**

84. Pollucite, H. Strunz, Zeits. Krist., 95, 1, 1936.
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