Clino-Amphiboles
(Monoclinic Amphiboles)

$A_0, B_2, C_5, T_8, O_{22}(OH,F,Cl)_2$

Presented by
Joyleen Desai
Paul Sandlin

Structure
Space group: C2/m

Crystallographic Sites

<table>
<thead>
<tr>
<th>Coordination</th>
<th>A</th>
<th>M4</th>
<th>M3</th>
<th>M1</th>
<th>M2</th>
<th>T1</th>
<th>T2</th>
<th>O4</th>
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</thead>
<tbody>
<tr>
<td>K</td>
<td>Na</td>
<td>Mn</td>
<td>Mn</td>
<td>Al</td>
<td>Al</td>
<td>Si</td>
<td>St</td>
<td>OH</td>
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<tr>
<td>Na</td>
<td>Ca</td>
<td>Fe$^{2+}$</td>
<td>Fe$^{3+}$</td>
<td>Ti</td>
<td>Si</td>
<td>Al</td>
<td>F</td>
<td></td>
</tr>
<tr>
<td>Mn</td>
<td>Mg</td>
<td>Mg</td>
<td>Fe$^{2+}$</td>
<td>Cl</td>
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<tr>
<td>Fe$^{2+}$</td>
<td>Mg</td>
<td></td>
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<tr>
<td>Mg</td>
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</table>

Source: Spear (1995)
Structural Cell Parameters

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
<th>a (Å)</th>
<th>b (Å)</th>
<th>c (Å)</th>
<th>â (°)</th>
<th>V (Å³)</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hornblende</td>
<td>(Na,K)₅₋₆(Ca,Na,Fe,Mg)₂₋₃(Mg,Fe,Al)₃₋₄(Si,Al)₈₂(OH)₂²⁻</td>
<td>2.885</td>
<td>5.218</td>
<td>10.2</td>
<td>102°</td>
<td>1396</td>
<td>921.26</td>
</tr>
<tr>
<td>Cummingtonite</td>
<td>(Na,Mg,Fe)₂₋₃(Mg,Fe)₅₋₆(Si,Al)₈₂(OH)₂²⁻</td>
<td>2.534</td>
<td>5.282</td>
<td>10.2</td>
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<td>905.18</td>
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<tr>
<td>Glaucophane</td>
<td>Na₂Mg₅Al₈O₂₁(OH)₂²⁻</td>
<td>2.85</td>
<td>5.25</td>
<td>10.5</td>
<td>102°</td>
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<td>Actinolite</td>
<td>Ca₅₋₆[Mg,Fe]₈₂Si₈O₂₁(OH)₂²⁻</td>
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<td>5.15</td>
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<td>Tarbeckite</td>
<td>Na₂(Mg,Fe)₅₋₆Si₈O₂₁(OH)₂²⁻</td>
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<td>5.34</td>
<td>10.4</td>
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<td>1414</td>
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</tbody>
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Amphibole Occurrences

- Common in igneous rocks
  - Essential in intermediate composition igneous rocks
- Metamorphosed mafic rocks
  - Amphibolite facies associated with plagioclase
- Hornblende is the name given to amphiboles with an indeterminate composition

Source: www.webmineral.com

Hornblende

\[(Na,K)₅₋₆(Ca,Na,Fe,Mg)₂₋₃(Mg,Fe,Al)₃₋₄(Si,Al)₈₂(OH)₂²⁻\]

- Common in igneous rocks
  - Essential in intermediate composition igneous rocks
- Metamorphosed mafic rocks
  - Amphibolite facies associated with plagioclase
- Hornblende is the name given to amphiboles with an indeterminate composition
**Cummingtonite Series**

Cummingtonite: $\text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$

Grunerite: $\text{Fe}_7\text{Si}_8\text{O}_{22}(\text{OH})_2$

- Occur in med-grade metamorphism
  - Grunerite found in metamorphosed Fe-rich sediments
- Grunerite is less pleochroic
- M4 (yellow) takes Mg in cummingtonite structure

**Actinolite Series**

Tremolite: $\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$

Actinolite: $\text{Ca}_2(\text{Mg,Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$

- Found in med-grade metamorphosed mafic rocks
  - Calcic amphiboles are the most abundant in greenschist and amphibolite facies
- Tremolite is one of the first minerals to form in metamorphosed carbonates
  - At high T, yields to diopside
- Fe goes into either M3 or M1 (yellow) in actinolite structure

**Na-Amphiboles**

Glaucophane: $\text{Na}_2\text{Mg}_3\text{Al}_2\text{Si}_8\text{O}_{22}(\text{OH})_2$

Riebeckite: $\text{Na}_2(\text{Fe,Mg})_3(\text{Fe,Al})_2\text{Si}_8\text{O}_{22}(\text{OH})_2$

- Glaucophane found only in metamorphic rocks
  - Blueschist facies
- Riebeckite most common in igneous rocks
  - Granites and pegmatites
- Na goes in M4 site
  - In Riebeckite, Fe and Al in M2 site, Fe and Mg in M3 and M1 sites
Expansion and Compression

- Clino-amphiboles are chemically similar to clino-pyroxenes
- Thermal expansion is taken up in the M-O bonds parallel to the c-axis

Oxidation-Dehydroxylation

- Dehydrogenation occurs rapidly at high temperatures in amphiboles containing Fe\(^{2+}\)
- Proceeds by the reaction
  \[
  \text{Fe}^{2+} + \text{OH} = \text{Fe}^{3+} + \text{O}^2^- + \frac{1}{2}\text{H}_2
  \]
- Mossbauer spectra suggest that considerable cation disorder accompanies oxidation