**May 3, 2021**

**Amphiboles**

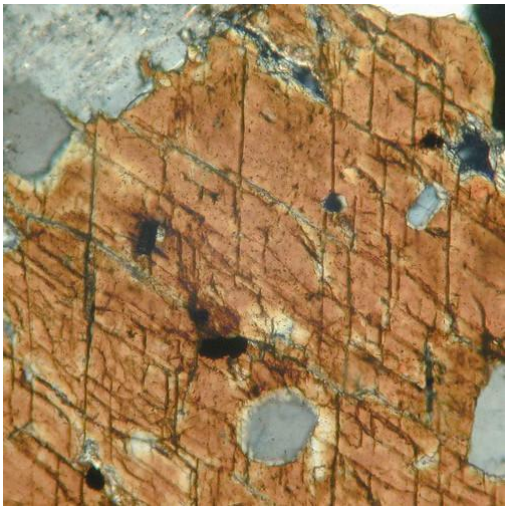

**Figure 1 - Amphibole in Thin Section**



Amphiboles form a large group of chain silicate minerals. Approximately 100 minerals have been identified within the amphibole group. Generally, amphiboles are found in coarse grained plutonic rocks and in a variety of metamorphic rocks formed under conditions ranging from the blueschist to the greenschist and to the granulite facies. Figure 2 illustrates the various facies in metamorphic rocks, the depths, temperatures and pressures in the diagram refer to the conditions under which the minerals were formed.

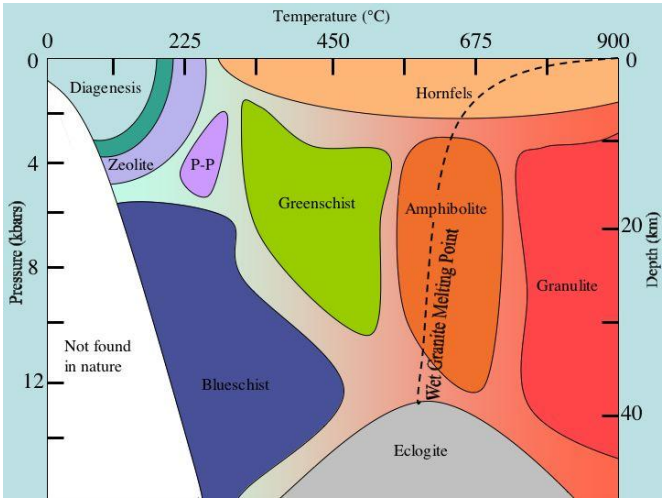


**Figure 2 - Metamorphic Facies**

All minerals in the amphibole group are characterized by perfect cleavage in two directions and a splintery fracture. Colours are typically dark green, brown or black. However, they can also be colorless, white, yellow, green, blue, and even lilac. One distinguishing feature of amphiboles is a parallelogram cross-section when seen in thin section, Figure 1, above, is a good example.

**Chemistry and Structure**

The general chemical formula for amphiboles is as follows:

$$\mathbf{X_{2\text{-}3}Y_5Z_8O_{22}(OH)_2}$$

Where: **X** is Ca, Na, K, Mg

**Y** is Mg, $Fe^{2+}$, $Fe^{3+}$, Al, Ti, Mn, Cr, Li, Zn

and where **Z** is Si, Al

The silica tetrahedra in amphiboles form double chains, as in Figure 3

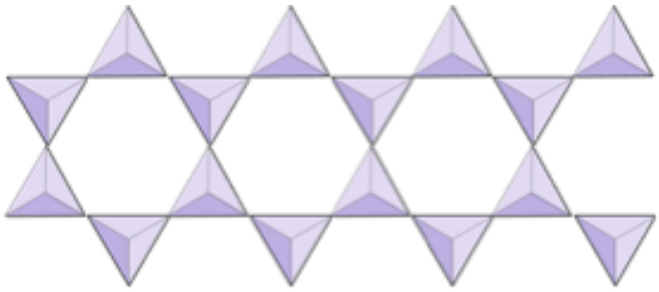

**Figure 3 - Amphibole Silica Tetrahedra**



The other ions (Ca, Na, K, Mg, Mg, $Fe^{2+}$, $Fe^{3+}$, Al, Ti, Mn, Cr, Li, Zn) will be found in the interstices between the tetrahedra. This structure allows for a wide variety of chemical formulae, thus the 100 different minerals in the amphibole group.

**Common Amphibole Minerals**

Common minerals within the amphibole group include: the ferro-actinolite actinolite tremolite series, hornblende, anthophyllite, cummingtonite, arfvedsonite, glaucophane, and riebeckite. Let's look at them separately.

**Ferro-Actinolite Actinolite Tremolite Series**

**Figure 4 - Actinolite**
**Credit: P.Fernandes (Trebaruna),**
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**Figure 5 - Tremolite**
**Credit:** John Sobolewski,
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Ferro-actinolite ($Ca_2Fe^{2+}{}_5(Si_8O_{22})OH_2$), actinolite ($Ca_2(Mg_4Fe)(Si8O_{22})(OH)_2$) and tremolite ($Ca_2(Mg_5)(Si_8O_{22})(OH)_2$) are closely related minerals and form a solid solution series, as in Figure 6**:**

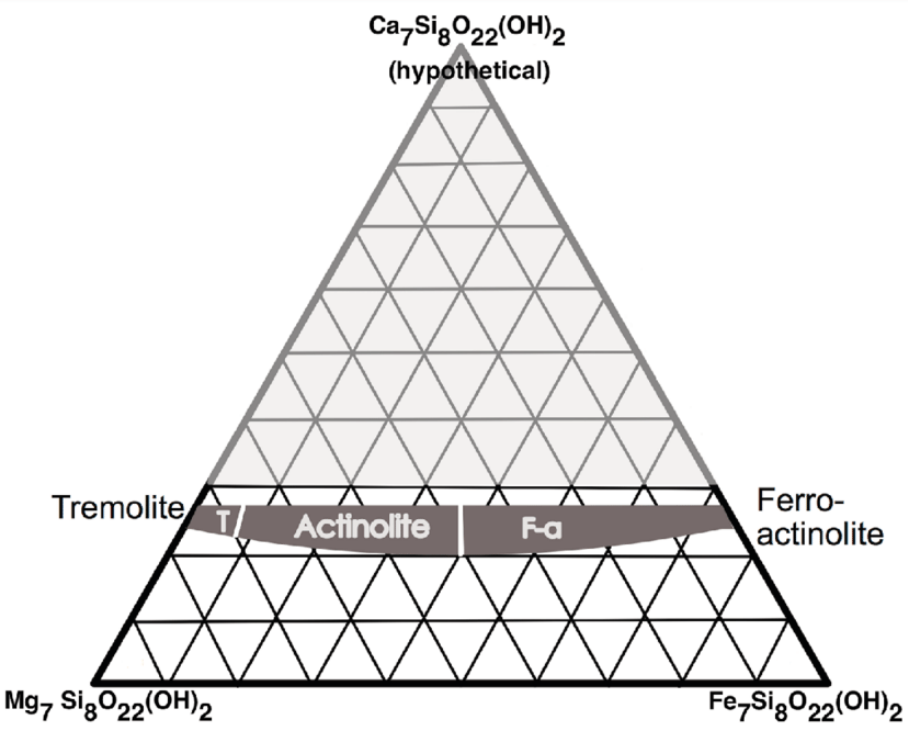


**Figure 6 - Tremolite - Actinolite Series**
**Credit: Gina Lee Barnes, ResearchGate**

Actinolite is typically green in colour, ferro-actinolite ranges from colourless to green to black and tremolite ranges from colourless to grey. Tremolite and actinolite occur in metamorphic rocks, either metamorphosed carbonate rocks or metamorphosed ultramafic rocks. Actinolite is the diagnostic mineral of the greenschist metamorphic facies. Nephrite, a type of jade, is a form of tremolite-actinolite.

## Hornblende

**Figure 7 - Hornblende**

**Credit:** Creator:Robert Lavinsky, Creative Commons Attribution-Share Alike 3.0 Unported

Hornblendes are another series that vary from magnesio-hornblende, $Ca_2(Mg_4Al)(AlSi_7O_{22})(OH)_2$, to pargasite, $NaCa_2(Mg_4Al)(Al_2Si_6O_{22})(OH)_2$. Hornblende varieties tend to be black but also occur in various shades of green. It is one of the most common minerals in regionally metamorphosed rocks and is also common in granites and intermediate plutonic rocks.

## Anthophyllite

**Figure 8 - Anthophyllite**

**Credit:** Ra'ike, GNU Free Documentation License

Anthophyllite, $Mg_2(Mg_5)(Si_8O_{22})(OH)_2$, varies in colour from white to brown and green and is found in metamorphic rocks such as gneisses and anthophyllite-talc schists.

## Cummingtonite

**Figure 9 - Cummingtonite, Dannemora Mine, Uppsala, Sweden**

**Credit:** Hannes Osterhammer, Creative Commons Attribution-Share Alike 3.0 Unported

Cummingtonite, $Mg_2(Mg_5)(Si_8O_{22})(OH)_2$ occurs as light brown to green aggregates of fibrous crystals. It is found in amphibolites, which are regionally metamorphosed mafic igneous rocks. Cummingtonite is also found in igneous rocks such as dacite.

## Arfvedsonite

**Figure 10 - Arfvedsonite**

**Credit:** Leonardo Cianchi, Public Domain

Arfvedsonite, $Na_3(Fe,Mg)_4FeSi_8O^{22}(OH)_2$, is another dark coloured amphibole ranging from black to green. It is characteristic of alkaline plutonic rocks and such as nepheline-syenite.

## Glaucophane and Riebeckite

**Figure 11 - Glaucophane**

**Credit:** Erik Vercammen,
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**Figure 12 - Crocidolite Riebeckite**

**Credit:** Siim Sepp (Sandatlas)
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Glaucophane, $Na_2(Mg_3Al_2)(Si8O_{22})(OH)_2$, and riebeckite, $Na_2(Fe^{2+}{}_3Fe^{3+}{}_2)(Si_8O_{22})(OH)_2$ also form an amphibole series. These two minerals are dark green to dark blue to black in colour. Glaucophane occurs in metamorphic rocks associated with folded geosyncline terraines such as amphibolites and greenschists. Riebeckite, on the other hand, occurs in igneous rocks such as granite and syenite. Crocidolite, a kind of asbestos, is a form of riebeckite.

### Standard Caveat

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**In science, the only authority is the evidence.**