

## Mafic Minerals in Igneous Rocks

Mafic Minerals in Igneous Rocks - We'll follow Bowen's Reaction Series

- Olivine (isolated tetrahedral silicate)
- Pyroxenes (single chain silicates)
  - Enstatite (orthopyroxene)
  - Augite (clinopyroxene)
- Amphiboles (double-chain silicates)
  - Hornblende
- Micas (sheet silicates)
  - Biotite
  - Muscovite (OK, it's not mafic, but is much like biotite)

We'll start with Olivine

- Olivine occurs in high temperature, mafic (hi Mg, low Si) igneous rocks
- Commonly the first mineral to crystallize from a basaltic magma
- Olivine also makes up much of the Earth's Mantle (metamorphic rock)
- Formula:  $(\text{Mg, Fe})_2\text{SiO}_4$

- An Isolated Tetrahedral Silicate
- complete solid solution with two end-members:
- $\text{Mg}_2\text{SiO}_4$  Forsterite (Fo) and
- $\text{Fe}_2\text{SiO}_4$  Fayalite (Fa)

Olivine Structure - see Fig. 5.25

[Olivine](#) Structure Movie

Olivine Properties

- Vitreous luster
- Olive-green color
- No good cleavages
- H=6.5 G=3.2
- Optical: high relief, high birefringence

Olivine Xenoliths from the Mantle

Clear, Gem-quality Olivine (Peridot)

Olivine in thin section

Pyroxenes

- Common in mafic and intermediate igneous rocks
- Commonly crystallize from basaltic magma after olivine (Bowen's reaction series)
- Pyroxenes are Single Chain Silicates
- General Formula:  $(\text{Ca}^{2+}, \text{Mg}^{2+}, \text{Fe}^{2+})_2\text{Si}_2\text{O}_6$
- Two kinds:
  - Orthopyroxenes  $(\text{Mg}, \text{Fe})_2\text{Si}_2\text{O}_6$  have perpendicular axes
    - Enstatite
  - Clinopyroxenes  $\text{Ca}(\text{Mg}, \text{Fe})\text{Si}_2\text{O}_6$  have inclined axes
    - Augite and Diopside

Pyroxenes are Single Chain Silicates – See Handout

Movie: [Pyroxene I-beam](#)

[Orthopyroxene](#) movie

[Clinopyroxene](#) movie

HRTEM Image of Pyroxene

Pyroxene Compositions and the Pyroxene Quadrilateral

Diopside  $\text{CaMgSi}_2\text{O}_6$  Hedenbergite  $\text{CaFeSi}_2\text{O}_6$  (clinopyroxenes)

Enstatite  $\text{Mg}_2\text{Si}_2\text{O}_6$  Ferrosilite  $\text{Fe}_2\text{Si}_2\text{O}_6$  (orthopyroxenes)

Pyroxene Properties, General

- Stubby Prisms
- Vitreous luster, translucent
- Two perfect prismatic cleavages at approximately  $90^\circ$  to each other

## Pyroxene Cleavage, Relief and Color

### Orthopyroxene Properties

- Enstatite (orthopyroxene)
- Color gray, bronze, brown
- Colorless in thin section
- High relief
- Low birefringence
- Parallel extinction

### Enstatite

### Clinopyroxene Properties

- Diopside
- Color light green
- Colorless in thin section
- Moderate birefringence, inclined extinction

- Augite
- Dark green to black
- Tan, light brown or green in thin section
- Moderate birefringence, inclined extinction

## Augite

Augite (moderate birefringence, twinning and cleavage)

## Hornblende (Hb)

- is the main amphibole in igneous rocks
- crystallizes after olivine and pyroxenes from mafic magmas, or at lower temperature
- is most common in intermediate composition igneous rocks

## Amphiboles

- General Formula:

- $(\text{Na,K})_{0-1}(\text{Ca,Na,Fe,Mg})_2(\text{Mg,Fe,Al})_5(\text{Si,Al})_8\text{O}_{22}(\text{OH})_2$
- large    medium    small    tetrahedral cations
- Simple Amphibole (Tremolite):
  - $\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$
- Double Chain Silicates (Inosilicates)

### Hydrous (OH-bearing) Minerals

Amphiboles are Double- Chain Silicates - see handout

Amphibole Structure - see handout

View [Tremolite](#) Movie

Igneous Amphiboles

Digression to talk about Asbestos

The term **asbestiform** describes a mineral habit characterized by long, thin, strong, flexible fibers equivalent to hairs or whiskers

Asbestos Minerals - see handout

Amphiboles are chain silicates and are inherently and predictably elongate or fibrous

Acicular to Fibrous Amphiboles

Chrysotile "white" asbestos

- Is a form of serpentine  $\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$ , a sheet silicate
- Sheet silicates are usually flaky, formed of thin flexible sheets, or leaf-like
- **How can a sheet silicate be fibrous?**

Serpentine is a tetrahedral-octahedral (t-o) Sheet Silicate

In normal serpentine, Antigorite, the sheets are wavy or corrugated - see handout

In asbestos serpentine, Chrysotile, the sheets roll to accommodate the misfit - see handout

Serpentine Asbestos, Chrysotile

Most of the asbestos used world-wide is Chrysotile (>95% in U.S.)

Chrysotile is **much less dangerous than amphibole asbestos**, in fact, there is little evidence that chrysotile

poses any health hazard to those who are exposed casually (e.g., in buildings)!!!!

Back to Igneous Amphiboles

## Hornblende Properties

- Black or dark green
- Vitreous luster, translucent
- H=5-6      G=3.0-3.5
- two perfect prismatic cleavages at about 60° and 120° to each other, sometimes "splintery" cleavage
- commonly in prisms with flattened hexagonal cross-sections

## Hornblende's Optical Properties

- Various shades of brown, red-brown, green, blue-green or tan in thin section
- Moderate to strong pleochroism typical
- Moderate birefringence, commonly obscured by its color
- Two good cleavages at ~60° and 120° to each other
- You have to be looking down the prisms to see 2 crossing sets of cleavages, in many sections you will see only one set of parallel cleavages

## Hornblende cleavage, color & pleochroism

Kaersutite (Na,Ti-rich igneous amphibole) - has very strong red-brown pleochroism