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: $(Mg, Fe)_2SiO_4$
• An Isolated Tetrahedral Silicate

• complete solid solution with two end-members:

• Mg$_2$SiO$_4$ Forsterite (Fo) and

• Fe$_2$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 \((\text{Mg,Fe})_2\text{Si}_2\text{O}_6\) have perpendicular axes
    - Enstatite
  - Clinopyroxenes \((\text{Ca,Mg,Fe})\text{Si}_2\text{O}_6\) 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° 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 (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 Mg$_3$Si$_2$O$_5$(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 worldwide 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