Chapter 4: Igneous Rocks

The earth's crust, both the continental and oceanic parts, has been formed by magmas rising towards the surface under the influence of gravity. How do these magmas form from the solid mantle? We will concentrate on the processes leading to melt formation and the diversity of igneous rocks found in the crust. To understand the diversity of rock types we will look at a simple phase diagram for crystallization/melting in the plagioclase feldspar system. Chapter 4 also contains considerable descriptive material about magmatism and igneous rocks that we will not discuss in detail in class. Much of this information will become more familiar in the labs. You should know the common igneous rock types, such as gabbro (basalt), diorite (andesite), granite (rhyolite) and peridotite. You should also be familiar with the common forms of igneous bodies: sills, dikes, batholiths, plutons etc.

Processes and Concepts:

Textural and mineralogical classification of igneous rocks
   Felsic, intermediate, mafic rocks
   Plutonic versus volcanic rocks
   Porphyritic texture

Processes for initiation of melting
   Temperature increase
   Pressure decrease (adiabatic decompression)
   Addition of volatiles

Tectonic settings of melting and magmatic activity
   Mid ocean ridges
   Subduction zones
   Hotspot (mantle plumes)

Importance of partial melting

Crystallization and melting in a simple system (Plagioclase feldspars)
   Perfect equilibrium crystallization/melting
   Perfect fractional crystallization/melting
   Batch (partial) crystallization/melting

Magmatic differentiation
   Bowen's reaction series
   Fractional crystallization
   Magma mixing/assimilation

Crustal accretion through time

First 10-15 minutes needed to finish up silicate groups and nonsilicates.

What is an igneous rock?

An igneous rock is one formed from the cooling of a high temperature silicate melt.

- **high T**: 700-1300°C
- **silicate melt**: SiO₂ weight percent which is on the order of 35-70%
- **cooling**: not necessarily complete crystallization since some Ig rx (obsidian) glassy
- **melt**: magma if underground, lava if above ground
  - essential characteristic is mobility which may occur with as little as 10-15% liquid

How do we classify igneous rocks?

A. Texture

- **extrusives** - fine grained rocks from lava cooling at surface or **pyroclastics**
  - can see process in action (Hawaii, Mt St. Helens ash deposits)
- **aphanitic** - textural term

- **intrusives** - coarse grained inferred to have formed at depth by slow cooling
  - **phaneritic** - textural term
  - how do we know that phaneritic/intrusive rocks represent cooling at depth?
    - > finer grained margins at edge of **plutons**
    - > high T metamorphism affects near pluton and decreasing away

![Diagram of igneous rock formation](image)

- some terms: dike, sill, pluton, batholith

- **porphyritic** - mix of large and small grains (bimodal)
  - **phenocryst** and groundmass
  - inference: change in cooling rate
B. Modal composition

overall clues to composition

*color index* - although color not necessarily diagnostic for individual minerals it does provide some general information on rock type.

- dark *mafic* minerals - olivine, pyroxene, hornblende, biotite, (Ca plag)
- light *felsic* minerals - K feldspar, Q, Na plagioclase

color as general proxy for % of mafic minerals classify as UM, mafic, intermediate, felsic examples from lab (caveats about strict use of color, e.g. obsidian)

**felsic rocks** (feldspar - silica)
- Q,Kspar,Plag,Muscovite (all light colored)

*granite (rhyolite)* - Q,Kspar>Plag, musc,biot,hb

**intermediate rocks**

*diortite (andesite)* - Plag>Kspar hb,bi,pyrox (significantly more mafic)

**mafic rocks** (magnesium + ferrum)
- Ol,Px,Amphibole,Biotite (all dark colored)

*gabbro (basalt)* - Plag, px, ol (typically no Q)

**ultramafic** - Ol,Px, (Gt) -- NB: error in Skinner book with basalt=peridotite

*peridotite (komatiite)* - higher temperatures early in earth history

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**Systematic changes in composition and properties**

From our previous look at the silicate mineral groups, a few relationships between the mineralogy and rock types should be obvious.
1) Links with Si:O ratio and the Si content of magma
- recall that the silica content of mineral groups systematically changes
  - olivines (1:4), pyroxenes (1:3), amphibole (4:11), micas (2:5), Q/Feld (1:2)

2) Other systematic changes in composition and physical properties

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<th>K, Na, Si</th>
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<td>Gabbro</td>
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<th>Ca, Mg, Fe</th>
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3) Bowen's reaction series and the major rock types

<table>
<thead>
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<th>Olivine</th>
<th>Ca-plag</th>
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<td>Pyrox</td>
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- mafic minerals (ol, px) crystallize at higher temperatures
- removal of constituents leads to decrease in these elements (Ca, Mg, Fe)
- consequently others enriched (look later at how this happens)