

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

Lecture 5: Igneous Rocks (Introduction and Classification) Oct. 2, 2006

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: 700-1300C

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

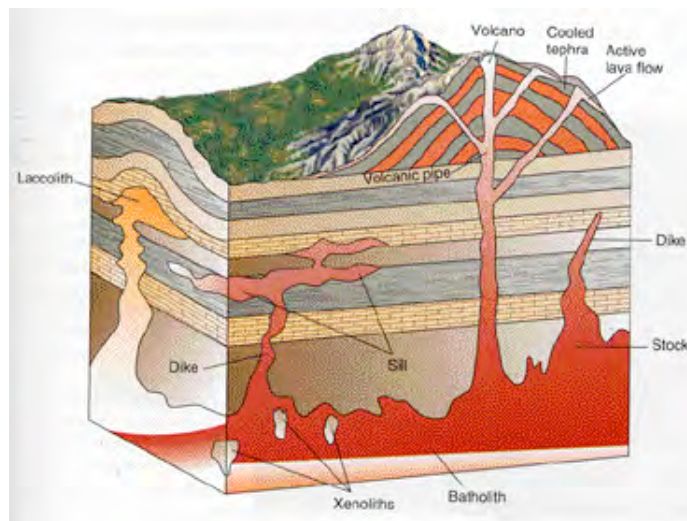
extrusives - fine grained rocks from lava cooling at surface or *pyroclastics*
can see process in action (Hawaii, Mt St. Helens ash deposits)
aphanitic - textural term

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



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

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

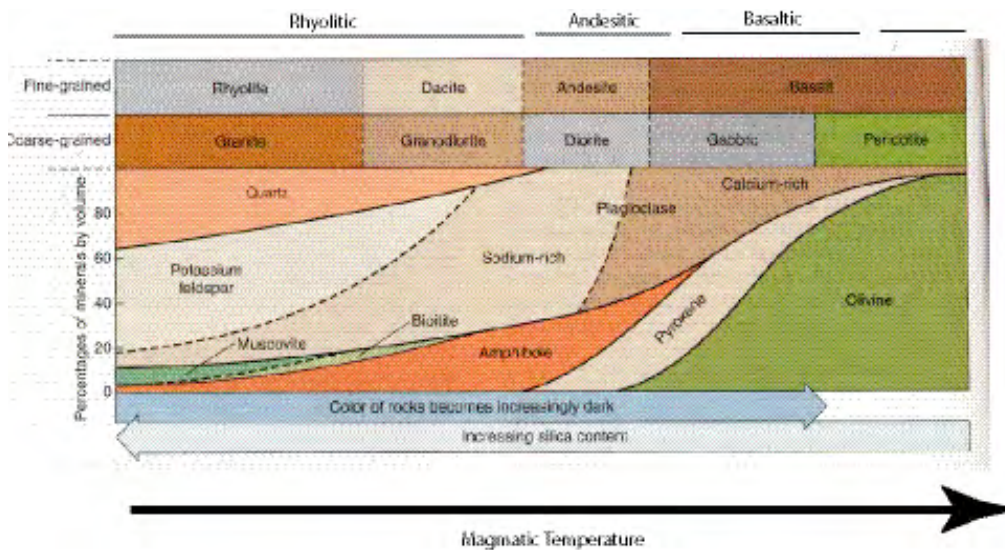
mafic rocks (magnesium + ferrum)

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



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

Granite	K,Na,Si	viscosity high
Diorite		
Gabbro	Ca,Mg,Fe	temperature high

- 3) Bowen's reaction series and the major rock types

Olivine	Ca-plag
Pyrox	/
Amph	/
Biotite	Na-plag
Kspar	
Musc	
Quartz	

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)