Notes: Igneous Rocks

Chapter 3 Notes

Igneous (fire) - rocks formed at very high temperatures, crystallized from a molten silicate melt

A. Origin of Magmas

- T increases with depth -- geothermal gradient = 30°C/km
- rock usually melts at depths of 50 to 250 km

1. Factors affecting melting T

a) Pressure: higher P favours the more compact solid arrangement of atoms so that a higher temperature is required to melt

- therefore most of the earth's interior is solid

ie
- boil at lower T at higher altitude (P less)
- pressure cooker - water hotter than 100^{o}C
- ice skating - water denser than ice so an increase in pressure favours water so skates glide

T= temperature
P= pressure

b) Dissolved volatiles (dissolved water & various gases) lowers the melting T of silicate minerals

- increased water pressure means more water in the melt and lowers melting T

* generally: more volatiles the lower the melting T

c) When 2 or more different minerals are mixed together, the presence of each lowers the melting T of the other (ie salt on ice causes ice to melt below 0^{o}C) See figure 3.3 and Box 3.1 pg 40

- more minerals present -- complex relationship
- rocks melt in stages, different minerals melt at diff T
- a magma may be thick with unmelted suspended crystals

2. Other factors that produce heat locally (besides depth)

a) radioactive decay of radioactive elements ← this is why ⊕ has not completely cooled inside.
b) friction between plates as they rub together
c) movement of existing magma may melt rocks they come in contact with.

B Crystallization of Magmas

- magma usually flows upward to lower T - crystallizes
- details of rock vary with composition of melt and conditions under which it crystallizes

* sequence of crystallization - different minerals crystallize at different T and time.

- most magma originates in upper mantle so have similar comp. mostly silica (SiO_2), lesser Al, Fe, Mg, Ca, Na, K, etc - so similar crystallization sequence

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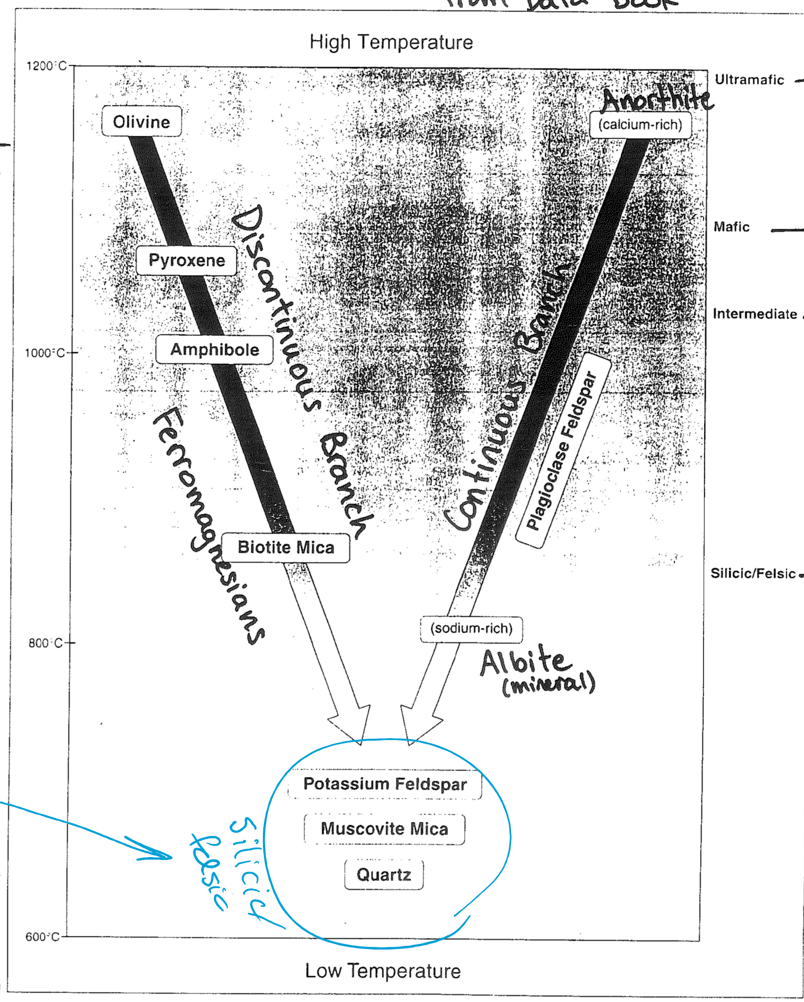
BOWEN'S REACTION SERIES

from Data Book

Mafic End
- dark
- dense
- high melting T
- less viscous = thinner



Felsic End
- light
- less dense
- lower melting T
- more viscous = thicker (unless residual)

	Extrusive (volcanic) Finegrained (aphanitic)	Intrusive (plutonic) Course grained (phaneritic)
Ultramafic	none	peridotite
Mafic	Basalt	Gabbro
Intermediate	Andesite	Diorite
Silicic/Felsic	Rhyolite	Granite

Pegmatite (huge crystals formed in veins of residual magma)

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* **Bowen's reaction series** (see Figure 3.4)

- minerals that crystallize at high T are low in silica so magma remaining is relatively high in SiO_2 compared to its starting composition

Two branches:

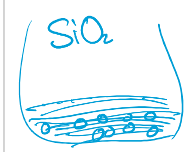
1. Continuous reaction series (plagioclase branch) – depends what is in the magma
   - plagioclase is a solid solution between calcium rich and sodium rich
   - Ca -rich crystallizes first then as magma cools the crystals react with melt and more Na enters the crystal
   - if happens too fast, end up with layers
2. Discontinuous reaction series (ferromagnesian)
   - simplest structure – olivine forms first leaving a silica rich melt
   - olivine out of balance chemically with melt so reacts with melt to form pyroxene (which contains more silica than olivine)
   - more complex – if enough silica available then all of olivine changes to pyroxene and when pyroxene is out of balance, reacts with melt, forms amphibole (contains more silica), etc
   - lastly, biotite mica forms. Note: if biotite mica is in a rock then there will be no olivine, etc (unless olivine gets separated from reacting)

- At the end, at lowest T, silica rich melt crystalizes to form k-feldspar, muscovite, quartz
- more mafic magma (rich in Mg and Fe) is completely crystallized before it makes it through the sequence
- very silicic magma reach final stages and have eliminated olivine, pyroxene, calcic plag -- gives felsic rocks (rich in feldspar & quartz(silica))

C. Modifying Melt Composition

- not usually a closed system

a) fractional crystallization ← gravitational settling – early formed crystals settle out of magma and can't react with it



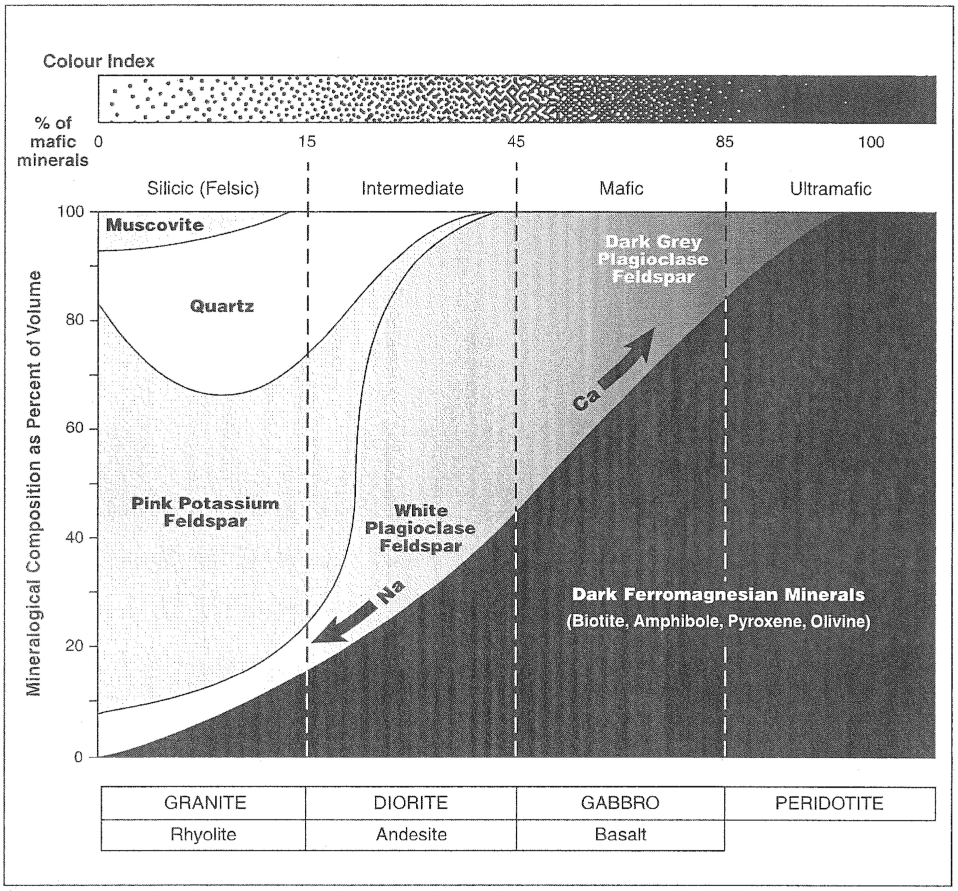
b) assimilation – magma incorporates pieces of rock from around it (usually hotter mafic assimilates more silicic rocks that melt a lower T's causing melt to become more silicic as a result and be able to move further down the crystalization sequence)

c) Magma mixing – two melts combine to produce a hybrid

D. Textures of Igneous Rocks

1. grain size
   - slow cooling rate gives atoms more time to move through melt and form large crystals
   - extremely fast cooling = no crystals = glassy
   - some fast cooling traps bubbles = vesicles (frothy)

Percentage of Minerals in Igneous Rocks



Example: An intrusive rock with
28% Quartz
7% Ferromagnesians
is called ___?___
has ___% Pink Feldspar

use a paper to mark then measure each % to get a list

2. two-stage cooling rate - porphyry
   - initial slow cooling -- large crystals form called phenocrysts
   - followed by rapid cooling -- rest small crystals called groundmass
3. grain size also affected by melt composition
   a. silicic melts are more viscous (thick) so atoms move less freely so require more time for crystals to grow -- most volcanic glass is silicic
   b. late stage residual melts have lots of dissolved volatiles so are quite fluid -- very large crystals can form -- pegmatite (some crystals can be several meters!)

felsic

E. Classification of Igneous Rocks

1. Plutonic - crystallized at depth, larger crystals, phaneritic texture (slower cooling)
2. Volcanic - crystallized at or near surface, fine-grained or glassy, aphanitic texture (porphyritic are also considered volcanic if have fine groundmass)

Intrusive (inside ⊕)

Extrusive (exited the ⊕)

* further subdivisions are based on composition - see Figure 3.13

- most plutonic rocks have volcanic compositional equivalents (granite + rhyolite)
- volcanic harder to identify since smaller crystals (can't see)
- obsidian (usually rhyolitic (felsic) in comp), pumice, tuff (ash consolidated) are names that lack compositional implications.

F. Intrusive Rock Structures

- Country Rock (wall rock) - surrounding rock that magma intrudes into
- Lava - magma at earth's surface (Chapter 4)
- Intrusive or plutonic - ig. rocks formed below earth's surface

* factors
- density of magma (more dense = less buoyant)
- viscosity - how easily will flow through cracks
- dissolved volatiles in it may cause unusual pressure, forcing it somewhere it couldn't normally have gone
- strength of wall rock, fractures, weakness between dissimilar rock types

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* forms
  - pluton - any igneous rock that cools below surface
  - concordant - contacts parallel to layers
  - discordant - cuts across country rock structure
  - Volcanic neck - cylindrical plutons, elongated in one dimension, remains of volcano feeder tube
  - dike - discordant structure
  - sill - concordant structure
  - laccolith - concordant, cause rocks above to rise or dome up (formed from silicic magmas)
  - lopolith - floors concave up (mafic magma cause floor to sag due to density)
  - stock - discordant, less than 100km^2 exposed
  - batholith - discordant, larger than stock exposed
  - chilled margins - hot magma cools more quickly at edges in contact with cooler country rock
  - contact metamophism - hot magma heats the country rock it comes in contact with causing it to metamorph
  - xenolith - alien bits of rock broken from country rock and caught up in molten mass
  - parallel alignment of crystals near edge indicates flow direction

G. Batholiths and Origin of Granite

What is the source of large volumes of granitic magma that make batholiths?

1. upper mantle (where most melt originates) is ultra mafic, you'd need to use a huge volume of the mantle to get a granitic melt to create the batholiths we have
2. or use the ultramafic magma and have fractional crystallization take place (still must start with huge volumes of melt)
3. involve some crust in the melt (enough heat to melt it?)

No single theory accounts for all the granitic plutons we have.

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Name: ________________
Partner(s): ____________

Geology 12
Igneous Rock Lab

Data Table

Complete the following table using the explanations for each column found on the next page.

#	Composition	Texture	Cooling Rate	Where Formed	Name
1					
2					
3					
4					
5					
6					
7					
8					

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Column Explanations:

Composition: Igneous rocks can be *felsic* (composed mostly of feldspars and silicates making them light coloured) or *mafic* (composed of more magnesium and iron along with the silicates making them dark coloured) or *intermediate*. If the crystals are large enough that individual colours can be distinguished then you are seeing the different minerals. Generally white is plagioclase feldspar, pink is potassium feldspar, glassy grey is quartz and dark (black or green) is ferromagnesians. Identify these minerals if you can and record in the table. Otherwise just label the composition as felsic, mafic or intermediate.

Texture: If you can see individual colours we call this *coarse-grained* or large crystals. If you can't see speckles, and the rock looks to be all one colour, it is probably *fine-grained* or small crystals. Rocks can also be *glassy* (no crystals), *vesicular* (frothy, trapped bubbles) or *porphyritic* (large crystals surrounded by small ones). Sometimes very large crystals (1cm or more) can form and this texture is called a *pegmatite*.

Cooling Rate: The *slower* a rock cools (i.e. the longer it takes to solidify) the more time the molecules of a mineral have to join together forming larger crystals. The *faster* a rock cools the smaller the crystals will be. Sometimes lava/magma is so thick *or* will cool so fast that no crystals will form at all (glassy texture.) A vesicular texture forms when lava cools so quickly that gas is trapped so there are holes throughout the rock.

Where Formed: Generally *extrusive* (volcanic) rocks that cool on or near the surface of Earth cool quickest. Rocks that formed *intrusively* (plutonicly) inside the Earth are the ones that have had time to form larger crystals. Sometimes a rock will begin to form slowly intrusively and then the magma is suddenly brought to the surface (volcano erupts) and the remaining magma cools quickly extrusively yielding a porphyritic texture.

Name: Use the lab manual (to be left in the classroom) to help you determine the name of each rock.

Summary Questions:

1. Write a paragraph summarizing how texture is related to a) cooling rate b) magma viscosity and c) where a rock forms. Also include examples for each situation.
2. Considering the fact that when a *geode* first forms it can be glassy on the outside but have well-formed, large quartz crystals (showing the prismatic crystal shape) on the inside, how do you think this type of geode forms?
3. Most volcanic glasses (obsidians) are felsic in composition. Fractional crystallization causing compositional layering is more often observed in mafic plutons. What property of magma may have a bearing on both of these observations? Explain.
4. A *xenolith* usually is a dark (mafic) rock surrounded by a light (felsic) igneous rock. Why is this more common than the reverse? Explain.

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