Lesson Four: Igneous Rocks

Background Reading: Igneous Rocks

Igneous Rocks: Cool (crystallize) from a magma

There are two main types of Igneous Rocks:

A. Intrusive or Plutonic
B. Extrusive or Volcanic

Igneous Rocks are defined by Texture and Composition

I. Igneous Textures:

Crystal Size
Crystal size is determined by the rate of cooling.
Slow cooling results in larger crystals.
Fast cooling results in smaller crystals.

Glass consists of unordered ions (and is therefore not crystalline). This can be the result of either extremely fast cooling or from a high silica content that prevents ions from bonding to form a crystalline structure.

Aphanitic (fine-grained texture) – from fast cooling. Found in volcanic rocks.
Phaneritic (coarse-grained texture) –from slow cooling. Found in plutonic rocks
Porphyritic: Larger crystals embedded in a matrix of smaller crystals. The larger crystals are called **phenocrysts**.
The term porphyritic is often used to describe volcanic rocks. However it is sometimes used to describe plutonic rocks if much larger crystals are embedded within a coarse-grained rock).

II. Igneous Composition:

Basic Subdivision of **Felsic** and **Mafic**

Felsic: rocks that include substantial amounts of feldspar (fel) and quartz (si). Felsic rocks have a composition close to granite. Felsic rocks have abundant quartz, potassium and sodium feldspars (Na-plagioclase), and muscovite, with lesser amounts of biotite, and amphibole.

Mafic: rocks include substantial amounts of Iron and Magnesium bearing minerals (MgFe=mafic). Mafic rocks have a mineral assemblage close to basalt. Mafic rocks include Calcium-rich feldspar (Ca-plagioclase), pyroxene, amphibole, and olivine (but little or no quartz).

III. Generation of Magma

Rock near their melting points will melt if **a) the pressure drops,** or if **b) volatiles** (including water) are added.
Water acts like salt does to ice. That is, it lowers the melting temperature of the material. Water added from plate subduction lowers the mantle rock melting temperature. This causes the mantle rock to melt, which then rises and heats crustal rocks to their melting point.

IV. Fractional Crystallization – the process of progressive crystal formation.
This results in progressive extraction of iron, magnesium, calcium and other elements from a magma, so the remaining magma becomes more felsic (richer in silica, sodium, and potassium).

How magmas change during cooling. Bowen's reaction series shows the crystallization temperatures for minerals.
Bowen's Reaction Series explains the sequence of crystallization from a magma, and it provides a mechanism to explain how the composition of magma changes during cooling.

Bowen's Reaction Series
A list of minerals arranged in the order of the temperature at which they crystallize (or melt).

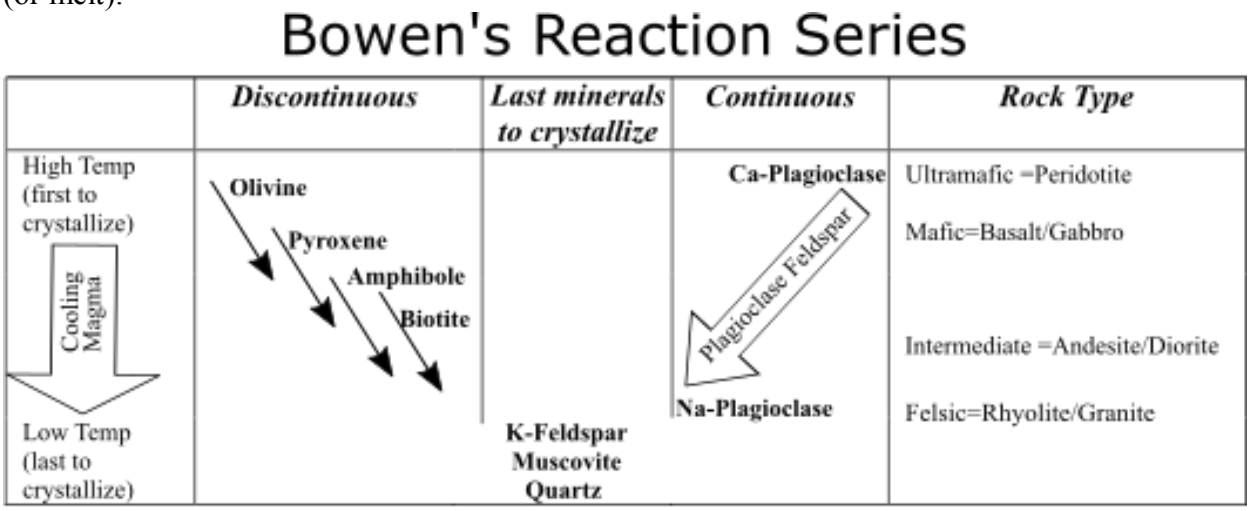


Figure: Bazard and Wright 2017

Mafic (dark) minerals crystallize at higher temperatures than felsic (light) minerals.

If cooling is slow and required elements present, early formed minerals will react with the remaining liquid to form new minerals (lower on the list).

The final rock composition depends on the initial composition of the magma.
Example: if a mafic magma cools, then olivine, pyroxene, Ca-plagioclase, and amphibole will crystallize and all the magma will be gone. If a felsic magma cools, then there may not be enough iron and magnesium to form olivine or early-formed olivine will react to eventually form amphibole.

Who cares?
This tells us that we will expect to find dark minerals together and light minerals together (grouping of minerals higher and lower on the list).
This explains how we can get a variety of rock types from the same initial magma (crystal settling or magma separation).
This explains how we can get a less mafic magma (more felsic) by a process of mafic rocks forming and enriching the magma in more felsic material.

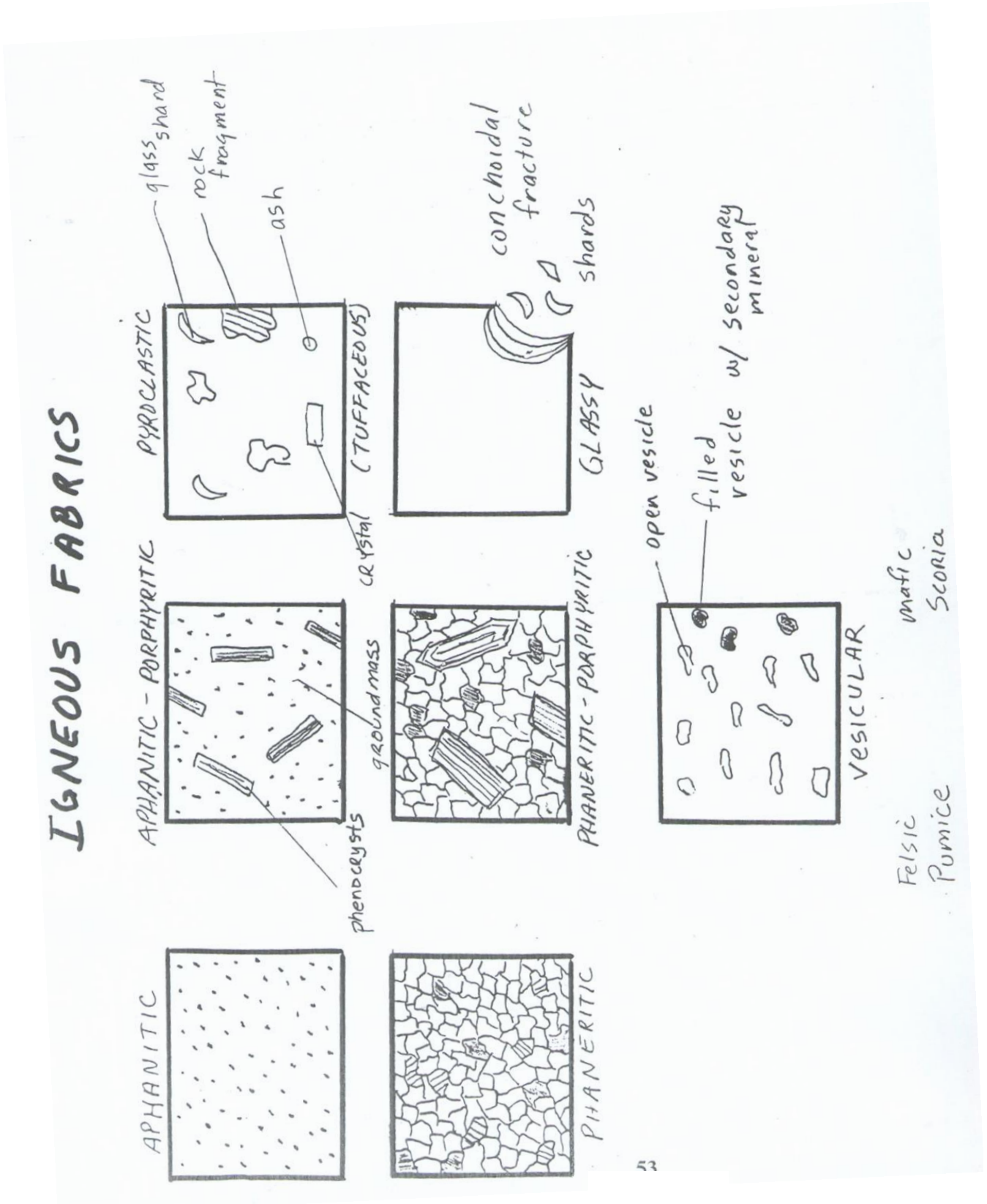
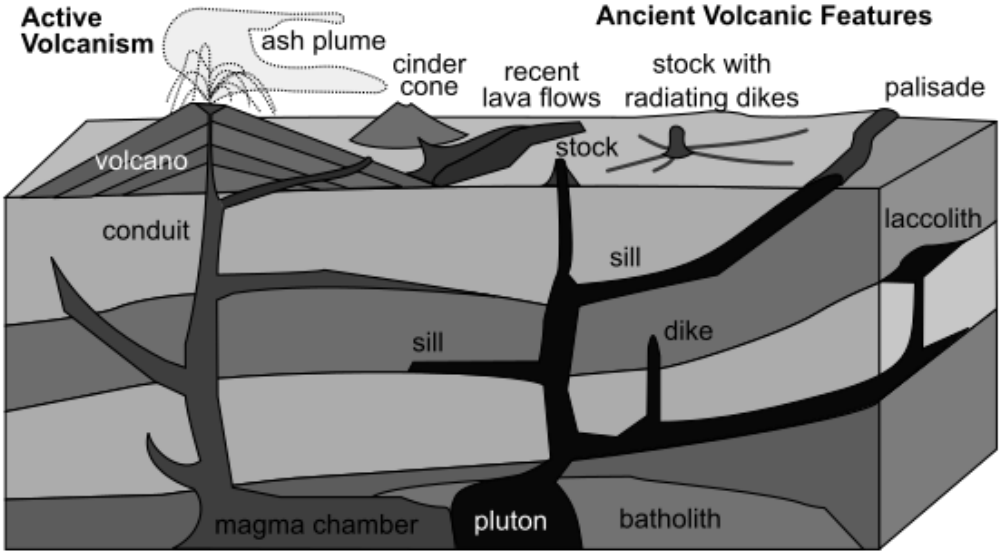


Figure Credit: Bob McPherson, used by permission

Clasification of major groups of igneous rocks based on mineral composition and textures

Chemical Composition	***Felsic (silicic)***	***Intermediate***	***Mafic***	***Ultramafic***
Dominant Minerals	Quartz Potassium (K) – Feldspar Sodium (Na) - Plagioclase	Amphibole Sodium (Na) – Plagioclase Calcium (Ca) - Plagioclase	Pyroxene Calcium (Ca) - Plagioclase	Olivine Pyroxene
Accessory Minerals	Muscovite Biotite Amphibole	Pyroxene Biotite	Amphibole Olivine	Calcium (Ca) - Plagioclase
Color/Shade	Lighter color → Intermediate Color (salt and pepper) → Dark Color			
Volcanic (Extrusive) Aphanitic or Aphanitic-porphyritic textures	**Rhyolite**	**Andesite**	**Basalt**	Uncommon
Plutonic (Intrusive) Phaneritic or Phaneritic-Porphyritic textures	**Granite**	**Diorite**	**Gabbro**	**Peridotite**
Glassy Textures	Vesicular Glass = **Pumice** (light) or **Scoria** (dark). Compact Glass = **Obsidian**			
Pyroclastic (Fragmental) Textures	Pyroclastic Volcanic Rocks: Ashy with pumice fragments = **Tuff**. Large Angular Fragments = **Volcanic Breccia**			

Worksheet 4.1: Igneous Rocks



1. Use the diagram above to identify features that are intrusive and extrusive. Fill our the chart below with the names of the features labeled in the diagram.

Intrusive Features	**Extrusive Features**

2. Indify the specific locations (labeled on the diagram) where large, medium and small crystals would form.

Largest Crystals	**Medium Crystals**	**Small Crystals**

3. (Multiple Choice) How do most intrusive igneous rocks reach the surface of the earth for geologist to study?
    a. They are erupted from volcanoes
    b. They are mined
    c. Millions of years of uplift and erosion of overlying material expose them at the surface
    d. They are found almost entirely in the deepest river canyons such as the inner gorge of the Grand Canyon where rivers have cut into the deep crust

4. Use the Bowen's Reaction Series diagram on pg. 32 to Identify each of the following minerals as either mafic (M), felsic (F), or Intermediate (I).

Olivine_____
Quartz_____
Potassium-Rich Feldspar ____
Pyroxene _____
Biotite _____
Muscovite _____
Calcium-Rich Feldspar _____
Amphibole _____
Sodium-Rich Feldspar _____

5. Use the Igneous Rock Identification Chart on pg. 34 to determine the appropriate name for each of the following rock descriptions.

Description	**Rock Name**
A dark colored rock found in a lava flow	
An intermediate, phaneritic rock	
The volcanic equivalent of granite	
A rock that contains visible crystals of quartz, potassium feldspar, sodium plagioclase feldspar and small amounts of biotite and amphibole	
A rock that contains some visible crystals, surrounded by a dull colored, fine grained groundmass. The abundant visible crystals (phenocrysts) can be identified as amphibole.	

6. Consider a sample of basalt with large olivine crystals (phenocrysts).
    a. Explain how this association (basalt and larger olivine crystals) formed.

    b. Explain if this association is consistent (or inconsistent) with Bowen's Reaction Series.

7. Consider a solid piece of Diorite that is made of the minerals Plagioclase Feldspar, Amphibole, and small amounts of quartz, muscovite, and biotite. If you slowly heat this rock, what are the first minerals that would melt, according to Bowen's Reaction Series?

8. The Fantastic Lava Beds in Lassen National Park are basaltic andesite to andesite in composition but contain visible crystals of quartz. Is this association consistent or inconsistent with Bowen's Reaction Series? Explain.

9. Some of the granite in the Pikes Peak Batholith in Colorado contains a small amount of a variety of olivine. Is this association consistent or inconsistent with Bowen's Reaction Series? Explain.

Lab 4.2: Igneous Knowns

Complete the following chart. Determining the minerals for aphanitic rocks may not be possible. In those cases either state none observed (NO) or list the color and the nature of any phenocrysts.

	Color (light, med., dark)	**Minerals Observed** (list only those that can actually be observed)	**Composition** (Mafic, Intermediate, Felsic)	**General Texture** (Phaneritic, Aphanitic, Porphyritic-Phaneritic, Porphyritic-Aphanitic)	**Special VolcanicTextures** (Glassy, Vesicular, Pyroclastic)
Specimen A (Granite)					
Specimen B (Rhyolite)					
Specimen C (Diorite)					
Specimen D (Andesite)					
Specimen E (Gabbro)					
Specimen F (Basalt)					
Specimen G (Peridotite)					
Specimen H (Obsidian)					
Specimen I (Pumice)					
Specimen J (Scoria)					
Specimen K (Tuff and/or Volcanic Breccia)					

Name:_____ Date:_____

Lab 4.3: Igneous Rock Unknowns

Determine the igneous rock properties for each of the unknowns. Only list minerals you actually observed

Specimen	**Color** (light, med., dark	**Minerals Observed** (list only those that can actually be observed)	**Composition** (Mafic, Intermediate, Felsic)	**General Texture** (Phaneritic, Aphanitic, Porphyritic-Phaneritic, Porphyritic-Aphanitic)	**Special VolcanicTextures** (Glassy, Vesicular, Pyroclastic)	**Rock Name**
A						
B						
C						
D						
E						
F						
G						

Specimen	**Color** (light, med., dark	**Minerals Observed** (list only those that can actually be observed)	**Composition** (Mafic, Intermediate, Felsic)	**General Texture** (Phaneritic, Aphanitic, Porphyritic-Phaneritic, Porphyritic-Aphanitic)	**Special VolcanicTextures** (Glassy, Vesicular, Pyroclastic)	**Rock Name**
H						
I						
J						
K						
L						
M						
N						

Name:_____ Date:_____

Igneous Rock Lab Quiz – Review Sheet

You are responsible for identifying the following rocks

Rhyolite
Andesite
Basalt
Granite
Diorite
Gabbro
Peridotite
Obsidian
Pumice
Scoria
Volcanic Breccia
Volcanic Tuff

You are responsible for identifying distinctive minerals in intrusive igneous rocks and phenocrysts in extrusive igneous rocks: Quartz, K-feldspar, Muscovite, Biotite, Na-Plagioclase, Ca-Plagioclase, Amphibole, Pyroxene, Olivine, and possibly one of the more common non-silicate minerals (calcite, pyrite)

You are responsible for identifying and explaining the formation of the following textures

Phaneritic, Phaneritic-Porphyritic
Aphanitic, Aphanitic-Porphyritic
Glassy
Pyroclastic
Vesicular

Sample Questions

- Describe (and name) one of the minerals in this rock that can be used to justify the rock name., and List the rock name
- Describe (and name) one of the **visible** minerals in this rock that can be used to justify the rock name.
- List the texture of this igneous texture **and** describe how it formed
- Both samples provided are classified as the same specific igneous rock type. Identify this rock

Notes: You can use one side of 8.5x11 paper – typed or hand written. **You are not allowed to use the lab sheets and table from this packet.**

NOT ALLOWED:

- The lab tables unless you type or write it onto a new sheet.
- Photocopies or scans of the lab, book, or another student's work.
- Photographs of minerals
- Consulting experts or other students during the exam

Photos of igneous rocks are available on the Canvas course page and at the following URL: http://tinyurl.com/g1igneous