Igneous Rocks
-Solids from Melts
Chapter 5

Does not contain complete lecture notes. To be used to help organize lecture notes and home/test studies.

Characteristics of magma

- **Igneous rocks form as molten rock cools and solidifies**
- **General Characteristic of magma**
  - **Parent material of igneous rocks**
  - **Forms from partial melting of rocks inside the Earth**
  - **Magma that reaches the surface is called lava**

Characteristics of magma

- **General Characteristic of magma**
  - **Rocks formed from lava at the surface are classified as extrusive, or volcanic rocks**
  - **Rocks formed from magma that crystallizes at depth are termed intrusive, or plutonic rocks**

Characteristics of magma

- **The nature of magma**
  - **Consists of three components:**
    - **A liquid portion, called melt, that is composed of mobile ions**
    - **Solids, if any, are silicate minerals that have already crystallized from the melt**
    - **Volatiles, which are gases dissolved in the melt, including water vapor (H_2O), carbon dioxide (CO_2), and sulfur dioxide (SO_2)**

Characteristics of magma

- **Crystallization of magma**
  - **Cooling of magma results in the systematic arrangement of ions into orderly patterns**
  - **The silicate minerals resulting from crystallization form in a predictable order**

Characteristics of magma

- **Crystallization of magma**
  - **Texture in igneous rocks is determined by the size and arrangement of mineral grains**
  - **Igneous rocks are typically classified by**
    - **Texture**
    - **Mineral composition**

Igneous textures

- Texture is used to describe the overall appearance of a rock based on the size, shape, and arrangement of interlocking minerals
- Factors affecting crystal size
  - Rate of cooling
    - Slow rate promotes the growth of fewer but larger crystals

Igneous textures

- Factors affecting crystal size
  - Rate of cooling
    - Fast rate forms many small crystals
    - Very fast rate forms glass
  - Amount of silica (SiO_2) present
  - Amount of dissolved gases

Igneous textures

- Six (6) Types of igneous textures
  - Aphanitic (fine-grained, volcanic) texture
    - Rapid rate of cooling of lava or magma
    - Microscopic crystals
    - May contain vesicles (holes from gas bubbles)
  - Phaneritic (coarse-grained, plutonic) texture
    - Slow cooling
    - Crystals can be identified without a microscope

Igneous textures

- Types of igneous textures cont'd
  - Porphyritic texture
    - Minerals form at different temperatures as well as differing rates
    - Large crystals, called phenocrysts, are embedded in a matrix of smaller crystals, called the groundmass
  - Glassy texture
    - Very rapid cooling of molten rock
    - Resulting rock is called obsidian

Igneous textures

- Types of igneous textures cont'd
  - Pyroclastic texture
    - Various fragments ejected during a violent volcanic eruption
    - Textures often appear to more similar to sedimentary rocks
  - Pegmatitic texture
    - Exceptionally coarse grained
    - Form in late stages of crystallization of granitic magmas

Igneous Compositions

- Igneous rocks are composed primarily of silicate minerals
  - Dark (or ferromagnesian) silicates
    - Olivine
    - Pyroxene
    - Amphibole
    - Biotite mica

Igneous Compositions

- **Igneous rocks are composed primarily of silicate minerals**
  - **Light (or non-ferromagnesian) silicates**
    - **Quartz**
    - **Muscovite mica**
    - **Feldspars**

Igneous compositions

- **Granitic versus basaltic compositions**
  - **Granitic composition**
    - **Composed of light-colored silicates**
    - **Designated as being felsic (*fel*dspar and *sil*ica) in composition**
    - **Contains high amounts of silica (SiO_2)**
    - **Major constituents of continental crust**

Igneous compositions

- **Granitic versus basaltic compositions**
  - **Basaltic composition**
    - **Composed of dark silicates and calcium-rich feldspar**
    - **Designated as being mafic (*ma*gnesium and *f*errum, for iron) in composition**
    - **More dense than granitic rocks**
    - **Comprise the ocean floor as well as many volcanic islands**

Igneous compositions

- Other compositional groups
  - Intermediate (or andesitic) composition
    - Contain at least 25 percent dark silicate minerals
    - Associated with explosive volcanic activity
  - Ultramafic composition
    - Rare composition that is high in magnesium and iron
    - Composed entirely of ferromagnesian silicates

Igneous compositions

- Silica content as an indicator of composition
  - Silica content in crustal rocks exhibits a considerable range
    - A low of 45 percent in ultramafic rocks
    - Over 70 percent in felsic rocks

Igneous compositions

- Silica content influences a magma's behavior
  - Granitic magma
    - High silica content
    - Extremely viscous
    - Liquid exists at temperatures as low as 700°C

Igneous compositions

- Silica content influences a magma's behavior
  - Basaltic magma
    - Much lower silica content
    - Fluid-like behavior
    - Crystallizes at higher temperatures

Igneous compositions

- Naming igneous rocks – granitic (felsic) rocks
  - Granite
    - Phaneritic
    - Over 25 percent quartz, about 65 percent or more feldspar
    - May exhibit a porphyritic texture
    - Very abundant as it is often associated with mountain building
    - The term granite covers a wide range of mineral compositions

Igneous compositions

- Naming igneous rocks – granitic (felsic) rocks
  - Rhyolite
    - Extrusive equivalent of granite
    - May contain glass fragments and vesicles
    - Aphanitic texture
    - Less common and less voluminous than granite

Igneous compositions

- **Naming igneous rocks – granitic (felsic) rocks**
  - **Obsidian**
    - **Dark colored**
    - **Glassy texture**
  - **Pumice**
    - **Volcanic**
    - **Glassy texture**
    - **Frothy appearance with numerous voids**

Igneous compositions

- **Naming igneous rocks – intermediate rocks**
  - **Andesite**
    - **Volcanic origin**
    - **Aphanitic texture**
    - **Often resembles rhyolite**

Igneous compositions

- **Naming igneous rocks – intermediate rocks**
  - **Diorite**
    - **Plutonic equivalent of andesite**
    - **Coarse grained**
    - **Intrusive**
    - **Composed mainly of intermediate feldspar and amphibole**

Igneous compositions

- **Naming igneous rocks – basaltic (mafic) rocks**
  - **Basalt**
    - **Volcanic origin**
    - **Aphanitic texture**
    - **Composed mainly of pyroxene and calcium-rich plagioclase feldspar**
    - **Most common extrusive igneous rock**

Igneous compositions

- **Naming igneous rocks – basaltic (mafic) rocks**
  - **Gabbro**
    - **Intrusive equivalent of basalt**
    - **Phaneritic texture consisting of pyroxene and calcium-rich plagioclase**
    - **Makes up a significant percentage of the oceanic crust**

Igneous compositions

- **Naming igneous rocks – pyroclastic rocks**
  - **Composed of fragments ejected during a volcanic eruption**
  - **Varieties**
    - **Tuff – ash-sized fragments**
    - **Volcanic breccia – particles larger than ash**

Origin of Magma

- Highly debated topic
- Generating magma from solid rock
  - Produced from partial melting of rocks in the crust and upper mantle
  - Role of heat
    - Temperature increases within Earth's upper crust (called the geothermal gradient) average between 20°C to 30°C per kilometer

Origin of Magma

- Role of heat
  - Rocks in the lower crust and upper mantle are near their melting points
  - Any additional heat (from rocks descending into the mantle or rising heat from the mantle) may induce melting

Origin of Magma

- Role of pressure
  - An increase in confining pressure causes an increase in a rock's melting temperature or conversely, reducing the pressure lowers the melting temperature
  - When confining pressures drop, decompression melting occurs

Origin of Magma

- **Role of volatiles**
  - **Volatiles (primarily water) cause rocks to melt at lower temperatures**
  - **This is particularly important where oceanic lithosphere descends into the mantle**

Evolution of magmas

- **A single volcano may extrude lavas exhibiting very different compositions**
- **Bowen's reaction series and the composition of igneous rocks**
  - **N.L. Bowen demonstrated that as a magma cools, minerals crystallize in a systematic fashion based on their melting points**

Evolution of magmas

- **Bowen's reaction series**
  - **During crystallization, the composition of the liquid portion of the magma continually changes**
    - **Composition changes due to removal of elements by earlier-forming minerals**
    - **The silica component of the melt becomes enriched as crystallization proceeds**
    - **Minerals in the melt can chemically react and change**

Evolution of magmas

- **Processes responsible for changing a magma's composition**
  - **Magmatic differentiation**
    - **Separation of a melt from earlier formed crystals to form a different composition of magma**
  - **Assimilation**
    - **Changing a magma's composition by the incorporation of foreign matter (surrounding rock bodies) into a magma**

Evolution of magmas

- **Processes responsible for changing a magma's composition**
  - **Magma mixing**
    - **Involves two bodies of magma intruding one another**
    - **Two chemically distinct magmas may produce a composition quite different from either original magma**

Evolution of magmas

- **Partial melting and magma formation**
  - **Incomplete melting of rocks is known as partial melting**
  - **Formation of basaltic magmas**
    - **Most originate from partial melting of ultramafic rock in the mantle**
    - **Basaltic magmas form at mid-ocean ridges by decompression melting or at subduction zones**

Evolution of magmas

- **Partial melting and magma formation**
  - **Formation of basaltic magmas**
    - **As basaltic magmas migrate upward, confining pressure decreases which reduces the melting temperature**
    - **Large outpourings of basaltic magma are common at Earth's surface**

Evolution of magmas

- **Partial melting and magma formation**
  - **Formation of andesitic magmas**
    - **Interactions between mantle-derived basaltic magmas and more silica-rich rocks in the crust generate magma of andesitic composition**
    - **Andesitic magma may also evolve by magmatic differentiation**

Evolution of magmas

- **Partial melting and magma formation**
  - **Formation of granitic magmas**
    - **Most likely form as the end product of crystallization of andesitic magma**
    - **Granitic magmas are higher in silica and therefore more viscous than other magmas**
    - **Because of their viscosity, they lose their mobility before reaching the surface**
    - **Tend to produce large plutonic structures**