

EENS 212	Petrology
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<b>Textures of Igneous Rocks</b>	

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## Introduction to Igneous Rocks

An **igneous rock** is any crystalline or glassy rock that forms from cooling of a magma.

A **magma** consists mostly of liquid rock matter, but may contain crystals of various minerals, and may contain a gas phase that may be dissolved in the liquid or may be present as a separate gas phase.

Magma can cool to form an igneous rock either on the surface of the Earth - in which case it produces a **volcanic** or **extrusive igneous rock**, or beneath the surface of the Earth, - in which case it produces a **plutonic** or **intrusive igneous rock**.

## Characteristics of Magma

### Types of Magma

Types of magma are determined by chemical composition of the magma. Three general types are recognized, but we will look at other types later in the course:

1. **Basaltic magma** -- SiO<sub>2</sub> 45-55 wt%, high in Fe, Mg, Ca, low in K, Na
2. **Andesitic magma** -- SiO<sub>2</sub> 55-65 wt%, intermediate in Fe, Mg, Ca, Na, K
3. **Rhyolitic magma** -- SiO<sub>2</sub> 65-75%, low in Fe, Mg, Ca, high in K, Na

### Gases in Magmas

At depth in the Earth nearly all magmas contain gas dissolved in the liquid, but the gas forms a separate vapor phase when pressure is decreased as magma rises toward the surface. This is similar to carbonated beverages which are bottled at high pressure. The high pressure keeps the gas in solution in the liquid, but when pressure is decreased, like when you open the can or bottle, the gas comes out of solution and forms a separate gas phase that you see as bubbles. Gas gives magmas their explosive character, because volume of gas expands as pressure is reduced. The composition of the gases in magma are:

- Mostly H<sub>2</sub>O (water vapor) with some CO<sub>2</sub> (carbon dioxide)
- Minor amounts of Sulfur, Chlorine, and Fluorine gases

The amount of gas in a magma is also related to the chemical composition of the magma. Rhyolitic magmas usually have higher dissolved gas contents than basaltic magmas.

## Temperature of Magmas

Temperature of magmas is difficult to measure (due to the danger involved), but laboratory measurement and limited field observation indicate that the eruption temperature of various magmas is as follows:

- Basaltic magma - 1000 to 1200°C
- Andesitic magma - 800 to 1000°C
- Rhyolitic magma - 650 to 800°C.

## Viscosity of Magmas

**Viscosity** is the resistance to flow (opposite of fluidity). Viscosity depends on primarily on the composition of the magma, and temperature.

- Higher SiO<sub>2</sub> (silica) content magmas have higher viscosity than lower SiO<sub>2</sub> content magmas (viscosity increases with increasing SiO<sub>2</sub> concentration in the magma).
- Lower temperature magmas have higher viscosity than higher temperature magmas (viscosity decreases with increasing temperature of the magma).

Thus, basaltic magmas tend to be fairly fluid (low viscosity), but their viscosity is still 10,000 to 100,000 times more viscous than water. Rhyolitic magmas tend to have even higher viscosity, ranging between 1 million and 100 million times more viscous than water. (Note that solids, even though they appear solid have a viscosity, but it is very high, measured as trillions time the viscosity of water). Viscosity is an important property in determining the eruptive behavior of magmas.

Summary Table					
Magma Type	Solidified Rock	Chemical Composition	Temperature	Viscosity	Gas Content
Basaltic	Basalt	45-55 SiO <sub>2</sub> %, high in Fe, Mg, Ca, low in K, Na	1000 - 1200 °C	10 - 10 <sup>3</sup> PaS	Low
Andesitic	Andesite	55-65 SiO <sub>2</sub> %, intermediate in Fe, Mg, Ca, Na, K	800 - 1000 °C	10 <sup>3</sup> - 10 <sup>5</sup> PaS	Intermediate
Rhyolitic	Rhyolite	65-75 SiO <sub>2</sub> %, low in Fe, Mg, Ca, high in K, Na.	650 - 800 °C	10 <sup>5</sup> - 10 <sup>9</sup> PaS	High

## Textures of Igneous Rocks

The main factor that determines the texture of an igneous rock is the **cooling rate** (dT/dt)

Other factors involved are:

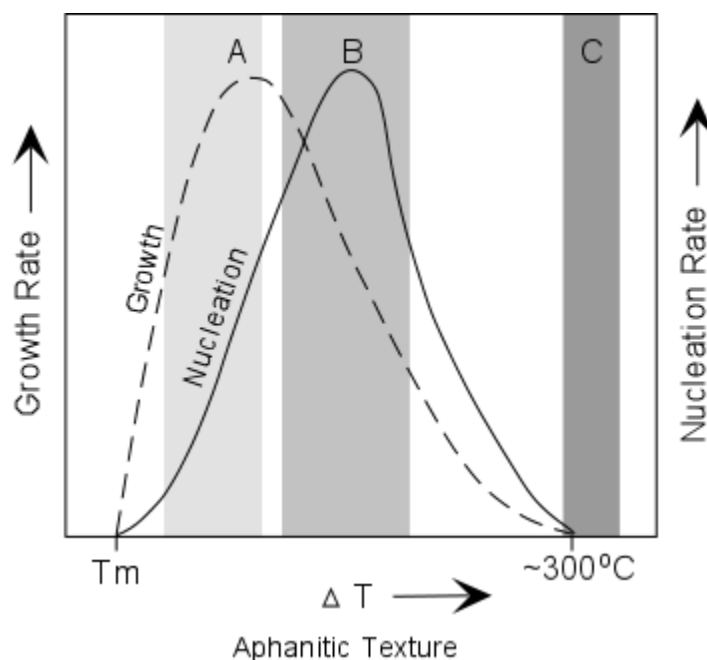
- The diffusion rate - the rate at which atoms or molecules can move (diffuse) through the liquid.

- The rate of nucleation of new crystals - the rate at which enough of the chemical constituents of a crystal can come together in one place without dissolving.
- The rate of growth of crystals - the rate at which new constituents can arrive at the surface of the growing crystal. This depends largely on the diffusion rate of the molecules of concern.

In order for a crystal to form in a magma enough of the chemical constituents that will make up the crystal must be at the same place at the same time to form a **nucleus** of the crystal. Once a nucleus forms, the chemical constituents must diffuse through the liquid to arrive at the surface of the growing crystal. The crystal can then grow until it runs into other crystals or the supply of chemical constituents is cut off.

All of these rates are strongly dependent on the temperature of the system. First, nucleation and growth cannot occur until temperatures are below the temperature at which equilibrium crystallization begins. Shown below are hypothetical nucleation and growth rate curves based on experiments in simple systems. Note that the rate of crystal growth and nucleation depends on how long the magma resides at a specified degree of undercooling ( $\Delta T = T_m - T$ ), and thus the rate at which temperature is lowered below the the crystallization temperature. Three cases are shown.

1. For small degrees of undercooling (region A in the figure to the right) the nucleation rate will be low and the growth rate moderate. A few crystals will form and grow at a moderate rate until they run into each other. Because there are few nuclei, the crystals will be able to grow to relatively large size, and a coarse grained texture will result. This would be called a **phaneritic texture**.

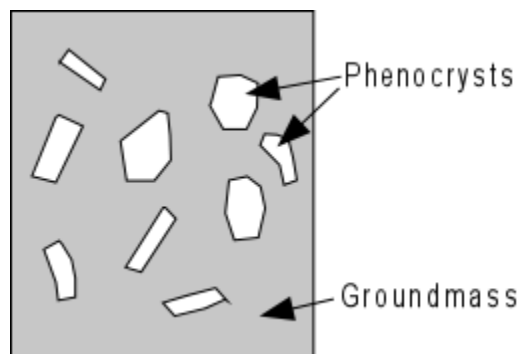


2. At larger degrees of undercooling, the nucleation rate will be high and the growth rate also high. This will result in many crystals all growing rapidly, but because there are so

many crystals, they will run into each other before they have time to grow and the resulting texture will be a fine grained texture. If the size of the grains are so small that crystals cannot be distinguished with a hand lens, the texture is said to be **aphanitic**.

- At high degrees of undercooling, both the growth rate and nucleation rate will be low. Thus few crystals will form and they will not grow to any large size. The resulting texture will be glassy, with a few tiny crystals called microlites. A completely glassy texture is called **holohyaline texture**.

Two stages of cooling, i.e. slow cooling to grow a few large crystals, followed by rapid cooling to grow many smaller crystals could result in a **porphyritic texture**, a texture with two or more distinct sizes of grains. Single stage cooling can also produce a porphyritic texture. In a porphyritic texture, the larger grains are called **phenocrysts** and the material surrounding the the phenocrysts is called **groundmass** or **matrix**



In a rock with a phaneritic texture, where all grains are about the same size, we use the grain size ranges shown to the right to describe the texture:

<1 mm	fine grained
1 - 5 mm	medium grained
5 - 3 cm	coarse grained
> 3 cm	very coarse grained

In a rock with a porphyritic texture, we use the above table to define the grain size of the groundmass or matrix, and this table to describe the phenocrysts:

0.03 - 0.3 mm	microphenocrysts
0.3 - 5 mm	phenocrysts
> 5 mm	megaphenocrysts

Another aspect of texture, particularly in medium to coarse grained rocks is referred to as fabric. **Fabric** refers to the mutual relationship between the grains. Three types of fabric are commonly referred to:

- If most of the grains are **euhedral** - that is they are bounded by well-formed crystal faces. The fabric is said to be **idomorphic granular**.
- If most of the grains are **subhedral** - that is they are bounded by only a few well-formed crystal faces, the fabric is said to be **hypidiomorphic granular**.
- If most of the grains are **anhedral** - that is they are generally not bounded by crystal faces, the fabric is said to be **allotriomorphic granular**.

If the grains have particularly descriptive shapes, then it is essential to describe the individual grains. Some common grain shapes are:

- Tabular** - a term used to describe grains with rectangular tablet shapes.
- Equant** - a term used to describe grains that have all of their boundaries of approximately

equal length.

- *Fibrous* - a term used to describe grains that occur as long fibers.
- *Acicular* - a term used to describe grains that occur as long, slender crystals.
- *Prismatic* - a term used to describe grains that show an abundance of prism faces.

Other terms may apply to certain situations and should be noted if found in a rock.

- *Vesicular* - if the rock contains numerous holes that were once occupied by a gas phase, then this term is added to the textural description of the rock.
- *Glomeroporphyritic* - if phenocrysts are found to occur as clusters of crystals, then the rock should be described as glomeroporphyritic instead of porphyritic.
- *Amygdular* - if vesicles have been filled with material (usually calcite, chalcedony, or quartz, then the term amygdular should be added to the textural description of the rock. An amygdule is defined as a refilled vesicle.
- *Pumiceous* - if vesicles are so abundant that they make up over 50% of the rock and the rock has a density less than 1 (i.e. it would float in water), then the rock is pumiceous.
- *Scoraceous* - if vesicles are so abundant that they make up over 50% of the rock and the rock has a density greater than 1, then the rock is said to be scoraceous.
- *Graphic* - a texture consisting of intergrowths of quartz and alkali feldspar wherein the orientation of the quartz grains resembles cuneiform writing. This texture is most commonly observed in pegmatites.
- *Spherulitic* - a texture commonly found in glassy rhyolites wherein spherical intergrowths of radiating quartz and feldspar replace glass as a result of devitrification.
- *Obicular* - a texture usually restricted to coarser grained rocks that consists of concentrically banded spheres wherein the bands consist of alternating light colored and dark colored minerals.

Other textures that may be evident on microscopic examination of igneous rocks are as follows:

- *Myrmekitic texture* - an intergrowth of quartz and plagioclase that shows small wormlike bodies of quartz enclosed in plagioclase. This texture is found in granites.
- *Ophitic texture* - laths of plagioclase in a coarse grained matrix of pyroxene crystals, wherein the plagioclase is totally surrounded by pyroxene grains. This texture is common in diabases and gabbros.
- *Subophitic texture* - similar to ophitic texture wherein the plagioclase grains are not completely enclosed in a matrix of pyroxene grains.
- *Poikilitic texture* - smaller grains of one mineral are completely enclosed in large, optically continuous grains of another mineral.

- *Intergranular texture* - a texture in which the angular interstices between plagioclase grains are occupied by grains of ferromagnesium minerals such as olivine, pyroxene, or iron titanium oxides.
  - *Intersertal texture* - a texture similar to intergranular texture except that the interstices between plagioclase grains are occupied by glass or cryptocrystalline material.
  - *Hyalophitic texture* - a texture similar to ophitic texture except that glass completely surrounds the plagioclase laths.
  - *Hyalopilitic texture* - a texture wherein microlites of plagioclase are more abundant than groundmass, and the groundmass consists of glass which occupies the tiny interstices between plagioclase grains.
  - *Trachytic texture* - a texture wherein plagioclase grains show a preferred orientation due to flowage, and the interstices between plagioclase grains are occupied by glass or cryptocrystalline material.
  - *Coronas or reaction rims* - often times reaction rims or coronas surround individual crystals as a result of the crystal becoming unstable and reacting with its surrounding crystals or melt. If such rims are present on crystals they should be noted in the textural description.
  - *Patchy zoning* - This sometimes occurs in plagioclase crystals where irregularly shaped patches of the crystal show different compositions as evidenced by going extinct at angles different from other zones in the crystal.
  - *Oscillatory zoning* - This sometimes occurs in plagioclase grains wherein concentric zones around the grain show thin zones of different composition as evidenced by extinction phenomena.
  - *Moth eaten texture* (also called *sieve texture*)- This sometimes occurs in plagioclase wherein individual plagioclase grains show an abundance of glassy inclusions.
  - *Perthitic texture* - Exsolution lamellae of albite occurring in orthoclase or microcline.
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