

# Igneous Rocks

- Formed by crystallization (or solidification) of melted material
- Molten material within the earth, MAGMA, cools to form PLUTONIC, or INTRUSIVE igneous rock.
- Molten material that emerges at the earth's surface, LAVA, cools to form VOLCANIC, or EXTRUSIVE igneous rock.

# Some Definitions

- **MAGMA:** a combination of melted silicate material, volatiles, and possibly already solidified crystals
- **VOLATILES:** substances that are gases at low temperature, chiefly H<sub>2</sub>O

# Viscosity

- **VISCOSITY:** resistance of a substance to flow. Examples: pine sap (higher viscosity) *vs.* water (lower viscosity)
- Viscosity increases as the lava starts to cool.
- The more complex the silicates melted in the magma, the higher the viscosity (examples of complex mineral structures: quartz, orthoclase).

# Classification of Igneous Rocks

- Classified by MINERAL COMPOSITION and TEXTURE
- BOWEN'S REACTION SERIES: (N. L. Bowen, 1911)

SIMULTANEOUS CRYSTALLIZATION

MAGMA TYPES  
↓  
Basaltic (low silica)  
↓  
Andesitic  
↓  
Rhyolitic (high silica)  
↓

DISCONTINUOUS REACTION SERIES OF MAFIC MINERALS

Olivine  
↓  
Pyroxene  
↓  
Amphibole  
↓  
Biotite mica

CONTINUOUS REACTION SERIES OF PLAGIOCLASE FELDSPAR

Increasing sodium content of plagioclase feldspar  
Calcium-rich  
↓  
Sodium-rich

Orthoclase feldspar  
Muscovite mica  
Quartz

Early, high-temperature (~1000°C) crystallization  
↓  
Late, low-temperature (~600°C) crystallization

# Bowen's Reaction Series

- Generalization about magma behavior and sequence of crystallization
- Silica tetrahedron: one silicon bound to 4 oxygens
- Continuous and Discontinuous Series
- Minerals crystallizing along the discontinuous series have distinctly different mineral structures (isolated, chain, double chain, sheet, framework).
- Olivine contains isolated  $\text{SiO}_4$  tetrahedrons.
- Quartz is a framework silicate in which every tetrahedron is linked at its corners to four other tetrahedrons (every oxygen atom is shared).

# Significance of Bowen's Series

- Minerals that crystallize first have higher melting points than minerals down the series.
- Complexity of silicate structures increases down the series.
- Viscosity of the magma increases down the series.
- Minerals lower down the series are more resistant to chemical weathering.
- Mineral densities decrease down the series.

# Terms Related to Mineral Composition

- Felsic: igneous rocks rich in light-colored minerals such as orthoclase and quartz
- Intermediate: igneous rocks rich in minerals such as Na-Ca plagioclase and hornblende
- Mafic: igneous rocks rich in dark-colored ferromagnesian minerals (augite, hornblende) but with abundant plagioclase feldspar
- Ultramafic: igneous rocks composed chiefly of dark-colored ferromagnesian minerals, especially olivine and augite, with no plagioclase



# Terms Related to Texture

- Crystal Size:
  - Fine-grained: less than 1mm
  - Medium-grained: 1-2 mm
  - Coarse-grained: larger than 2 mm
  - Pegmatitic: very coarse-grained, approx. 5cm to as large as a house
- Porphyry: igneous rock with large crystals (PHENOCRYSTS) set in a matrix of fine-grained crystals (GROUNDMASS)

# Cooling History

- Absence of crystals (glassy) indicates extremely rapid cooling (quenching).
- Absence of crystals (frothy) indicates extremely rapid cooling with high dissolved gas content.
- Small crystals indicate rapid cooling.
- Large crystals indicate slow cooling.
- Pegmatitic texture indicates slow cooling in the presence of H<sub>2</sub>O.
- Porphyritic texture indicates two distinct cooling histories: slowly at depth, then rapidly at the surface.

# Igneous Landforms

- Plutonic rock body: sill, dike, batholith
- Volcanic landform: fissure flow, shield volcano, composite volcano
- Crater (constructional feature) (example: Mt. Rainier, Washington State)
- Caldera (destructional feature) (example: Crater Lake, Oregon)

# Mafic Magma

- Mafic magma typically has a higher temperature than felsic magma.
- Higher-temperature magmas commonly have:
  - lower viscosity
  - lower volatile content
  - less explosive tendency (lava rather than pyroclastic material)

# Volcanic Terms

- Pyroclastic rock: explosively erupted as hot but nevertheless solid particles
- Tuff: explosively erupted, fine-grained volcanic rock whose grains are commonly welded together
- Vesicles: cavities in a volcanic rock, once occupied by gas bubbles

