Igneous Rocks

Geology 200
Geology for Environmental Scientists
Magma Compositions

- Ultramafic - composition of mantle
- Mafic - composition of basalt, e.g. oceanic crust. 900-1200°C, 50% SiO₂
- Intermediate - mix of oceanic and continental crust
- Felsic or Silicic or Sialic - composition of continental crust. <850°C, 75% SiO₂
Two Major Divisions

- Intrusive igneous rocks - magma that solidifies below the surface of the earth
- Extrusive igneous rocks - magma that cools on the surface of the earth
- The rock textures are different for each division.
Texture of Igneous Rocks

- Glassy: caused by rapid cooling; no crystals
- Pyroclastic: fragments of glass and crystals; volcanic ash and bombs
- Aphanitic: microscopic crystals
- Phaneritic: macroscopic crystals
- Porphyritic: grains of two distinct sizes; can occur in phaneritic or aphanitic matrix
Can you fill in the question marks?
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Classification of Igneous Rocks - Fig. 4.4
based on both composition and texture
Felsic and intermediate igneous rocks

(A) Granite: K-feldspar, quartz, plagioclase, and biotite.

(B) Rhyolite: K-feldspar, plagioclase, quartz, and biotite.

(C) Diorite: plagioclase, amphibole, quartz, and biotite.

(D) Porphyritic andesite: plagioclase, pyroxene, and amphibole.
Mafic and ultramafic igneous rocks

(E) Gabbro: pyroxene, plagioclase, and olivine.

(F) Porphyritic basalt: plagioclase, pyroxene, and olivine.

(G) Peridotite: olivine and pyroxene.

(H) Komatiite: olivine, pyroxene, and plagioclase. (D. A. Williams)
Granite --
K-feldspar, quartz, plagioclase, hornblende, biotite
Rhyolite -- an extrusive felsic igneous rock
Basalt -- an extrusive mafic rock
Andesite -- an extrusive intermediate igneous rock
A welded tuff formed from hot ash and glass.
A composite volcano composed of ash layers and lava flows.
Pillow lavas - formed by underwater eruption of basalt
Physical weathering of columnar basalt
Genesis of different types of intrusive igneous bodies
Archean plutons, western Australia
Close-up of last slide showing Archean granitic plutons and greenstone belts (ancient oceanic crust)
WVU Students on a Gabbro Dike in Maine during Geology Field Camp
A Xenolith in a Magma Chamber or Pluton, Maine
Origin and Differentiation of Magma

- Source rock composition - what rocks were melted?
- Partial melting - produces magmas of different composition than source rocks; more felsic or silicic.
- Fractional crystallization - increases silica content of remaining melt.
- Magma mixing
- Assimilation - xenoliths fall into magma chamber
Figure 4.22 - The Order of Crystallization: Bowen’s Reaction Series
Bowen’s Reaction Series

Temperature Regimes

- High temperature (first to crystallize)
  - Cooling magma
- Low temperature (last to crystallize)

Bowen’s Reaction Series

- Olivine
- Pyroxene
- Amphibole
- Biotite mica
- Potassium feldspar
  + Muscovite mica
  + Quartz
- Plagioclase feldspar
- Continuous Series of Crystallization
- Calcium-rich
- Sodium-rich

Igneous Rock Types

- Ultramafic (komatiite/peridotite)
- Mafic (basalt/gabbro)
- Intermediate (andesite/diorite)
- Felsic (rhyolite/granite)
Bowen’s Reaction Series

The order of crystallization for the discontinuous series from olivine to pyroxene to amphibole to biotite to quartz and K-feldspar follows a sequence of increasingly complex arrangements of silicon-oxygen tetrahedra. These arrangements progress from single tetrahedra, to single chains, to double chains, to sheets, and finally to framework arrangement of tetrahedra.
Figure 3.18 -- The silicon-oxygen tetrahedron
Figure 3.19 -- Silicon-oxygen tetrahedral groups
Igneous Rocks and Plate Tectonics

• Divergent plate boundaries - convection cells move mantle peridotite closer to the surface. These rocks are at high temperatures so the pressure reduction causes partial melting and production of basaltic magmas.
Igneous Rocks and Plate Tectonics

- Convergent plate boundaries - the subduction of oceanic crust produces partial melting of the hydrated basalt. This produces intermediate (andesitic) magmas which rise to form mountains (e.g. Andes). These magmas can in turn melt continental crust producing granitic magmas.
Types of Convergent Boundaries

- Oceanic-Continental
- Oceanic-Oceanic
- Continental-Continental
Igneous Rocks and Plate Tectonics

• Over geologic time these processes first created oceanic crust from ultramafic mantle rocks. In turn, the mafic oceanic crust created felsic continental crust from partial melting of hydrated basalt. Continental crust is less than 1% of earth’s mass, so there isn’t a lot of felsic material in the earth. Most has risen to the crust.
Continental crust is less than 1% of Earth’s mass