Igneous Rocks and Processes
Other minerals are important for the full description of igneous rocks: Olivine, Pyroxene, Hornblende, Biotite and Muscovite
Streckheisen classification is based on only three minerals: Quartz, Plagioclase, Potassium Feldspar
Norman Bowen (1887-1956)
Father of Experimental Petrology
**Bowen’s Reaction Series**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Igneous Rock Types</th>
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<td>High temperature (first to crystallize)</td>
<td>Ultramafic (komatite/ peridotite)</td>
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<tr>
<td>Cooling of magma</td>
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- Discontinuous series of crystallization
  - Olivine
  - Pyroxene
  - Amphibole
- Continuous series of crystallization
  - Biotite mica
  - Plagioclase feldspar
- Sodium-rich
- Calcium-rich
- Potassium feldspar
- Muscovite mica
- Quartz
- Feldspar (rhyolite/ granite)
Bowen’s Reaction Series

Discontinuous Series

- High temperature (first to crystallize)
- Discontinuous series of crystallization
- Low temperature (last to crystallize)

Igneous Rock Types
- Ultramafic (komatiite/peridotite)
- Mafic (basalt/gabbro)
- Intermediate (andesite/diorite)
- Felsic (rhyolite/granite)

Temperature
- Cooling of magma

Minerals
- Olivine
- Pyroxene
- Amphibole
- Biotite mica
- Potassium feldspar
- Muscovite mica
- Quartz
Bowen’s Reaction Series

What is the trend in silicate structures? Why?

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- Biotite mica
- Potassium feldspar
- Muscovite mica
- Quartz
- Plagioclase feldspar
- Calcium-rich
- Sodium-rich

Discontinuous Series
Bowen’s Reaction Series
Bowen’s Reaction Series

Why would aspects of this igneous concept apply to sedimentary rocks as well?

Most Common Minerals in Sediments

- Ultramafic (komatiite/ peridotite)
- Mafic (basalt/ gabbro)
- Intermediate (andesite/ diorite)
- Felsic (rhyolite/ granite)

Temperature

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

Igneous Rock Types

- Continuous series of crystallization
- Discontinuous series of crystallization

Minerals

- Olivine
- Pyroxene
- Amphibole
- Biotite mica
- Plagioclase feldspar
- Potassium feldspar
- Muscovite mica
- Quartz
Bowen’s Reaction Series

Completely Melted ~ 1200°C

Completely Solid ~ 600°C
Bowen’s Reaction Series

Rock melting temperatures are inconsistent with mineral melting temperatures.

Mineral Melting Temp

- Olivine: 1800°C
- Ca-Feld: 1500°C
- Pyroxene: 1400°C
- Na-Feld: 1100°C
- K-Feld: 1250°C
- Quartz: 1650°C

High temperature (first to crystallize)

Cooling of magma

Low temperature (last to crystallize)
Minerals are chemical compounds

- Freshwater (a compound):
  Freezing/Melting point = 0°C

Rocks are chemical mixtures

- Seawater (a mixture):
  Freezing/Melting point = -2°C

Mixtures have lower melting points

- Rocks have lower freezing/melting temperatures than the individual minerals that they contain
Binary Phase Diagrams

- Show the melting/crystallization relationships between mixes of two components
- The lowest melting temperature is called the EUTECTIC
Geochemists and petrologists experiment with rocks to understand magmas
- How do they form?
- How do they cool?

Add different chemicals (fluxes) to powdered rocks, heat them in a furnace, and see how they behave
- Does it melt?
- What minerals form?
Ternary Phase Diagrams

- Show melting/crystallization relationships between mixes of three components
- Combination of 3 binary diagrams
- Used extensively to understand igneous rock processes
Si-Ab-Or Ternary Diagram: Felsic and Intermediate Rocks

- Used for rocks that contain a mixture of quartz and feldspars
- What is the composition of the first magma to form?
Granite: A Eutectic Composition
Petrologists and Potters: Shared Methods and Equipment

Experimental Petrologist

Potter
Glazes as Igneous Rocks

- A ceramic glaze is a glass
  - Glass is a solid without an ordered atomic structure that forms from rapidly cooling a silicate melt
  - OBSIDIAN is a natural silicate glass (igneous rock)

- The ideal glaze would be made of pure silica glass (molten quartz) but the melting temperature of quartz (1650°C) is higher than the firing temperature of a potter’s kiln
- Potters experiment to find glazes that work

- Add fluxes powdered quartz in different proportions to find the ideal percentages to make a shiny glass

- Add transition metals to color the glaze
Components of Glazes

- Potters consider glazes to be composed of three components
  - **Silica**: the glass former (quartz or flint)
  - **Flux**: materials that make the glaze melt at kiln temperatures (e.g. feldspar, calcite, dolomite, talc)
  - **Amphoteric**: binds the glaze to the clay pot (e.g., clay minerals such as kaolin, bentonite)
Feldspar as a Glaze

- Feldpars can act as glazes by themselves for stoneware
  - Albite: NaAlSi$_3$O$_8$
  - K-Feldspar: KAlSi$_3$O$_8$

- They contain all three components:
  - SiO$_2$ (silica)
  - Al$_2$O$_3$ (amphoteric)
  - Na$_2$O/K$_2$O (Flux)
Feldspar as a Glaze

- Feldpars can act as glazes by themselves for stoneware
  - Typical stoneware firing is around 1200°C
  - Albite: NaAlSi$_3$O$_8$
    Melting T = 1100
  - Microcline: KAISi$_3$O$_8$
    Melting T = 1250
  - Mixing ~ 70% Albite with 30% K-Feldspar will produce a glaze that melts at 1050

![Feldspar as a Glaze Diagram](image)