Igneous Processes

- Today’s Questions –
  - What happens when magmas cool and crystallize?
  - Why happens to the composition of the magma during crystallization?
  - Why are there so many igneous rock types?

What happens when magmas cool and solidify?

- Bowen’s Reaction Series
  - The Discontinuous Series
  - 1920’s
    - N. L. Bowen demonstrated that minerals crystallize in a specific order based on their melting temperature.

   1. Olivine crystallizes from cooling magma
   2. Olivine reacts with magma to form pyroxene
   3. Pyroxene crystallizes
   4. Pyroxene reacts with magma to form amphibole
   5. Amphibole crystallizes
   6. Amphibole reacts with magma to form biotite
   7. Biotite crystallizes
   8. Biotite reacts with magma to form muscovite
   9. Muscovite crystallizes
   10. Muscovite reacts with magma to form quartz
   11. Quartz crystallizes

   - Decreasing temperature
   - Increasing pressure
Bowen’s Reaction Series
The Continuous Series

Hi Temp
Ca-rich plagioclase feldspar

Na-Rich plagioclase feldspar

Low Temp

Composition of plagioclase feldspar

Initial crystal is calcium-rich

Crystal becomes more sodium-rich as it grows

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What happens to the composition of the magma as different minerals crystallize?

What can you say about the starting composition?

What can you say about the composition of the early crystallizing minerals?

How does that effect the composition of the melt?

Another way to look at it…

Part of the mantle has melted.

What is melt composition?
Another way to look at it…

Part of the mantle has melted. What happens as it cools?

- Ultramafic (peridotite)

What happens to the composition of the magma as different minerals crystallize?

- Is our melt hot or cold?
- What mineral crystallizes at the hottest temperature?
- As our melt cools, which mineral will crystallize first?

What happens to the composition of the magma as different minerals crystallize?

- As our melt cools, which mineral will crystallize first?
- Now we have crystals and melt? Which one is denser? Can you predict what may happen to the olivine crystals?

What happens to the composition of the magma as different minerals crystallize?

- Olivine sinks to the bottom of the magma chamber. How does the absence of olivine change the composition of the remaining melt?

- Olivine crystals settle
What happens to the composition of the magma as different minerals crystallize?

How will the absence of olivine change the composition of the melt?

- Melt:
  - Decreased iron
  - Increased silica
- Olivine crystals settle

Which rock/magma type has lower iron, higher silica?

What happens to the composition of the magma as different minerals crystallize?

As the melt cools (ascends farther away from its heat source), which mineral or minerals will crystallize next?

- Pyroxene
- Plagioclase

What will happen if our less dense melt rises further from our heat source, and continues to cool?

Which mineral or minerals will crystallize next?

- Mafic (gabbro)

What happens to the composition of the magma as different minerals crystallize?

These crystals may settle too!

What happens to the composition of the melt?
What happens to the composition of the magma as different minerals crystallize?

What happens to the composition of the melt?

Silica goes up more and iron goes down more!

What magma/rock type would this be?

Pyroxene
Plagioclase

Magmatic Differentiation
(by Crystal Settling or Fractionation)

The first-to-form crystals can either settle downward (if denser) or stay where they form on the walls (cooling occurs from outside in).

So, why are there so many types of igneous rocks?

At any temperature, the melt may be completely used up as minerals crystallize.

Why are there so many different kinds of igneous rocks?
• Or…
• Crystallization and fractionation of the melt can continue until it becomes more and more silica-rich, creating a whole suite of rock types.
Summary

• What happens when magmas cool and solidify?
  – Crystals form in the magma in a specific sequence with high temperature minerals crystallizing first.

• What happens to the composition of the magma as minerals crystallize?
  – The composition of the remaining melt changes to become depleted in iron and richer in silica.

• Why are there so many different types of igneous rocks?
  – Crystal settling (and other differentiation processes) can cause ultramafic and mafic magmas to become more silica rich and form rocks with higher silica content.