Bowen’s Reaction Series

The crystallization of magma (the process by which hot, liquid magma cools and solidifies to become a rock) is one of the most important concepts in igneous geology and is described by Bowen’s Reaction Series. This process is called **Magmatic Differentiation** – the process by which liquid magma can crystallize (solidify) to form volcanic rock of different compositions.

Bowen’s Reaction Series was performed in a laboratory using one of the most common extrusive igneous rocks: **Basalt**. Basalt is a dark volcanic rock rich in iron, magnesium, calcium, and silicates. It is thought to be representative of the magma that exits deep within the Earth’s crust and is the reason Bowen chose to use it in his laboratory experiments.

![Bowen’s Reaction Series Diagram](image)

The Bowen’s Reaction Series diagram above shows the relative, but not exact, sequence of crystallization: Olivine and Calcic Plagioclase crystallize first (at approximately the same time) and, as temperatures cool, other minerals form until the minerals comprising the Lower Series ultimately crystallize, which then completes the reaction series.

The detailed sequence description for Bowens Reaction Series:

- Liquid magma, with the composition of basalt, is allowed to cool slowly. The first minerals to crystallize (solidify) from the cooling melt are Olivine and Calcic Plagioclase.

- As temperatures continue to cool, the Discontinuous Series (on the left) progresses: Olivine reacts with the melt to form Pyroxene, Pyroxene reacts with the melt to form Amphibole, Amphibole reacts with the melt to form Biotite.

- At the same time, Plagioclase (the Continuous Series on the right) crystallizes and reacts with the remaining melt to form other Plagioclase minerals which are increasing rich in sodium. In other words, as temperatures cool, Plagioclase crystallizes but its composition becomes more sodic with falling temperatures.
• The process of crystallization of minerals in the Discontinuous and Continuous Series ends when all of the iron-magnesium minerals (Discontinuous Series) and Plagioclase (Continuous Series) are formed.

• After all the Discontinuous Series and Continuous Series minerals crystallize, temperatures continue to cool and minerals in the Lower Series begin form from the remaining magma melt. Potassium Feldspar, Muscovite, and Quartz crystallize in that order, and comprise the Lower Series. As these minerals form, they do NOT react with the remaining melt, they simply cool to become solid.

In summary, Bowen's Reaction Series comprises 3 series:

1. The left side of the diagram shows the **Discontinuous Series**. Minerals crystallize and change from one mineral to the next in discrete steps as the liquid magma cools.

2. The right side of the diagram shows the **Continuous Series**. This series is termed “continuous” because only one mineral forms as the magma cools: Plagioclase. **Plagioclase crystallizes with an initial composition entirely calcic**; as temperatures cool, the final composition of Plagioclase becomes entirely sodic. Between the time when Calcic Plagioclase crystallizes at higher temperatures and Sodic Plagioclase crystallizes at lower temperatures, a variety of different compositions of Calcic-Sodic Plagioclase can form.

3. The **Lower Series** is a sequence of crystallization only, no reaction with the residual melt occurs when Potassium Feldspar, Muscovite and Quartz form.