**The Bowen's Reaction Series**

The Bowen reaction series is a description of how magma minerals change as they cool.

The petrologist Norman Bowen (1887-1956) carried out decades of melting experiments in the early 1900s in support of his theory of granite. He found that as a basaltic melt slowly cooled, minerals formed crystals in a definite order. Bowen worked out two sets of these, which he named the discontinuous and continuous

**Discontinuous Series- changes in distinct steps**

The *discontinuous series* starts with olivine, then pyroxene, amphibole, and biotite.

What makes this a "reaction series" rather than an ordinary series is that each mineral in the series is replaced by the next one as the melt cools. As Bowen put it, "The disappearance of minerals in the order in which they appear ... is of the very essence of the reaction series." Olivine forms crystals, then it reacts with the rest of the magma as pyroxene forms at its expense. At a certain point, all the olivine is resorbed and only pyroxene exists. Then pyroxene reacts with the liquid as amphibole crystals replace it, and then biotite replaces amphibole.

**Continuous Series-changes gradually**

The *continuous series* is plagioclase feldspar. At high temperatures, the high-calcium variety anorthite forms. Then as temperatures fall it is replaced by more sodium-rich varieties: bytownite, labradorite, andesine, oligoclase, and albite.

As the temperature continues to fall, these two series merge and more minerals crystallize in this order: Alkali feldspar, muscovite, and quartz.

A minor reaction series involves the spinel group of minerals: chromite, magnetite, ilmenite, and titanite. Bowen placed them between the two main series.

**Notes:**

* The series occurs in a closed system (nothing can enter or leave the magma)
* In reality closed systems are not truly possible therefore the following results:
  + Fractional crystallization- minerals are removed from magma as they form

Eg. Minerals that form first are dense and sink to the bottom preventing interactions

* + Assimilation- surrounding rock aka “country rock” is added or incorporated into the rock
  + Magma mixing- different magmas mix as they cool