Bowen's Reaction Series II: A silicon-centered explanation

One might ask, why are the minerals in Bowen's Reaction Series arranged as they are - why can olivine, anorthite, and the spinels form first, and quartz form last? If anything, we might expect a melt rich in silica to produce silica as its first mineral, rather than its last. Why instead is the silica mineral usually last?

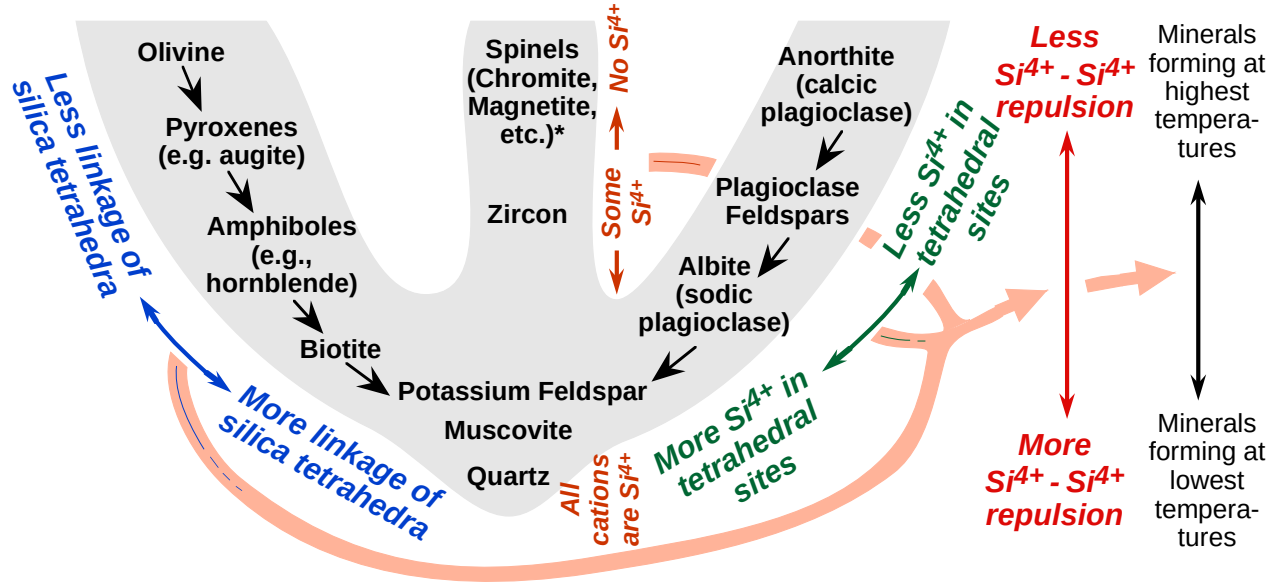
The answer usually given (and it's a good answer) is that the order of crystallization from a melt is dictated in part by the repulsions between cations. Formation of a mineral requires cations, bundles of positive charge, to come into close proximity in a mineral structure. Si^{4+} is a cation of high ionic potential (i.e., high density of charge, defined as charge divided by radius). Thus formation of a Si-rich mineral becomes a disfavored process, relative to formation of minerals with cations of lesser ionic potential.

With that in mind, we can see why each branch of Bowen's Reaction Series goes in the order that it does. In the discontinuous series from olivine to biotite, we progress from minerals with no linkage of silica tetrahedra to much linkage of silica tetrahedra (and thus much "potential" for repulsion) (see the blue labels below). In the continuous series, where all tetrahedra share all four oxygens and so linkage is maximized, we progress from anorthite to albite. We thus progress from more substitiution of Al^{3+}, a cation of lower ionic potential than Si^{4+}, to less substitution, and thus from less cation-cation repulsion to more (see the green labels below). In the middle branch, the spinels have no Si^{4+} at all and thus obviously minimize Si^{4+}-Si^{4+} repulsion. Zircon, inserted in the series below, has some Si^{4+}, but only half as much as quartz (see the brown labels below).

To summarize, as we pass down each branch of Bowen's Reaction Series, we go from less Si^{4+}-Si^{4+} repulsion to more. That means we go from more readily-formed minerals to less readily-formed ones. As a result, we go from those that can form at higher temperatures to those that will only form at lower temperatures.

That's a good explanation of why the minerals of Bowen's Reaction Series are in the order they are. However, it is a silicon-centered explanation - it pays little attention to the other cations in the minerals involved. With a little more insight, we can reach a more complete explanation. That's what we'll find in Parts III and IV of this series of pages on Bowen's Reaction Series.

An Si^{4+}-centered explanation of the order of Bowen's Reaction Series



*Bowen's (1922) original formuation of the "reaction principal" included this middle branch for the spinels. Zircon is added here for the sake of completeness.