

Repulsion between cations, and mineral stability

The plot below shows the ionic potential of cations in O^{2-} -bearing minerals (oxides, and oxysalts such as sulfates, carbonates, phosphates etc.). As an X-Y plot, it's limited to minerals of two cations (e.g., Fe^{2+} and Fe^{3+} in magnetite, or Ca^{2+} and S^{6+} in anhydrite). In addition, it can show oxides of one cation, for example by treating TiO_2 as Ti_2O_4 .

Ionic potential (charge \div radius) is a measure of the density of charge of an ion. The greater the value of ionic potential, the more the ion is a tightly focused beacon of charge.

One interesting thing to emerge is that all the "simple" minerals (minerals without H_2O , OH^- , F^- , or Cl^- , or O^{2-} in excess of that in the oxysalt radical) plot to the left and below the curve across the diagram. In short, no simple mineral can accommodate two cations that both have high ionic potential: there are no $Mg(NO_3)_2$ or $BeCO_3$ minerals. Seemingly the mutual repulsion between two cations of high ionic potential makes such substances too unstable to survive as minerals. Instead, minerals combining two cations of high ionic potential must have some "extra" uncharged (H_2O) or negatively charged (e.g., OH^- , F^- , Cl^-) constituents to shield the cations from each other.

Two noteworthy minerals fall very close to the limiting curve on the plot above. They are magnesite and quartz,

and they have a peculiarity in common: both are slow to form. Magnesite is supersaturated in seawater (its saturation state in any seawater is about four times that of calcite), but it does not precipitate from seawater. In terrestrial settings, Mg^{2+} -carbonates may form, but they're always hydrous minerals (as with hydromagnesite) rather than magnesite. Formation of magnesite is thus seemingly inhibited, at least in low-temperature settings.

Precipitation of quartz is also inhibited. In crystallization of silicate magmas rich in SiO_2 , quartz is commonly the last mineral to form (i.e, it forms only at the lowest temperature). In the oceans, Si^{4+} precipitates only as hydrous silica, and it commonly remains in that form in deep-sea sediments for tens of millions of years before finally recrystallizing to quartz. In sandstone diagenesis, newly nucleated crystals of quartz cement are never observed; secondary quartz is only present as overgrowths on sedimentary quartz grains.

The reluctance of quartz and magnesite to precipitate can probably be explained in terms of the plot above. Precipitation of a mineral requires bringing cations into close proximity in the crystal structure. Precipitation of minerals near the limiting curve above thus requires overcoming the mutual repulsion of cations of high ionic potential, and thus such precipitation is a rare event.

