

Differential Degassing of H₂ Causes Redox Changes Affecting Multivalent Element Partitioning During Volatile Phase Saturation of Crystallizing Magmas: Evidence from Granophile Magmatic Systems and Associated Mineralization

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The emplacement of highly fractionated magmatic systems are susceptible to synemplacement redox changes due to their low iron content and enhanced differential degassing issues associated with carbon-bearing exsolved fluids. CO₂ and CH₄ in exsolved volatiles enhance volatile exsolution from crystallizing magmas, and those fluids have higher H₂ gas as well, such that the dissolved volatiles in a remaining melt are more susceptible to the valence state of ions in that melt—in particular, iron. In low iron magmatic systems, the ratio of iron to water makes certain magmatic systems susceptible to differential degassing and as a result oxidation as devolatilization progresses.

The redox state of magmas has long been known to affect multivalent metal solubilities and partitioning into the evolving volatile phase; this is enhanced at lower geostatic pressure conditions. The H₂O/Fe is highest in evolved leucogranitic magmatic systems, i.e., the most fractionated granophile element (e.g., Mo, Sn, U) deposit forming magmas and relationship to H₂S/SO₂ evolution. Ferric-ferrous ratio (Fe³⁺/Fe²⁺) in rocks, proportion of magnetite versus ilmenite (magnetic susceptibility), and minerals like biotite are also known to be sensitive indicators of redox; combinations of these types of data are used to assess redox of crystallized magmatic systems in addition to examination of gasses in the magmas or in the related ore-forming systems. Porphyritic textures in these hypabyssal magmatic systems are known to be quenched by catastrophic degassing and/or pressure quenching of these magmas. Within individual evolved magmatic systems, a comparison of porphyritic to aplitic groundmass compositions and mineralogy to phenocrysts generally shows that the proportion of Fe³⁺ has increased relative to Fe²⁺ in the pressure quenched systems. A comparison of these evolved magmatic systems to their relationship to granophile-element mineralization that they are related to commonly shows effects related to redox increase in pressure quenched systems.

In the Late Devonian Mount Pleasant (MP) and associated subvolcanic systems, as an example, there are several pulses of magmas that are responsible for the (1) endo to exogranitic W-Mo-Bi mineralization associated with MP Granite I that is termed a microgranite; and (2) the later mineralized system produces Sn-Cu-Zn-In mineralization associated with MP Granite II, which has quenched dikes phases, but most of the intrusion is slightly porphyritic, but medium grained. In the subvolcanic Mount Douglas Granite suite related to MP, the porphyritic phase has a higher Fe³⁺/Fe²⁺ (>0.5) with a W-Mo vein association as well, whereas the later intrusion (<0.5) is more medium grained and is associated with endogranitic Sn, base-metals, and locally W veins. Biotite color and Fe-Ti oxides consistent with these observations. The higher redox associated with the porphyritic phases favors Mo mineralization, whereas the less pressure quenched phases of these evolved leucogranitic magmas hosts reduced Sn-rich mineralization, without Mo. Both phases of the intrusion (porphyritic versus medium grained) are virtually indistinguishable compositionally beyond their redox differences. Therefore degassing behavior in low iron, high water (H₂O/Fe) highly evolved magmatic systems (leucogranitic) will affect the partitioning behavior of multivalent elements and species of S associated with the mineralizing fluid.