American Mineralogist, Volume 109, pages 422–438, 2024

The effects of oxygen fugacity and sulfur on the pressure of vapor-saturation of magma

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Abstract

Geobarometers are commonly used to determine the pressure (and hence depth) of magmatic bodies. For instance, at equilibrium, the concentration of dissolved volatiles in a vapor-saturated melt can be used as a barometer: this is the pressure of vapor-saturation (P^v_{sat}). Most determinations of P^v_{sat} assume that melt and vapor contain only oxidized C-O-H species. However, sulfur is the third most abundant volatile element in magmas, and oxygen fugacity (f_{O_2}) exerts a strong influence on the speciation of the melt and vapor. To explore how S and f_{O_2} affect calculations of P^v_{sat}, we model a Hawaiian tholeiite that contains both reduced and oxidized C-O-H-S species in the melt and vapor. We find that excluding reduced C-O-H species in the system can result in significant underestimations of P^v_{sat} under reducing conditions ($\Delta FMQ < 0$). The effect of S on P^v_{sat} is small except in the vicinity of the "sulfur solubility minimum" (SS^{min}; $0 < \Delta FMQ < +2$), where excluding S-bearing species can result in underestimates of P^v_{sat}.

The implications of these results depend on the volatile concentration of the system being investigated, its f_{O_2}, and the melt composition and temperature. Our results suggest there will be little impact on P^v_{sat} calculated for mid-ocean ridge basalts because their f_{O_2} is above where reduced C-O-H species become important in the melt and vapor and yet below the SS^{min}. However, the f_{O_2} of ocean island and arc basalts are close enough to the SS^{min} and their S concentrations high enough to influence P^v_{sat}. However, high-CO_2 and high-H_2O concentrations are predicted to reduce the effect of the SS^{min}. Hence, P^v_{sat} calculated for shallowly trapped melt inclusions and matrix glass are more affected by the SS^{min} than deeply trapped melt inclusions. Lunar and martian magmas are typically more reduced than terrestrial magmas, and therefore accurate P^v_{sat} calculations for them require the inclusion of reduced C-O-H species.

Keywords: Pressure of vapor saturation, thermodynamics, oxygen fugacity, carbon, hydrogen, sulfur; Experimental Halogens in honor of James Webster