Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.10737

Sulfur_X: A model of sulfur degassing during magma ascent

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The degassing of CO_2 and S from arc volcanoes is fundamentally important to global climate, eruption forecasting, and cycling of volatiles through subduction zones. While the behavior of CO_2-H_2O is relatively well understood from thermodynamic and empirical models, significant discrepancies exist in predicting the behavior of sulfur. In this study, we develop a degassing model, Sulfur_X, to track the evolution of S, CO_2, H_2O and redox states in melt and co-existing vapor in ascending mafic-intermediate magma.

Sulfur_X combines an existing H_2O-CO_2 degassing model with sulfur partitioning between vapor and silicate melt (), assuming the magma is not sulfide or sulfate saturated. Particularly, Sulfur_X employs a that applies over the range of fO_2 encountered in arc magmas by combining separate sulfur partition coefficients for three relevant equilibria: RxnI. FeS (m) + H_2O (m)H_2S (v) +FeO (m), RxnIa. FeS (m) + 1.5O_2 (v)SO_2 (v) +FeO (m), and RxnII. $CaSO_4$(m)SO_2 (v) + O_2 (v)+CaO (m), based on the sulfur speciation in the melt and co-existing vapor. Individual partition coefficients for these reactions (, , are parameterized as functions of T, P, fO_2, H_2O, and melt composition, guided by published experiments. Furthermore, Sulfur_X tracks the evolution of sulfur and iron redox states in the system following the redox equilibria between S (S^{2-} and S^{6+}) and Fe (Fe^{3+} and Fe^{2+}) in the melt and SO_2, H_2S, H_2O and O_2 in the vapor using electron balance calculations.

Sulfur_X successfully predicts the distinct sulfur degassing trends described by rehomogenized melt inclusions from the 1974 eruption of Fuego Volcano, melt inclusions from Kilauea Volcano and submarine glasses from Mauna Kea Volcano. It also reproduces the evolution of Fe^{3+}/σFe in the Kilauea melt inclusions and S6+/σS and Fe3+/σFe in the Mauna Kea glasses during degassing, as measured by XANES. Our results show that a typical H_2O-rich (4.5 wt.%) arc magma with high initial S^{6+}/σS ratio (>0.5) will degas much more (2/3) of its initial sulfur at high pressures (> 200 MPa) than dry and reduced ocean island basalt, which will degas very little sulfur until shallow pressures (<50MPa).