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Monitoring Magmatic-Hydrothermal Eruptive Degassing at Costa Rican Volcanoes

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Costa Rica provides a natural laboratory for investigating magmatic-hydrothermal fluid interactions and eruptive processes. Here we report on the results of MultiGAS and DOAS near real-time monitoring of gas emissions from Turrialba and Poás volcanoes spanning several periods of unrest (2014-present) and present interpretations of the processes driving phreatic and phreatomagmatic eruptions. These volcanoes present distinctly different patterns of behavior in terms of degassing style and eruptive behavior, yet both are driven by mantle-subduction input and interaction of magmatic fluids with hydrothermal systems. Turrialba tends to show precursory peaks of CO_2/S_{total}, associated with variable H_2S/SO_2, followed by drops in both parameters. SO_2 emission rates are generally >500 T/d, and in some cases decrease before eruptions. At Poás, SO_2 emission rates increase before and during eruptions and are associated with decreases in CO_2/SO_2, whereas H_2S/SO_2 can display either increases or decreases before eruptions.

Both systems are ultimately driven by mantle input ($^3He/^4He$ >7 Ra) through complex and variably differentiated magmatic systems. Subduction fluids also contribute volatiles as can be seen in C and S isotope compositions. Infiltration of meteoric water in this wet tropical environment also plays a fundamental role, leading to gas-water-rock interactions that strongly influence gas compositions and particularly impacts S chemistry. Peaks in CO_2/S_{total} could either be caused by injection of deep magma or by hydrothermal scrubbing of SO_2, which should correspond with a decrease in SO_2 emissions and an increase in H_2S/SO_2. However, variations in H_2S/SO_2 could be caused by several processes including SO_2 dissociation reactions (scrubbing), interaction of oxidized magmatic gases with reduced hydrothermal fluids, pressure of magmatic gas equilibration, or remobilization of hydrothermally sequestered sulfur.

Eruptive processes at Turrialba and Poás seem to be the result of a dynamic tension between bottom-up and top-down processes. Hydrothermal conduit sealing due to the precipitation of secondary minerals likely plays a fundamental role in overpressurization prior to eruption and can occur very rapidly, as can magma injection triggering. The dynamics of S chemistry in magmatic-hydrothermal systems remains somewhat enigmatic yet is key in understanding volcanic gas precursors to phreatic eruptions.