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Passive degassing during quiescence: a trigger of volcanic unrest

Társilo Girona, Fidel Costa, and Chris Newhall
Earth Observatory of Singapore, Nanyang Technological University, Singapore (tarsilo1@e.ntu.edu.sg)

Unveiling what initiates a volcanic unrest is crucial for making progress towards improved eruption forecasts. Many active volcanoes, like Mayon (Philippines), Masaya (Nicaragua), and Etna (Italy), show a characteristic pattern: they alternate unrest episodes, sometimes culminating in strombolian-vulcanian eruptions, with quiescent periods dominated by abundant but passive gas emissions. These quiescent periods typically last between several months or a few years, and the mean passive gas fluxes (mainly of H_2O, CO_2, and SO_2) are on the order of several kilotonnes per day. Volcanoes with these features are the so-called openly degassing volcanoes. Here, we investigate if the duration of the quiescent periods of openly-degassing volcanoes is related to the gas released passively. We address this issue by developing a mass-balance lumped-parameter model that allows calculating how passive degassing affects the pressure at depth. Our model is driven by the gas fluxes measured with monitoring systems, and accounts for different conduit-reservoir sizes, the rheology of the crust, the bubble exsolution and expansion at depth, and the hydraulic connectivity between reservoirs and deeper magma sources. We find that, for a vast majority of scenarios, openly degassing volcanoes can depressurize several MPa in only a few months or years, coinciding with the inter-eruptive timescales. The depressurization rate is larger for larger gas fluxes, smaller magmatic systems, larger effective viscosities of the host-rock, deeper magma reservoirs, lower magma viscosity, and narrower dykes connecting the feeder magma sources with the reservoir. Our model also predicts that pressure drops of 5 - 10 MPa, considered critical for the evolution of volcanic systems, can occur after the volcanoes have released passively between 10^4 - 10^6 tonnes of SO_2. This mass loss of SO_2 matches with the average mass of SO_2 released passively between eruptions by a dataset of 22 openly-degassing volcanoes. Thus, our results suggest that many of the unrest episodes at openly-degassing volcanoes are causally linked to the gas emitted during quiescence. We propose that degassing-induced depressurization is a trigger of different physical processes, such as magma replenishment and fractures, which can culminate in unrest episodes and eventual eruption. This study opens the possibility to use the total mass of gas released during quiescence as a new proxy to anticipate unrest at openly-degassing volcanoes.