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Linking repose, intrusion and unrest times at openly degassing volcanoes

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Openly degassing volcanoes are among the most active on earth (e.g., Llaima, Etna, Stromboli, Mayon, Arenal), producing mildly explosive eruptions (VEI 1-3) every few months or years. During quiescence they deliver thousands of tones of gas per day to the atmosphere. Many of these volcanoes erupt similar bulk magma composition for decades and their deposits tend to be crystal-rich. Petrological and geochemical studies show that crystals are strongly zoned (e.g. Fe/Mg in olivine and pyroxenes), which can be interpreted as evidence for shallow crystallization and partial dissolution by intrusion of a volatile-rich primitive melt in a crystal-rich shallow reservoir/conduit. However, the time scales between the first intrusion and eruption can vary significantly: at Stromboli and Etna intrusion times are days to months, whereas in Mayon or Llaima they are months and years (e.g., Kahl et al., 2015; Ruth et al., in prep). There seems to be a correlation between volcanoes with longer repose periods showing longer times since the first intrusions and eruption, and perhaps also between the first unrest and eruption (Passarelli and Brodsky, 2012). The mass and pressure balance of open vent volcanoes suggests that magma intrusions could be induced by pressure instabilities driven by the gradual loss of mass occurring during quiescent degassing (Girona et al., 2015). We propose that during quiescence the shallow magma cools, degasses and crystallizes. This leads to an increase in viscosity and density of the resident magma, which becomes stiffer with time. Thus, volcanoes with longer repose times may need more magma replenishment before eruption, either through multiple intrusion episodes or larger intrusion volumes. The eruption frequencies or repose times of openly degassing volcanoes are the combined result of intrusion times (which depend on degassing fluxes) and the crystallization kinetics which depend on initial volatile contents and on heat diffusivity.