The geochemistry of magmatic solicitations on volcanic-hydrothermal systems: the long-standing unrest of La Soufrière de Guadeloupe dissected via non-condensable gases

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At volcanoes in unrest, the interpretation of geochemical time-series is a major issue for decrypting volcano dynamics and forecast eruptive scenarios. However, interpretation cannot be purely observational and demands the assessment of the main physicochemical features of the hydrothermal system. In the case of La Soufrière of Guadeloupe (FWI) andesitic volcano, a careful analysis of different techniques adopted historically for gas sampling and analysis by the local observatory has allowed us to model degassing and assess gas indicators from non-condensable species in the H\textsubscript{2}-N\textsubscript{2}-CH\textsubscript{4}-He-Ar system available since 2006. Here we report on the nature of discharged gases, resulting from the mixing of atmospheric component and a magmatic-hydrothermal gas evolving along a lineage connecting MORB-like upper mantle and arc-volcano components. We show that along this lineage we can track the hydrothermal build-up of pressure and temperature modulated by magmatic variations, particularly decompression. A careful analysis of inert gas fractionation allows recognizing two main regimes: one is about hydrothermal degassing conditions perturbed by the deep impulsive gas infiltration after magma refilling in a 4 to 8 km deep chamber; the other is determined by ascent of magma batches to a shallower (about 3 km deep) chamber. Further changes of the bulk permeability structure in the hydrothermal reservoir due to fracture sealing and clogging effect may exacerbate observed evolutions but do not represent the primary control of the degassing process. We also show that gas ratios in the H\textsubscript{2}-He-CH\textsubscript{4} subsystem can effectively discriminate and anticipate such tendencies and, particularly, they can be turned into reliable precursors of magma-derived solicitations and set possible thresholds for next crises. The main test is made with reference to the 2013-2014 and 2018
episodes of accelerated unrest: we confirm that the latter is as an aborted phreatic eruption, triggered by the injection of hot magmatic fluids into the magmatic system. On the other hand, for the 2013-2014 period, poorly studied, we document for the very first time the ascent of a small batch of magma which refilled the 3 km deep shallow magma chamber. This triggered seismicity just on top of the brittle-ductile transition. Besides, our method reveals that in 2007-09 an unrest phase similar to the 2018 one occurred, although not marked by the same seismic activity likely because the volcanic system was more sealed and less fractured before the magmatic upward excursion of the 2013-14 phase. Our results and conclusions are suitable for all those volcanic systems at the hydrothermal stage and allow a better definition of unrest scenarios whenever sampling frequency of fumarolic fluids is compatible with the expected transit times of magmatic fluids from magma chambers to surface.