S-Cl-F degassing during ascent and eruption of water-CO_2-rich alkali basalt: modelling and relationship with eruptive styles on Mount Etna.

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The degassing pattern of water- and CO_2-rich alkali basalts is poorly known, owing to the lack of experimental data, but can be constrained by studying dissolved volatiles in natural samples of such basalts. Mount Etna is a typical volatile-rich alkali basaltic volcano where a robust data set has been obtained for volatiles (CO_2, H_2O, S, Cl, F) dissolved in olivine-hosted melt inclusions. Based on data for two recent flank eruptions in 2001 and 2002 and central conduit eruptions in the period 1989-2000 [1,2, and references therein], here we present a pressure-constrained modelling of the evolution of S, Cl, F and S/Cl and Cl/F ratios in the melt and the gas phase during decompression, differentiation and degassing of water-CO_2-rich Etna magmas. Pressures have been derived from the H_2O and CO_2 content of the melt inclusions and the VolatilCalc software [3]. For each step of magma evolution, the vapour-melt partition coefficients D_S and D_{Cl} during either open or closed system degassing were derived from best fitting of melt inclusion data. Our results show significant differences, linked to magma dynamics, between lateral dyke eruptions and central conduit eruptions. The former are best described by closed-system ascent and degassing of the volatile-rich basaltic melt from >10 km depth b.s.l.. This process generates a surface gas with S/Cl molar ratio of 5.4 to 3.7, corresponding to an observed bulk Cl loss from 22% to 35%, that is very similar to the values measured in gas emissions of the 2001 and 2002 flank eruptions using OP-FTIR spectroscopy [4,5]. The lower value reflects more efficient Cl release during enhanced magma fragmentation in the external envelop of more energetic lava fountains. Instead, any pre-eruptive gas-melt separation at depth produces higher S/Cl ratio in surface gas. As an example, a ratio of 19, as measured in late November 2002 [5], implies gas separation from ∼50 MPa

($\sim$2 km below vents). Closed system magma ascent in the central volcano conduits produces the same pattern as in lateral dykes. However, more common conditions of slower magma rise or even ponding in these conduits favour sulphide saturation of the magma (sulphide globule), possible open degassing, and therefore strongly affects the evolution of S/Cl ratio (reduction by factor of $\sim$2 at similar pressure). Taking account of this process, we verify that a S/Cl ratio of 10 as was measured during a powerful summit lava fountain in June 2000 [6] can only result from gas accumulation and separation at $\sim$2 km depth below the crater. This magic depth actually corresponds to the transition between the volcanic pile and its sedimentary basement, where magma may temporarily reside. Finally, the sustained non eruptive excess degassing through Etna summit craters [7], with mean S/Cl ratio in the range 1.5-3, requires that volatile-rich magma rises up to very shallow depth ($\leq$1 km) in central conduits, before bubbles can migrate upward separately. At such a level the magma vesicularity ($\geq$45%) exceeds the permeability threshold and both convective overturn and magma permeability may contribute to sustain the excess gas flow. Hence, our modelling provides a reference background to which routine monitoring of Etna gas emissions could be referred to. In particular, it verifies that the S/Cl ratio can be used to distinguish between the different source mechanisms of lava fountains [6]. More broadly, the conclusions drawn for Etna shed new light on the driving degassing mechanisms at open-conduit basaltic volcanoes, particularly when their magmas are rich in water and carbon dioxide.

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