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One decade of OP-FTIR monitoring of Mount Etna gas plume emissions: lessons and implications

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Solar occultation OP-FTIR measurements of Mt. Etna volcanic plume emissions have been carried out on average 1-2 times per week since March 2000 by geochemists from INGV-Catania, providing the largest such data set ever obtained, on a very active basaltic volcano. These measurements allowed simultaneous retrieval of the bulk plume content of SO2, HCl and HF – three gas species with highly contrasted solubility behaviour in Etnean magma. Important temporal variations in SO2/HCl, HCl/HF and SO2/HF ratios and in the HCl and HF fluxes (obtained from routine UV monitoring of the SO2 plume flux) were observed in relationship to volcanic activity, providing important constraints on the processes of magma feeding and degassing. Between and during eruptions we observed large systematic variations in the volcanic plume composition released from the summit craters, with SO2/HCl varying between 1 and 8, SO2/HF between 3 and 60 and HCl/HF between 2 and 6. SO2 fluxes varied from 500 tonnes per day (t/d) to 25,000 t/d. These remarkable variations in gas emissions contain critical information on the state of the volcano. Eruptions were found to be preceded by several weeks to months of increasing or elevated SO2/HCl and SO2/HF ratios, produced by a relative reduction in the fluxes of more soluble HCl and HF from the volcano. Based on recent studies of melt inclusions and gas percolation, this observation can be accounted for by magma convection (in which buoyant, vesiculating magma rises up through a sinking flow of dense degassed magma to the surface) and separate gas flow once the vesiculating magma becomes sufficiently permeable. Calculations of vesicularity as a function of pressure suggest that gas percolation may begin at pressures of up to 100 MPa. We will show that the heightened SO2/HCl ratio observed prior to Mt. Etna's eruptions is consistent with inefficient magma circulation that partially inhibits ascent of magma to the surface and enhances the probability of eruptions. Cumulative plots of the mass of degassed SO2, HCl and HF allow detailed examinations of such deviations from steady-state magma supply. We also frequently observe recovery from such deviations, suggesting that the magma supply system is efficient over a wide range of pressures, from depths of 3-5km where SO2 begins to exsolve, up to the near surface, where HF is lost from the magma. The combination of these unique, decade-long observations of SO2, HCl and HF allow us to define a well-constrained model for the magma and gas dynamics that provide the fundamental control on volcanic activity at Mt. Etna.