New insights into volatile adsorption by tephra in volcanic eruptions

Paul M Ayris[1], Pierre Delmelle[2], Elena Maters[2], Donald B Dingwell[1]

[1]Ludwig Maximilians Universitat, Germany, [2]Universite Catholique de Louvain, Belgium

E-mail: paul.ayris@min.uni-muenchen.de

The scavenging of S, Cl and F –bearing volatiles by silicate ash from eruption plumes is a source of diverse physical and chemical effects in volcanic, atmospheric and environmental systems. Retention on ash particles within the plume decreases the volcanic volatile flux to the atmosphere, moderating any perturbation of its chemical or radiative properties. The soluble salts and aqueous acids formed by scavenging may alter ash surface properties, influencing dispersal and fallout by promoting particle aggregation. Upon deposition into the environment, aqueous leaching of the ash surface may result in corrosive damage to vegetation and calcareous biota; algal blooms in lake and ocean surface waters; and changes to soil and sediment pore water chemistry. To determine the severity and significance of these potential effects requires knowledge of the abundance and chemical properties of the salts and acids formed on the ash surface. This necessitates a new, in-depth and quantitative understanding of volatile scavenging mechanisms, expanding upon the simple, conceptual, 'solid aerosol adhesion – volatile adsorption – acid condensation' scavenging model proposed by N. Oskarsson in 1980.

Here we present the results of SO_2 and HCl uptake experiments on tephrite, phonolite, dacite and rhyolite glass powders conducted over a range of in-plume temperatures (100–800°C). We identified coupled adsorption-diffusion mechanisms driving SO_2 and HCl scavenging. These volatiles reacted with Ca- and Na-bearing surface sites to form $CaSO_4$, Na_2SO_4 and NaCl deposits, sustained respectively by near-surface co-diffusion of O^{2-} with Ca^{2+} or Na^+, and interdiffusion between H^+ and Na^+. Our experimental results identify the thermal, temporal and compositional controls acting in the post-fragmentation conduit and eruption plume which regulate the adsorption of SO_2, HCl, and by analogy, HF, on ash surfaces. This constitutes the first significant update to the classical scavenging model of Oskarsson in over thirty years. Using our experimental data, and by reference to plume evolution and conduit flow models, we constructed a predictive model of SO_2 and HCl adsorption by tephra surfaces. We therefore highlight those eruptions where gas-ash interactions may strongly affect ash surface chemistry and the intensity of any induced physical or chemical effects in volcanic, atmospheric or environmental systems.