Petrological Methods for Evaluating the Sulfur Yield of Past Eruptions

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Sulfur in magmas resides in three main reservoirs: the silicate melt, S-bearing crystals such as pyrrhotite and anhydrite, and the fluid phase. We presently have three petrological tools to restore the sulfur content of magmas: analyses of melt inclusions, thermodynamic calculations and hydrothermal experiments. Analysing the sulfur concentration of melt inclusions trapped in phenocrysts allows to retrieve the pre-eruptive S concentration of the melt phase but, owing to the possible presence of a coexisting fluid phase, this method has been shown to underestimate the sulfur content of magmatic reservoirs by more than 2 orders of magnitude. Thermodynamic calculation of heterogeneous (fluid-melt) and homogeneous (fluid) equilibria help constrain the fluid phase composition. From measured H2O, CO2 and S abundances, the corresponding fluid species fugacities (fH2O, fCO2 and fS2) can be derived using thermodynamic models of volatile solubilities, which in turn allow calculation of the composition of the fluid in the COHS system, at the P-T conditions of magma last equilibration. Application of this approach to well characterised andesitic to rhyolitic explosive eruptions shows that the S concentration in the fluid ranges from negligible to up to 6-7 wt%. Assuming that 1-5 wt% fluid is present at depth, and considering the typical S content of silicate melts under pre-eruptive conditions, then more than 90 % of S is stored in the fluid phase. The validity of the thermodynamic approach heavily relies on the accuracy of the determination of pre-eruptive P and T parameters. The best way to determine these parameters is via conventional experimental petrology. Application of the above three methods to the Mt Pinatubo (1991) and Huaynaputina (1600) eruptions, shows that the magmas were indeed fluid-saturated, as required by either TOMS (Pinatubo) or ice core (Huaynaputina) constraints. Clearly then, detailed petrological characterisation of the eruption products combined to thermodynamical calculations as well as phase equilibrium constraints, are all needed to assign correct values of sulfur atmospheric loading of past explosive events. Only a few such studies have been carried out and they still do not enable to propose an average volcanic S-input even for historical times. Such a work remains to be done for most historical eruptions and appears to be a necessary step for a rigorous validation of ice-core based S estimates that form the main source of information built in volcanic forcing of climate models.