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Sulfur and fO_2 evolution of the 1257 AD Samalas eruption (Indonesia), viewed through the apatite lens

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The injection of sulfate aerosols into the stratosphere by plinian eruptions of low latitude volcanoes can cause global cooling of multiple degrees over multi-year timescales. The 1257 AD eruption of Mount Samalas (Lombok, Indonesia) was the source of the largest bipolar sulfate aerosol fallout anomaly in polar ice core records for the last 2,000 years. Recent microgeochemical work on melt inclusions and crystal cargo of this eruption demonstrated that a narrow range of redox conditions is required for the retention of sulfur and its subsequent partitioning into a fluid phase preceding eruption (Ding et al., 2025) . Furthermore, magma recharge must be invoked to achieve the high volumes of eruptible sulfur produced by the climactic eruption.

We further explore the redox and recharge evolution of the Samalas system by investigating sulfur concentrations and isotope ratios in apatite crystals from the 1257 eruption and the preceeding, lower volume, 2550 BP trachydacite eruption. These data are combined with published S isotope ratio, concentration and speciation measurements from melt inclusions from the same samples to present a wholisitc picture of the complex evolution of this magmatic system.

Sulfur isotope ratio and concentration measurements were conducted via secondary ionization mass spectrometry. Concentrations are calculated from the same analytical volume as isotope ratios utilizing Cl as a ratioing element (measured independently via electron microprobe). This method allows for a much tighter correlation between sulfur isotope and concentration measurements in complex, zoned crystals.

S isotope ratios and concentrations in apatite crystal cores and apatite inclusions in plagioclase from both eruptions suggest a similar source for incoming magmas with a $\delta^{34}S_{V\text{-}CDT}$ of ~ 9‰ and S concentrations that are compatible with previous estimates of 870 ppm S. Both eruptions evolve along redox-controlled trajectories from lower to higher fO_2. The 1257 sample records the subsequent transfer of sulfur to the fluid phase, with falling S concentrations in apatite crystal mantles and rims. Apatite phenocryst rims match concentrations and isotope ratios calculated from melt inclusions and matrix glasses.

[1]Ding et al., 2025, *Nature Comm.*