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New insights into the ~74 ka Toba eruption from sulfur isotopes of polar ice cores

Laura Crick¹, Andrea Burke¹, William Hutchison¹, Stephen Sparks², Sue Mahony², Eric W. Wolff³, Emily A. Doyle³, James W. B. Rae¹, Joel Savarino⁴, Mika Kohno⁵, Sepp Kipfstuhl⁶, and Gerhard Wörner⁵

¹School of Earth and Environmental Sciences, University of St Andrews, St Andrews, UK (lc258@st-andrews.ac.uk)

²School Of Earth Sciences, University Of Bristol, Bristol, UK

³Department Of Earth Sciences, University Of Cambridge, Cambridge, UK

⁴Institut des Géosciences de l'Environnement, Grenoble, France

⁵Department of Geochemistry, GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN, Göttingen, Germany

⁶Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

The ~74ka Toba eruption in Indonesia was one of the largest volcanic events of the Quaternary and loaded an estimated 100 million tonnes of H₂SO₄ into the atmosphere. Understanding the precise timing of this colossal eruption is vital to unravelling the climatic and environmental impacts of the largest volcanic events on Earth. Sulfur aerosols injected into the stratosphere following large volcanic events scatter incoming radiation and lead to global cooling, and in the case of Toba it has been suggested that it led to cooling of 1 – 5°C and extinctions of some local hominin populations. One of the most enigmatic features of the Toba eruption is that the S peak has yet to be identified in the ice core records, although numerous candidate sulfate peaks have been identified in both Arctic and Antarctic ice cores. To address this, we analysed the sulfur isotope fingerprint ($\delta^{34}\text{S}$ and $\Delta^{33}\text{S}$) of 11 Toba candidates from two Antarctic ice cores by multi-collector inductively coupled plasma mass spectrometry. This approach allows us to evaluate injection altitudes and to distinguish large tropical eruptions from proximal eruptions because stratospheric sulfur aerosols undergo UV photochemical reactions that impart a sulfur mass-independent isotopic fractionation (S-MIF). In contrast, tropospheric sulfur aerosols do not exhibit S-MIF because they are shielded from the relevant UV radiation by the ozone layer.

We identify three stratospheric, tropical eruption candidates with two recording the largest $\Delta^{33}\text{S}$ signals measured to date in the ice core archives. The largest of these $\Delta^{33}\text{S}$ signals is >2 ‰ more negative than previous measurements of the 1257 Samalas eruption (the largest eruption of the last 2000 years), despite having a similar integrated sulfate flux for this event to the ice core. These three candidates are within uncertainty of the Ar⁴⁰/Ar³⁹ age estimates for the Toba eruption and when considered with other paleoclimate proxies place the event during the transition into Greenland Stadial 20. Finally, we further analyse the relationship between the Toba eruption candidates and these proxies to determine the precise timing and potential climatic impacts of one of the largest eruptions of the Quaternary period.

