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Sulfur-in-clinopyroxene: tracing potential volcanic winters in deep time from a within-magma perspective

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Large Igneous Province (LIP) volcanism is a major driver of past global change via degassing of large volumes of climate-altering and poisonous gases (such as H₂O, CO₂, CH₄, SO₂). These volatile species can produce contrasting effects on the atmosphere, from long-term global warming to short-lived volcanic winters. We know from historical cases (e.g., the 1783–84 Laki fires, the 1991 Pinatubo eruption) that sulfur-rich eruptions can produce global cooling with societal consequences. In deep time, repeated volcanic winters occurring during LIP emplacement, superimposed on long-term warming, could have stressed ecosystems and contributed to mass extinction, but their short duration makes them difficult to detect in the stratigraphic record (Callegaro et al., 2020; 2023; Kent et al., 2024). Sedimentary proxies of short-term cooling such as glendonite crystallization are being explored, but their signals remain ambiguous (Vickers et al., 2020). We propose a complementary, “within-magma” approach for tracing sulfur-rich magmatic pulses capable of generating volcanic winters. Using synchrotron X-ray microfluorescence, we measure sulfur concentrations in clinopyroxene from LIP magmas, and calculate equilibrium melt concentrations with established partition coefficients. Since clinopyroxene is an early and almost ubiquitous phase in LIPs magmas, this method allows the detection of variations in sulfur budgets throughout the stratigraphy of a lava pile, identifying intervals of sulfur-rich lavas as potential drivers of volcanic winters. We discuss future developments of the method, and results obtained for magmas of the Deccan Traps (Western Ghats lava pile, India), and Franklin large igneous province.

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