Assessing the significance of sulfate driven cooling for the Deccan Traps

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Large igneous province (LIP) eruptions impacted the environment through the emission of CO_2 and SO_2. The long lifetime of CO_2 in the atmosphere can lead to volcanogenic warming persisting for 10s or 100s of thousands of years (ka). In contrast, SO_2 release is hypothesized to cause significant and rapid global cooling for only the duration of each individual eruption, as the lifetime of sulfate aerosols is short (<2 years). The actual magnitude and duration of these cold "snaps" is not known, as due to their brevity, it is difficult to detect them in paleoclimate records with 1-2 ka resolution. In order to indirectly estimate their dynamics, we must address two key challenges: 1) did the sulfur (S) reach the stratosphere and was it widely distributed as required for global climate effects? and 2) how long and frequent were individual eruptions? At present, radioisotopic dating of Mesozoic LIPs is currently unable to resolve individual eruptions (<10 ka).

We investigate the Deccan Traps (DT) LIP, using new high-resolution (2-7 ka) terrestrial mercury (Hg) concentration and S and carbon (C) isotope records spanning 66.3 to 65.1 Ma, from NE Montana. The Hg record has peaks and higher background during the main Deccan eruptive interval (66.3-65.6 Ma). Simultaneously, the S isotope composition shifts to values similar to mantle derived SO_2. Both changes are independent of S and C concentration and lithology. This is the first direct evidence of global distribution of LIP-derived sulfate aerosols.

Using the Hg record coupled with an environmental Hg box model and statistical framework, we find that the eruptions on average lasted 50-500 years, occurred every 2-4 ka, and erupted ~50 km^3/yr of basalt. We use a modified LOSCAR model to predict the environmental effects of CO_2 and SO_2 for these eruptions and find a cooling of ~2 degrees during each eruption as well as long-term warming. We compare these quantitative predictions with global paleoenvironmental records and find systematic increases in variability in high-resolution records during this interval. Hence, in addition to CO_2 warming, sulfur-driven cooling is confirmed to have been a significant process during the DT eruptive interval, resulting in environmental and ecological perturbations.