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Nitrates Production by Volcanic lightning during Explosive Eruptions

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Volcanic lightning during explosive eruptions has been suggested has a key process in the abiotic nitrogen fixation in the early Earth. Although laboratory experiences and thermodynamic models convincingly suggest that volcanic lightning can fix atmospheric nitrogen (e.g. Navarro-Gonzalez et al., 1998, Martin et al., 2007). No geological archives of N-fixed by volcanic lightning have been found yet. Recently, high nitrate concentrations in volcanic deposits from large Neogene explosive eruptions (VEI>7; Aroskay et al. 2023) have been discovered. It is tempting to infer that these nitrates correspond to the end-product of N-fixation by volcanic lightning. However long-term atmospheric deposition of nitrate is suggested to be responsible of nitrate deposits in arid environment (e.g. Atacama Desert and Mojave Desert – Michalski et al. 2004, Lybrand et al. 2013). Therefore, the long-term atmospheric deposition could contribute to nitrates preserved in volcanic deposits.

Our study aims to distinguish the origin of nitrates in volcanic deposits: end-product of volcanic lightning or long term atmospheric deposition? To answer this question, volcanic samples from super-eruptions as well as sediments have been collected in the Tecopa Basin – California, USA. The whole sedimentary column (sediments interspersed with volcanic deposits) has been preserved in the same arid conditions for the last 2Ma. The multi-isotopic composition of nitrate has been measured ($\delta^{18}O$, $\delta^{15}N$ and $\Delta^{17}O$) and shows clear distinction between nitrate from volcanic deposits and those from sediments. It appears that while nitrate from sediments result from a mix between atmospheric nitrate and biogenic nitrate, in volcanic deposit the nitrate are most likely the end product of volcanic lightning.

As a conclusion, we demonstrate that volcanic deposits can be an archive of N-fixation by volcanic lightning. This is an open window on the direct quantification of N-fixation by large explosive volcanic eruptions and their role on the development of life on the early Earth.