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Fulgurites: the Earth's minute melts and their interaction with the atmosphere

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Fulgurites are silicic melts formed by lightning discharge, causing milliseconds-long heating of the target rock to temperatures commonly in excess of 20,000°C. Fulgurite forms typically show elongated hollow tubes of massive to vesicular glass, transitioning laterally to unmelted rock. We here report the first triple oxygen isotope analyses of a worldwide collection of natural fulgurites, fulgurites formed by fallen powerlines, and synthetic experimental fulgurites generated in a high-voltage and high-current apparatus, simulating actual lightning conditions [1]. The collection spans compositions ranging from dunites to rhyolites to quartz sand. We investigate whether they record rapid exchange with high-$\delta^{18}O\approx+24‰$, low-$\Delta'^{17}O\approx-0.5‰$ atmospheric oxygen, or with low-$\delta^{18}O$, high-$\Delta'^{17}O$ soil and groundwaters. Clayton et al. (1986, 2) and Pack (2021, 3) reported that low-$\Delta'^{17}O$ values are recorded by tektites and experimental glass spheres exposed at the air/gas interface, over 1-100 sec of heating to 1300°C, and a 0.1‰ $\Delta'^{17}O$ drop occurs within 5 sec. Some tektites and crusts of iron meteorites exhibit low-$\Delta'^{17}O$ values, suggesting an interaction of high-temperature atmospheric friction melts with low-$\Delta'^{17}O$ atmospheric O_2. Our Fe-poor experimental fulgurites reacted with air for a maximum of 0.1-0.5 sec and do not exhibit measurable shifts in $\delta^{18}O$ and $\Delta'^{17}O$ values, and further experiments of longer duration are pending. We also observe moderate -0.04‰ shifts to low-$\Delta'^{17}O$ values for several natural fulgurites, including Mt Thielsen, Oregon andesitic fulgurites, and an experimental dunitic fulgurite, and a positive shift +0.05‰ in an industrial (fallen powerline, wet soil fulgurite). The talk will report more data and analysis of lightning interacting with surface materials and explore the use of fulgurites as a tool to measure atmospheric oxygen isotopes.

[1] Çalışkanoğlu et al. (2023) Sci. Rep., 13:11685; [2] Clayton et al. (1986) EPSL 79, 235. [3] Pack (2021) RIMG 86, 217.