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Insight on gem opal formation in volcanic ash deposits from a supereruption: A case study through oxygen and hydrogen isotopic composition of opals from Lake Tecopa, California, U.S.A.

Erwan Martin[1,*] and Eloïse Gaillou[2]

[1]Sorbonne Université, CNRS-INSU, Institut des Sciences de la Terre Paris, ISTeP UMR 7193, F-75005 Paris, France
[2]MINES ParisTech, PSL Research University, Musée de Minéralogie, 60 boulevard Saint-Michel, 75006 Paris, France

Abstract

At Lake Tecopa, in California, white play-of-color opals are found in vesicles of a volcanic ash layer from the Huckleberry Ridge Tuff super-eruption (2.1 Ma). They show characteristic traits of opal-AG by X-ray diffraction and scanning electron microscopy (silica spheres of ~330 nm). These properties are not typical for volcanic opals, and are usually associated with opals formed in a sedimentary environment, such as opal-AG from Australia. The conditions under which opal was formed at Lake Tecopa were determined by oxygen and hydrogen isotopic analyses and give a better understanding of the formation of opal in general.

Tecopa opal's $\delta^{18}O$ is ~30‰, which leads to a formation temperature between 5 and 10 °C from water composition similar to the present spring water composition ($\delta^{18}O = -12$‰), or between 15 and 30 °C (the present day spring water temperatures) in water having a $\delta^{18}O$ between –9.5 and –5.5‰. As a result, opal experienced 25–50% evaporation at the Tecopa basin. Contrary to long-held views, the formation of opal-AG vs. opal-CT (or opal-C) is not determined by the type of deposits, i.e., respectively sedimentary vs. volcanic, but mostly by the temperature of formation, low (≤45 °C for opal-AG) vs. high (≥160 °C for opal-CT) as suggested in most recent papers.

The isotopic composition of water contained in Tecopa opals is assessed and results show that water in opal records different stages of opal formation from groundwater. Opal seems to precipitate from groundwater that is undertaking isotopic distillation during its circulation, most likely due to 15% up to 80–95% evaporation. Hydrogen isotopes are poorly documented in opal and require more systematic work, but this study reveals that, in Tecopa opals, molecular water (H_2O_m) is isotopically heavier than structural water (OH), a phenomena already well known in amorphous volcanic glass. Overall, opal isotopic composition reflects the composition of the water from which it precipitated and for that reason could be (as established for amorphous silicic glass) a useful tool for paleoenvironments, and paleoclimatic reconstitutions on Earth and on other terrestrial planets.

Keywords: Gem opal formation, oxygen and hydrogen isotoptes, volcanic deposit, paleoclimate and paleoenvironments, Lake Tecopa Basin