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LIP Dikes as Paleoclimate Archives: A Global $\delta^{18}O$ Record of Hydrothermal Alteration

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While the eruption environment of Phanerozoic LIPs (submarine, continental, subglacial, deep crustal and shallow crustal) can often be inferred from the sedimentologic and geologic records, this is not the case for the fossil-free Precambrian record. Stable isotopes of O and H can help, as water-rock interaction environment-specific isotopic signatures of surface water are preserved. By investigating triple oxygen isotopes in dikes and adjacent country rocks of Large Igneous Provinces (LIPs), which cool slowly in the presence of ground waters (if shallow enough), we can gain insights into ancient parental waters at variable water-rock ratios. When dikes are emplaced at depths exceeding 3 km, the extent of oxygen exchange between the altering meteoric waters and the whole rock is limited, and mantle signatures prevail. We used the youngest and best-exposed LIP, the Columbia River Basalt group (CRB), where multiple dikes are exposed at a known erosional level of 0-2 km to test our results. We found that out of the 146 CRB dikes analyzed, 32% were depleted in $\delta^{18}O$ (Vialichka and Bindeman, 2025, ref 1) however, triple O and H isotopes returned expected interglacial Miocene water signatures. These depletions are linked to shallow meteoric hydrothermal activity in the crust. We also report on widespread hydrothermal effects around dikes that intruded between 2.5 Ga and 16 Ma. We aimed to identify low $\delta^{18}O$ signatures in the global record that could serve as fingerprints of surface waters interacting with cooling dikes and adjacent country rocks at elevated temperatures. Our findings reveal that 30% of the analyzed 300 different dikes exhibit clear evidence of high-temperature hydrothermal alteration, indicated by $\delta^{18}O$ signatures below 4.8‰.The most depleted sample thus far comes from the ca. 2.37-2.36 Ga Bangalore LIP in India, with a $\delta^{18}O$ signature of -0.7‰. Plutonic rocks (dikes and intrusions) associated with LIPs also produce climate effects via magmatic devolatilization of sediments and by interaction with the hydrosphere. The search for ultra-low $\delta^{18}O$ glacial meltwaters worldwide dikes continues, pertaining to episodes of Neo and Paleoproterozoic Snowball Earth and Permian glaciations.

[1] Vialichka K, Bindeman IN (2025) Chem Geol 696 /10.1016/j.chemgeo.2025.123087