Abstract

The analysis of triple oxygen isotopes ($\delta^{17}O$ and $\delta^{18}O$) in various natural compounds is increasingly being used to understand the chemical pathways in terrestrial and extra-terrestrial processes. Due to analytical difficulties related to the low abundance of ^{17}O and the production of NF_3 contamination during sample fluorination, $\delta^{17}O$ measurement in silicates and oxides remained restricted to a few laboratories worldwide. Despite many earlier works, there is no widely accepted analytical technique for precise and accurate $\delta^{17}O$ measurement. The present work developed a simple cryogenic cleaning method that ensures precise and accurate measurement of $\delta^{17}O$, $\delta^{18}O$ and $\Delta'^{17}O$ with a precision of $\leq \pm 0.1$‰ and ± 4–6 ppm, respectively. Prior to measurement, the effects of a few other factors namely sample size, BrF_5 cleaning, ablation technique etc. were also investigated those might cause unintended sample O_2 fractionation. Once the experimental protocols were established, the technique was applied to two specific geological problems: (1) Understanding the genesis of basalts from Deccan Volcanic Province (DVP), and (2) Effect of Deccan volcanism on the climate at Cretaceous Paleogene boundary (CTB). For the first objective, basalt samples were collected from the Bushe, Poladpur, Ambenali, and Mahabaleshwar Formations, which comprise about 80% of the DVP. Elemental and triple oxygen isotopic compositions of these basalts demonstrate that their source magma originated from mixture of the Réunion hotspot mantle and CIR-MORB (Central Indian Ocean-Mid-Ocean Ridge Basalt) source magma with varying degrees of partial melting of a spinel-garnet lherzolite rock. The mean $\delta^{18}O$-$\Delta'^{17}O$ values of Bushe, Poladpur, Ambenali, and Mahabaleshwar basalts are 6.0 ± 0.3‰, - 49 ± 8 ppm; 5.8 ± 0.4‰, - 51 ± 6 ppm; 5.4 ± 0.3‰, - 39 ± 11 ppm; and 5.6 ± 0.3‰, - 38 ± 8 ppm respectively. The data suggest that the Bushe basalts were most contaminated (~60%) with upper continental crust while Poladpur (~20%), Ambenali, and Mahabaleshwar (~10%) have much lower contamination. The Poladpur basalts are distinct with its source having ~70% MORB type magma and is much higher than Ambenali type (~35% MORB) source. This is in contrary to earlier inference of Poladpur basalt generated from Ambenali type source with finite amount of crustal contamination. Poladpur volcanism, synchronous to the Chicxulub crater at ~65.5 Ma, has been inferred to be a product of global seismic disturbances by impact that triggered highest rate of volcanic outpour (>10 km^3/year) during the DVP. It is possible that such a disturbance drove deep plumbing of the shallow upper mantle above the Réunion plume rapidly mobilising higher volume of magma from the source of modern-day CIR-MORB through the already existing conduits. Our data also shows that the contribution of MORB type magma decreases in basalts overlying the Poladpur Formation, probably due to subsidence of the impact generated seismic energy. For the second objective, host basalts, opal, silicified wood, and gastropod shell samples were collected from DVP intertrappean sediments with $\delta^{18}O$ and $\Delta'^{17}O$ ranging from 5.6 to 5.7‰, -76 to -54 ppm; 22.1 to 22.6‰, -113 to -107 ppm; 20.2 to 26.6‰, -110 to -46 ppm; and 21.0 to 22.8‰, -40 to -87 ppm respectively. The data suggest wood-silicification at temperatures between 24 and 92°C, mediated by fluid with a $\delta^{18}O$ range of -14 to 0‰. The depleted range of $\delta^{18}O_{fluid}$, associated with silicification temperatures, close to Cretaceous land surface temperatures (25–36°C), is assumed to represent local meteoric water. The enriched $\delta^{18}O_{fluid}$ range associated with higher temperature is similar to the local hydrothermal condition obtained from opal and basalt $\delta^{17}O$ - $\delta^{18}O$ ratios, indicating a mixing of meteoric water and hydrothermal water during silicification. When compared to current precipitation (-5‰ in central India), the mean meteoric water composition from Cretaceous (-12‰) and Paleogene (-11‰) samples are 7 − 6 ‰ more depleted. This translates to an increased paleo-rainfall of 1700–1800 mm/yr (against ~1200 mm/yr today) possibly driven by higher Deccan induced CO_2 as predicted by various climate models.

Keywords: Triple oxygen isotope, silicates, protocol establishment, Deccan volcanic province, genesis of basalts, silicified wood, paleoclimate.