O-isotope evidence for a hydrothermally altered volcanic roof to the Bushveld Complex

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The preserved rocks of the Bushveld Complex are mainly plutonic, and intrusion culminated in the production of > 90 000 km^3 of granite and granophyre. We present mineral $\delta^{18}O$ values that suggest that these granitic magmas assimilated hydrothermally altered material, presumably from a once substantial volcanic edifice. In the granites and granophyres, high-temperature equilibrium O- isotope fractionations are preserved between quartz and zircon, but not between quartz and feldspar, with many samples having -ve values for $\Delta_{quartz\text{-}feldspar}$. Quartz separated from four granite samples, showed no significant difference in core and rim $\delta^{18}O$ values. These data indicate that quartz was not significantly affected by the alteration that raised feldspar $\delta^{18}O$ values. Quartz is, therefore, a reliable proxy for magma $\delta^{18}O$ values in these rocks, leading to estimates of 6.8‰ (assuming $\Delta_{quartz\text{-}magma}$ = 1.18‰), and 6.9‰ (assuming $\Delta_{quartz\text{-}magma}$ = 0.66‰) for the granites and granophyres, respectively. Similar magma $\delta^{18}O$ values (6.6‰) were obtained from zircon data, assuming $\Delta_{zircon\text{-}magma}$ = -1.3‰. The similarity in $\delta^{18}O$ value between granites and granophyres from the three major lobes of the complex suggests a common origin.

Whereas the mafic and ultramafic rocks of the Rustenburg Layered Suite (RLS) have abnormally high $\delta^{18}O$ values (7.1‰) compared to other layered intrusions, the Bushveld granites have abnormally low $\delta^{18}O$ values compared to granites worldwide. Both the RLS and the granitic rocks have similar crustal ε_{Nd} values (mean = -6.4 and -5.3, respectively). Granitic magma derived from mafic magmas similar to those that produced the RLS would have had a magma $\delta^{18}O$ value of about 7.7‰, 1‰ higher than observed. We therefore suggest that the granite magmas assimilated a significant quantity of hydrothermally altered volcanic material with low $\delta^{18}O$ value as has been postulated for Yellowstone.

Cloud processing measured with sulfur isotopes during HCCT 2010

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Processing of aerosol by clouds has been shown to modify the CCN spectrum, leading to important climatological effects [1, 2]. In-cloud SO_2 oxidation and uptake of sulfate play a large role in this processing, causing both mass increases and hygroscopicity changes. However, the uptake of sulfate and SO_2 is not well constrained or resolved for different particle types and sizes [3, 4].

This study uses isotopic measurements to investigate the uptake of sulfur to particles in an orographic cloud during the HCCT campaign. The campaign took place at the Schmücke mountain in Germany and used connected flow conditions between measurement sites to study the evolution of air masses due to cloud processing. The FEBUKO campaign at the same site saw in-cloud mass production of up to 0.38 µg m^{-3}, 5% of the upwind aerosol mass [5]. Upwind, downwind, cloud droplet residue and interstitial particles were collected during HCCT, as well as SO_2 and H_2SO_4 gases at upwind and downwind sites. NanoSIMS isotopic analysis was then used to constrain the formation and uptake of sulfate in the cloud.

Clear changes were seen in the isotopic composition of the samples between the different sites. Sulfuric acid was depleted in ^{34}S following the cloud. Fine particles were enriched in ^{34}S, consistent with H_2SO_4 condensation as the dominant process. Coarse droplets were also enriched in ^{34}S following the cloud, however SO_2 oxidation to sulfate appeared to be the dominant process. In two out of three measured events, SO_2 gas was enriched while coarse mineral dust sulfate was depleted in ^{34}S, showing a reaction other than aqueous oxidation by H_2O_2 or O_3 had dominated overall SO_2 removal. Laboratory studies are being carried out to identify this 'missing' in-cloud oxidation pathway.

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