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Volatile characteristics of Central American geothermal fluids

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Earth's various mantle retain distinct volatile geochemical features that inform our understanding of planetary accretion, mantle convection and mixing, as well as subduction-driven recycling processes. At subduction zones, volatile elements (e.g., helium, carbon, nitrogen) are actively cycled between terrestrial reservoirs by plate tectonics. The efficiency of volatile transfers between Earth's interior (crust and mantle) and exterior (atmosphere and oceans) controls Earth's redox conditions, mantle heterogeneities and atmospheric evolution.

The Central America Volcanic Arc (CAVA), is one of the best studied arc segments globally. However, relatively few studies have focused on constraining volatile fluxes throughout the southern segment of the CAVA due to the lack of active volcanism in the region. This area represents the transition between the orthogonal subduction of the Cocos Plate and the oblique subduction of the Nazca Plate relative to the Caribbean Plate. Here, we present unpublished He, CO_2 and N_2 isotope and relative abundance data from geothermal fluids in southern Costa Rica and western Panama from 65 localities. These data reveal a clear southeastward increase in $^3He/^4He$, from typical volcanic arc values in Costa Rica, up to 8.9 R_A, equivalent to the highest values ever reported for active volcanic arc settings worldwide. These data suggest contribution from a ^{3}He-rich mantle source under western Panama, potentially associated with the presence of Galapagos plume-related material and occurrence of a prominent tear in the slab beneath the CAVA. Carbon isotopes are consistent with CO_2 loss due to calcite precipitation. N isotopes and clumped N isotopologues in CAVA samples cluster around +5‰ vs. air, suggesting that N in subduction zone fluids is mainly derived from isotopically heavy sediments. Flux considerations suggest that subducting N may be quantitatively recycled into the arc, although uncertainties on fluxes allow up to 63% of slab-N to be transported into the mantle past the arc melting region. In summary, we show evidence for 1) the existence of a pervasive (plume) mantle component in southern CAVA samples, and 2) extensive CO_2 fractionation during low temperature C sequestration as calcite in the forearc region, and 3) strong N sediment signatures in arc fluids.