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Method development for routine heavy noble gas isotopic analysis in commonly available oceanic basalts

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Isotope systematics of heavy noble gases (Ne, Ar, Kr, and Xe) can provide powerful insights into volatile origins as well as the outgassing and volatile recycling histories of Earth's deep reservoirs [1-5]. However, obtaining high-precision mantle-derived heavy noble gas isotopic signatures is analytically challenging for the majority of oceanic basalt samples due to (a) low gas contents and (b) the presence of alteration minerals bearing atmospheric gas and/or driving mass fractionation during gas extraction due to adsorption effects [5]. The set of deep mantle heavy noble gas isotopic data, especially Xe isotopic data, is currently limited to a handful of samples emplaced under conditions that facilitated magmatic gas preservation and prevented significant alteration. Recent studies have aimed to advance methodology [5-7] in order to expand the deep Earth heavy noble gas record. Here we investigate strategies to facilitate heavy noble gas isotopic analysis of commonly available gas-poor mantle-derived basalt samples affected by alteration.

To address the challenge of low magmatic gas content, we conducted a survey of ionization source settings with the Noblesse 5F5M mass spectrometer. We identified combinations of trap current, filament voltage, and analytical cycles that optimize the external reproducibility for small gas signals (i.e., released ^{129}Xe on the order of 1e-13 ccSTP). We investigated potential mechanisms that lead to mass fractionation of heavy noble gas isotopic compositions released from sample vesicles upon interaction with hydrous alteration minerals after gas release into ultra-high vacuum volumes. Via controlled experiments with a highly altered glassy vesicular basalt, we tested how the duration during which gases released by step-crushing were left in contact with altered remnant material affected the observed mass-fractionation. Our investigation on potential improvements in gas extraction and mass spectrometry methods will further the goal of routine heavy noble gas analysis in widely-available oceanic basalt samples to provide in-depth and multidimensional insights into the acquisition and distribution of terrestrial volatiles.

[1] Mukhopadhyay (2012), Nature; [2] Parai et al. (2019), Lithos; [3] Broadley et al. (2020), PNAS; [4] Péron et al. (2021), Nature; [5] Zhang et al. (2024), EPSL; [6] Bekaert et al. (2023), Sci. Adv.; [7] Parai (2023), GPL.