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Magmatic Heavy Noble Gases in Ancient Anorthosites

SAMUEL PATZKOWSKY, RITA PARAI AND ROBERT DYMEK

Washington University in St. Louis

Presenting Author: spatzkowsky@wustl.edu

The noble gas isotopes measured in modern mantle rocks tell a time-integrated story of the evolution of the deep Earth volatile budget. Their compositions reflect primordial volatile delivery during accretion, radiogenic ingrowth, volcanic outgassing of the mantle, and influx of atmospheric volatiles into the mantle through subduction. The mantle noble gas isotope composition has evolved from an initial, primordial source to the modern and numerical models have been used to predict how those compositions evolved over Earth history [1,2]. However, these models are constrained purely by modern mantle compositions. Samples derived from the ancient mantle would provide a glimpse into how past geodynamics has evolved. Archives of the ancient atmosphere have been used to constrain the evolution of atmospheric noble gases [3-6]; thus, pursuing archives of ancient magmatic gas is worthwhile. Challenges arise when analyzing ancient samples, as their great age gives ample time for reaction and over printing by crustal fluids. Such reactions may have the added effect of raising the water content, giving rise to analytical problems during measurements (high $H_2{}^{18}O$ backgrounds and high overall system pressure).

Here we present high-precision heavy noble gas isotopic data from mantle-derived anorthosites. We describe a new gas preparation method to handle samples with high water content. Petrographic analysis revealed inclusions of minor mineral phases (e.g., mica and amphibole) within the feldspar crystals, and these may host trapped magmatic noble gases [7]. We combine our measured compositions with numerical models of mantle isotope evolution to place constraints on past geodynamic scenarios. We present a mixing model to predict the contribution of plausible components and find that a mixture between the ancient upper mantle and ancient atmosphere best describes the Ne and Xe data from an Archean anorthosite. Our results allow us to estimate the $^{130}Xe/^{22}Ne$ ratios for both the ancient atmosphere and ancient mantle.

[1] Parai and Mukhopadhyay (2018) *Nature*; [2] Zhang et al (2023) *EPSL*; [3] Pujol et al. (2011) *EPSL*; [4] Avice et al. (2017) *Nature Comm.* [5] Avice et al. (2018) *GCA*; [6] Broadley et al. (2022) *EPSL*; [7] Jackson et al. (2013) *Nature Geosci*.