Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.29711

Noble gas accumulation in deep aquifers: Insights into ^{40}Ar accompanied by He isotopes

KERSTIN L. URBACH[1], JAKOB K. BRINKMANN[1], ROI RAM[1,2], ALAN M. SELTZER[3], ITAY J. REZNIK[2], WEI JIANG[4], ZHENG-TIAN LU[4], JENNIFER C. MCINTOSH[5], CHANDLER NOYES[5], REBECCA TYNE[6], ANDY LOVE[7], EDDIE W. BANKS[7], JUSTIN T. KULONGOSKI[8] AND WERNER AESCHBACH[1]

[1]Institute of Environmental Physics, Heidelberg University
[2]Geological Survey of Israel
[3]Woods Hole Oceanographic Institution
[4]University of Science and Technology of China
[5]University of Arizona
[6]University of Manchester
[7]Flinders University
[8]Scripps Institution of Oceanography, UCSD

Noble gas isotopes, such as the radioactive ^{81}Kr and radiogenic ^{4}He [1] and ^{40}Ar [2], are useful tracers for old (10^4–10^5-yr-order) groundwater, providing possible insights into groundwater residence time, water rock interaction and mixing processes. Together, they can help to deconvolute complex groundwater systems. These tracers undergo distinct processes enabling age estimation. ^{81}Kr can be utilized to date groundwater on timescales between approximately 50–1000 ka due to its radioactive decay, while the stable isotopes ^{40}Ar and ^{4}He accumulate from the radioactive decay in rocks and subsequent release into the liquid phase. Furthermore, while excess ^{4}He ($^{4}He_{ex}$) in old groundwater can be quantified using 'traditional' mass spectrometry [1], excess ^{40}Ar ($^{40}Ar_{ex}$) is largely masked by the atmospheric input and difficult to detect. This study builds upon recent developments in measurement techniques [2,3], which enable quantification of $^{40}Ar_{ex}$ in old (^{81}Kr-depleted) groundwater from the northern tip of the Red Sea.

High $^{4}He_{ex,}$ combined with $^{40}Ar_{ex}$ of up to ~6‰ relative to the atmospheric-derived background, were identified in the hundreds-of-meters deep Nubian Sandstone Aquifer. Furthermore, ^{3}He and ^{4}He supported by Ne measurements allow the differentiation of crustal and mantle influence. All samples are dominated by terrigenic He, with mantle He contributing to up to 3.5% of this component. While $^{40}Ar_{ex}$ shows no clear correlation with ^{81}Kr, it strongly correlates with $^{3}He_{ex}$. This suggests that $^{40}Ar_{ex}$ largely reflects mantle input rather than in-situ accumulation from potassium decay in aquifer minerals. This hypothesis is corroborated and expanded upon by several new, unpublished datasets from other parts of the world [4-6], which show a tight coupling between $^{3}He_{ex}$ and $^{40}Ar_{ex}$. We hypothesize that radiogenic ^{40}Ar is readily released from minerals at high temperatures, such as in the mantle, but is largely unreleased from colder crustal minerals.

[1] Purtschert et al. (2023), *Science of The Total Environment* 859, 159886.
[2] Seltzer et al. (2021), *Chemical Geology* 583, 120458.
[3] Seltzer & Bekaert (2022), *International Journal of Mass Spectrometry* 478, 116873.
[4] Noyes et al. (in review), *Water Resources Research.*
[5] Tyne et al. (in review), *Nature Geoscience.*
[6] Kulongoski et al. (2003), *Chemical Geology* 202, 95-113.