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Noble Gas and Radiocarbon Evidence for Long Residence Times of Groundwater from a Salinized Endorheic Aquifer

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Groundwater in arid, endorheic basins commonly exhibits strong salinization, low recharge rates, and long subsurface residence times. Yet it remains difficult to disentangle the roles of modern recharge and paleorecharge. In the Bahira Basin (central Morocco), increasing groundwater demand has pushed pumping toward deeper aquifer units as shallow groundwater has become extremely saline, with electrical conductivity locally exceeding 60,000 µS/cm. To clarify the residence time of groundwater, we analyzed 19 samples using a multi-tracer approach that integrates major-ion chemistry, stable isotopes ($\delta^{18}O$, $\delta^{2}H$), noble gas concentrations and isotopic ratios (He and Ne), and radiocarbon (^{14}C). Deep groundwater is moderately saline (500-3,000 µS/cm) and shows depleted $\delta^{18}O$-$\delta^{2}H$ values, pointing to recharge from higher elevations and/or under cooler paleoclimatic conditions. Elevated radiogenic ^{4}He concentrations (>4 × 10^{-6} ccSTP/g) further suggest extremely low recharge rates and long-term residence time. Most samples show ^{14}C activity below detection (<1.1 pMC), implying apparent ages >~35 ka and indicating that old groundwater dominates across much of the basin. However, water pumped from wells near recharge areas exhibits atmospheric noble-gas signatures and measurable ^{14}C (~35 pMC), suggesting mixing between recharge-freshwater and an older water component. The results reveal strong spatial heterogeneity in recharge and indicate that deep groundwater in the Bahira Basin is largely an old resource with minimal renewal at human timescales. More broadly, the study highlights the value of combining noble gases, radiocarbon, and stable isotopes to resolve groundwater age distribution and recharge dynamics in arid, data-scarce regions.

