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Groundwater Noble Gas Insights into Past Hydroclimate and Volatile Fluxes in South Australia

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Fossil groundwater (> 12 ka) holds records of past climate and hydrogeologic conditions through dissolved geochemical tracers. Noble gases are useful recorders of physical processes and properties in groundwater systems. We present noble gas (He, Ne, Ar, Kr, and Xe) abundance and isotope data, along with carbon ($\delta^{13}C$, ^{14}C) and stable water isotope ($\delta^{18}O$, $\delta^{2}H$) measurements, from the confined Dilwyn aquifer in the Otway Basin (Australia) to explore past climate and deep mantle and crustal gas input to groundwater. Noble gas recharge temperatures and conventional (uncorrected) ^{14}C ages suggest a last glacial period mean annual surface temperature of 9.8 ± 0.2 °C, implying a minimum warming of 6.2 ± 0.9 °C into the Holocene. Gravitational settling signals preserved by dissolved Kr and Xe isotopes suggest that water table depths remained stable over the last deglaciation (mean = 5.0 ± 1.9 m), despite regional evidence for hydroclimatic variability. Covariation among $\delta^{18}O$, noble gas temperatures, and deuterium excess suggests different moisture sources for the last glacial period and the Holocene. We use high-precision triple-argon-isotope measurements with excess ^{3}He and ^{4}He to evaluate crustal and mantle volatile inputs. Although He isotopes indicate predominantly crustal volatile sources, minor but detectable radiogenic ^{40}Ar that correlates with excess ^{3}He may reveal a slight mantle volatile contribution, likely attributable to the history of volcanism from nearby Mount Gambier. These results demonstrate that integrating the full suite of noble gas and isotope tracers, including newly developed high-precision techniques, into hydrogeological studies provides powerful constraints on paleoclimate evolution and volatile sources to aquifers.