

Regional Tectonic Influence on Saudi Arabian Groundwater Age Identified by Basinal Helium Diffusion Profiles

FAHAD SOUID¹, DARREN HILLEGONDS¹, SATTAM MUTAIRI², EKATERINA KAZAK², ORFAN SHOUAKAR-STASH^{3,4}, ANRAN CHENG⁵ AND CHRIS J BALLENTINE¹

¹University of Oxford

²Aramco

³Isotope Tracer Technologies Inc.

⁴University of Guelph

⁵Snowfox Discovery

Groundwater residence time is critical for the management of non-renewable groundwater resources, carbon storage, and helium and hydrogen exploration. Helium accumulation in groundwater provides a dating tool for older groundwater beyond radiocarbon capability, but is sensitive to the helium flux into and out of the aquifer. This study constructs a helium diffusion model from the crystalline basement to the surface [1] for two basins in the Arabian Peninsula: The Northwestern and Jafurah Basins. Groundwater ⁴He concentrations (n=66) were determined in fluids from different formations within the sedimentary succession of the two basins. ³He/⁴He, corrected for atmospheric contributions, range between 0.005R_a and 0.078R_a (R_a is the air ratio = 1.4x10⁻⁶) indicating the helium to be dominated by crustal sources. Within the Northwestern basin, ⁴He groundwater concentrations from the Devonian and the Ordovician formations (n=30) provide a best fit with the diffusion model (R² = 0.97), identifying a groundwater mean residence age of 5Ma. The model fit to the Devonian fluids is insensitive to the basement helium flux due to shale underlying the Devonian aquifer. Within the Jafurah basin (n=36), samples from the Cretaceous and Permian aquifers suggest a common upper age of 21Ma, with lower helium concentrations within the Jurassic formation still within 2σ of the model (R² = 0.76). The Paleocene and Cretaceous aquifers contain measurable ¹⁴C, evidence for significantly younger groundwaters, but contains ⁴He that would require ca 5Ma to accumulate. In the absence of structural conduits promoting cross formation flow, this is consistent with dual/multiple porosity and groundwater components that have a different residence history. Key tectonic events corresponding to these ages include the collision of the Arabian and Eurasian plates (24 – 21Ma), followed by Red Sea seafloor spreading from 13 to 5 Ma. We argue that the independently determined convergence of groundwater ages (21Ma and 5Ma) provides strong evidence for regional closure to significant recharge of main Saudi Arabian aquifers at the end of these major tectonic events.

[1] Cheng, A., Lollar, B. S., Warr, O., Ferguson, G., Idiz, E., Mundle, S. O., ... & Ballentine, C. J. (2021), *Earth and Planetary Science Letters* 574, 117175.