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Application of multiple age tracers to characterize groundwater flow within a uranium-bearing formation in South Korea

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Understanding groundwater flow within uranium-bearing formations is critical for predicting the long-term mobility of uranium, with implications for environmental safety and resource management. This requires a detailed assessment of hydrogeological conditions, including flow pathways, residence times, and mixing processes that influence radionuclide transport. This study investigates groundwater flow patterns at a uranium-bearing natural analogue site in Korea by characterizing groundwater age using multiple age tracers, including ^{14}C, ^{3}H, and ^{4}He. The ^{3}H data indicated post-bomb groundwater ages, except at the deepest sampled depth, which uniquely exhibited radiogenic ^{4}He accumulation. However, conventional ^{14}C-based age calculations yielded results inconsistent with the other tracers, likely due to modern recharge influences which overestimated groundwater ages. To resolve this discrepancy, the ^{14}C age was re-evaluated under the assumption of post-bomb recharge. A comprehensive multi-tracer analysis revealed that dissolved uranium concentrations were more strongly correlated with groundwater age than with the depth of highest rock uranium content. This finding suggests that groundwater residence time is one of the key factors in uranium transport within the system. Furthermore, groundwater age did not increase monotonically with depth, indicating a complex flow regime within this fractured aquifer system that further influences uranium transport dynamics. Overall, these findings highlight the critical role of groundwater age in interpreting uranium transport within geologically and structurally complex settings. Furthermore, it is anticipated that this can serve as a foundation for interpreting the chemical mechanisms that influence uranium migration.

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