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^{81}Kr dating of groundwater covering the entire Late-Pleistocene period

HAO LI[1], WEI JIANG[1], GUOMIN YANG[2] AND ZHENG-TIAN LU[1]

[1]University of Science and Technology of China
[2]Hefei National Laboratory

Paleo-groundwater serves as a natural archive of geological and climatic changes, preserving valuable information in its rich chemical and isotopic signatures. The Late Pleistocene (129 ka - 11.7 ka), a period marked by major climatic events such as the Younger Dryas and the Last Glacial Maximum, remains a critical period for understanding Earth’s climate history, requiring reliable groundwater ages across this period. The radioactive isotope ^{14}C (half-life = 5.73 ka) is a widely used tracer in groundwater studies for estimating ages and inferring flow patterns. It covers an effective age range with an upper limit at 30 - 40 ka, or 5 - 7 times the half-life of ^{14}C.

In comparison, the radioactive isotope ^{81}Kr offers a much longer dating window due to its half-life of 229 ka, making it suitable for groundwater dating in an age range up to 1.5 Ma. In previous studies, ^{81}Kr dating has not been able to reach ages younger than 50 ka. This limitation has until now prevented direct comparisons of ^{81}Kr and ^{14}C ages, and left ^{81}Kr unsuitable over a significant portion of the Late Pleistocene period.

In this work, we present advancements in the Atom Trap Trace Analysis (ATTA) method that reduce analysis uncertainty to 1% of the modern level. This improvement extends the lower age limit of ^{81}Kr dating down to 10 ka, enabling coverage of the entire Late Pleistocene period. The expanded dating range bridges the critical gap between ^{14}C and ^{81}Kr. Building on this advancement, groundwater samples from the North China Plain are analyzed using both tracers. This dual-tracer approach not only demonstrates the compatibility of ^{14}C and ^{81}Kr dating but also provides new insights into groundwater mixing and the dynamics of paleo-groundwater systems.