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^{14}C groundwater age dating in a Fe-rich, reducing aquifer

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Radiocarbon (^{14}C) groundwater ages are highly sensitive to geochemical processes that modify dissolved inorganic carbon (DIC). Existing correction frameworks primarily account for dead carbon influence due to carbonate mineral dissolution and/or CO_2 exchange. However, in Fe-rich reducing aquifers, siderite precipitation is common, yet its influence on ^{14}C-based age interpretation remains to be clarified. In this study, we evaluate the influence of siderite precipitation on ^{14}C groundwater-age interpretation in an Fe-rich, reducing aquifer where siderite formation is favored. Apparent ^{14}C ages were systematically older than independent age constraints from tritium (^{3}H) and radiogenic helium (^{4}He), indicating significant age overestimation. We tested conventional explanations and correction components, including carbonate mineral dissolution, geogenic CO_2 inputs, binary mixing, and organic matter influences. However, these factors did not reconcile the discrepancy. We therefore assessed isotopic fractionation associated with siderite precipitation as an additional bias mechanism. Incorporating siderite-related fractionation reduced the ^{14}C age overestimation at shallow depths, where siderite precipitation was relatively pronounced. In contrast, at depths where sulfate reduction and subsequent pyrite formation suppress siderite precipitation, the correction effect was limited and the age reduction was smaller. Accounting for siderite precipitation reshapes the interpreted groundwater age distribution across the study site (i.e., natural analogue study site) and highlights that siderite formation can be a control on ^{14}C-based groundwater dating in Fe-rich reducing environments.

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