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Isotope tracing of iron cycling in a crustal deep fracture-hosted hydrogeosphere

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Deep fracture fluids hosted in crystalline basement rocks may represent 30% of the groundwater inventory (*1*) and feature diverse geochemistry and microbial ecosystems. These include fluids with geochemical characteristics of prolonged water-rock interaction and noble gas components with multiple-billion-year ages (*1–3*). These ancient and highly saline fluids host chemolithoautotrophic microbial ecosystems that derive energy primarily from coupling sulfate reduction to oxidation of hydrogen produced by serpentinization and/or radiolysis, potentially in isolation from Earth surface process (*4–6*). Little is known, however, about associated metal cycling within these systems, specifically, how dissolved metal loads may reflect diverse host rock lithologies and respond to *in situ* biogeochemical processes.

One such system is encountered in Kidd Creek mine, Ontario, a Cu-Zn sulfide mine hosted within a volcanogenic massive sulfide (VMS) deposit in the Neoarchean Abitibi greenstone belt (*1*, *2*), where pyrite accounts for 70% of the VMS. Here fracture fluids contain a small standing sulfate pool maintained by indirect radiolytic oxidation of pyrite (IROP), and consumed by *in situ* microbial sulfate reduction (*4*). We analyzed iron isotope ratios (δ^{56}Fe) for fracture fluids, and the surrounding VMS and other host rocks from this locality, to constrain likely lithological sources of high dissolved Fe^{2+} to these fluids and to determine whether iron is, like sulfur, actively cycled within the fracture fluid environment (*4*). Fracture fluid δ^{56}Fe and Fe/Mn suggest that the dissolved Fe^{2+} pool is impacted by secondary sulfide mineral formation, likely coupled to microbial reduction of IROP-derived sulfate. This study identifies these key processes that may control the Fe and S cycle in deep crustal settings such as Kidd Creek, and thereby sustain long-term chemolithoautotrophic ecosystems in the deep subsurface.

References

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