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Iron Isotope Variability in Fe-Mn Oxyhydroxides from the Mid-Atlantic Ridge: Insights into Hydrothermal and Hydrogenetic Processes

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Mineral precipitation within hydrothermal deposits not only removes hydrothermally sourced metals but also scavenges trace elements from seawater. Additionally, biomineralization may contribute to the metal enrichment. This study investigates the geochemical composition, mineralogy and Fe isotope systematics (δ^{57}Fe, δ^{56}Fe) of hydrothermal products both from Fe-oxide and sulfide chimneys, as well as from crusts. Samples were collected from hydrothermal sites along the Mid-Atlantic Ridge, including Luso (38º58'N, 29º52'W; 570m depth), Menez Gwen (37º50'N, 31º31'W; 850 m depth), Lucky Strike (37º18'N, 32º16'W; 1700 m depth), Saldanha (36º34'N, 32º26'W; 2200 m depth) and Rainbow(36º14'N, 34º05'W; 2300 m depth).

Results show that isotopic variability in hydrothermal systems, can be influenced by factors such as temperature, hydrothermal fluid-rock interactions, and biological activity, with Fe isotopic ratios ranging from highly negative (δ^{57}Fe = 4.138‰) to strongly positive values (δ^{57}Fe = +2.827‰). Luso oxyhydroxide chimney samples exhibit highly positive δ-values, with δ57/54 reaching up to +2.827‰ and +2.816‰, respectively, suggesting significant isotopic enrichment. This enrichment likely results from fractionation during oxidative precipitation processes or interactions with seawater perhaps in conjunction with Fe-oxidizing bacteria, as supported by moderate Fe/Mn ratios and the high Fe isotope values. Menez Gwen contains negative Fe isotopic values and the lowest Fe/Mn ratio among the studied fields, suggesting strong Mn enrichment and oxidative processes. Lucky Strike displays Fe isotopic similar to Menez Gwen but with a higher Fe/Mn ratio, indicating more direct hydrothermal influence. Rainbow samples exhibit a wide range of Fe/Mn ratios and display slightly positive to negative Fe isotopic values (δ^{57}Fe: +0.759‰ to -0.923‰), reflecting a mixture of hydrothermal fluids and seawater. Some samples show metal enrichments likely associated with sulfide weathering and secondary mineral precipitation. The highly negative isotopic compositions (δ^{57} = −3.501‰), along with high Mn/Fe and REE content in Saldanha, support isotopic fractionation during precipitation from vent fluids when mixing with seawater and an input from biological activity.

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