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Effects of off-axis hydrothermal systems on the oceanic Mg budget

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The chemistry of the ocean and its variations throughout time are controlled by the oceanic budgets of various elements, with hydrothermal reactions between seawater and the oceanic crust off-axis of mid-ocean ridges playing a fundamental role. The water flux through these systems is on the same order of magnitude as the river discharge to the ocean, and approximately three orders of magnitude higher than that of on-axis systems. Thus, understanding and quantifying the reactions occurring at ridge flanks are essential for studies that use the oceanic budgets of elements and their isotopes to understand variations in Earth's surface environment over time. However, our current knowledge of such reactions is limited mainly due to system heterogeneity and challenges in sampling.

Here, we focus on the importance of these off-axis systems for the oceanic Mg budget and model this budget over the last 20 Myr using Mg isotope compositions (δ^{26}Mg). The Mg dynamics in these off-axis systems can be viewed as two competing reactions: 1) the dissolution of the oceanic crust, which supplies Mg to the fluids and ultimately to the ocean; and 2) the precipitation of secondary minerals, primarily saponite, a Mg-rich smectite mineral, which removes Mg from the fluids. Thus, our model is run for two endmember scenarios: 1) where off-axis hydrothermal systems act solely as a sink for Mg; and 2) where the flux of Mg supplied by dissolution equals the flux of Mg removed by precipitation.

These two scenarios resulted in different outcomes in terms of the Mg input and output fluxes required to balance the Mg (and Mg isotope) budget. Specifically, the Mg fluxes of the off-axis hydrothermal systems, dolomite, and groundwater differ between the scenarios. In both scenarios, the dolomite flux accounts for more than 30–40% of all oceanic Mg sink fluxes, contradicting the conventional view that dolomite formation has been negligible since the Neogene. These findings highlight the importance of further research into Mg (and Mg isotope) dynamics in hydrothermal systems at ridge flanks for understanding variations in seawater Mg concentrations and δ^{26}Mg values throughout Earth's history.