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Trace and rare earth element dynamics in the marine ecosystem of Deception Island volcano (South Shetland Islands, Antarctica)

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Deception Island, an active volcanic caldera in the South Shetland Islands, presents a complex and heterogeneous environment due to its dynamic hydrothermal system with diverse plume signatures. Snow-covered from June through November, the island experiences increased sunlight and reduced ice cover during the austral summer (November to February), allowing for a regular annual phytoplankton bloom. This study presents distribution of trace metals (Cd, Co, Cu, Fe, Mn, Ni, Ti, V, Zn) and rare earth elements (REE: La–Lu) in waters surrounding Deception Island during February–March 2024, in the bloom-decline phase of the phytoplankton cycle. An extensive sampling encompassed 260 water samples from multiple coastal locations around the caldera, as well as depth profiles in the inner bay and at two external sites associated with penguin colonies, previously identified as significant contributors to trace metal cycling. The objective of this study is to assess the spatial distribution and sources of these elements, providing insights into the key factors influencing trace metal dynamics in this unique ecosystem. The results reveal highly variable trace metal concentrations and distinct distribution patterns across different locations. Volcanic activity is identified as a major source and primary driver of Co, Fe, and Mn, with a lesser contribution to Ni. Elevated concentrations of Cu, Ti, V, and Zn were detected only at specific sites, while Cd appears to lack significant sources within the caldera. Preliminary REE analyses, although ongoing, suggests that hydrothermal processes may not be a substantial contributor to dissolved REE concentrations. Instead, we hypothesize that processes within the caldera function as their net sink, primarily through scavenging onto Fe and Mn particles, particularly in areas characterized by rapid particle removal. This effect is expected to be especially pronounced for light REEs, leading to an unusually variable heavy-to-light REE ratio over a relatively small spatial scale. Our findings underscore the complex interplay between hydrothermal inputs, varying water chemistry, and biological influences on trace metal dynamics around Deception Island. The study highlights how localized factors can create a mosaic of environmental conditions, influencing biogeochemical processes on a fine spatial scale.