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A new perspective on changing Southern Ocean micronutrient cycling: Zn isotope insights from the last 45,000 years

MATT DRUCE[1], CLAUDINE H. STIRLING[1] AND HELEN BOSTOCK[2]

[1]University of Otago
[2]University of Queensland

The Southern Ocean is one of Earth's most important carbon sinks, where primary production and ocean circulation regulate atmospheric CO_2. Today, Southern Ocean primary productivity is largely limited by trace metal micronutrients such as iron, with zinc and cadmium also playing key roles in phytoplankton growth. Micronutrient limitation may intensify under a warming climate regime, weakening the biological pump and disrupting marine ecosystems. While decades of research have advanced our understanding of modern micronutrient cycling in the Southern Ocean, paleo-reconstructions remain sparse, and only recently have proxies emerged that reliably capture surface ocean micronutrient dynamics on Quaternary glacial-interglacial timescales.

Here, we present a zinc isotope record from the Subantarctic Zone of the Southern Ocean spanning the past 45,000 years, derived from the geochemical signatures extracted from the calcite fossil shells of coccolithophores (phytoplankton) from sediment core TAN1106-28. This record provides a micronutrient-based perspective on past nutrient availability, primary productivity, and ocean circulation changes, offering a means to refine model calibrations needed to improve future climate projections and support environmental-economic resilience in a warming world. Our findings underscore the necessity of integrating micronutrient proxies alongside traditional macronutrient records to fully resolve glacial-interglacial variations in biological pump efficiency.