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Indian Ocean Deep-Water Circulation and Its Atlantic Linkages Over the Past 50 kyr

SAYANTAN DE[1] AND SUNIL KUMAR SINGH[2]

[1]CSIR-NATIONAL INSTIUTE OF OCEANOGRAPHY
[2]CSIR-National Institute of Oceanography

Global overturning circulation (GOC) regulates the exchange of heat, carbon, and nutrients between the surface and deep oceans. The Indian Ocean lies downstream of the global overturning system and therefore records the relative influence of northern- versus southern-sourced deep waters. However, abyssal circulation in the Indian Ocean remains relatively under-resolved, particularly along the western boundary pathway. As this pathway intersects major mid-ocean ridge systems, it is critical to evaluate whether authigenic ε_{Nd} in ridge-proximal sediments can reliably record deep-water provenance.

Here we present a ~50 kyr authigenic ε_{Nd} record from ridge-axis sediment core SSD77-GC03 (3984 m water depth; Carlsberg Ridge, western Arabian Sea) to evaluate whether ambient bottom-water ε_{Nd} can be recovered in an active mid-ocean ridge environment. Multiple lines of evidence indicate minimal local overprinting. Authigenic ε_{Nd} is decoupled from detrital Nd and shows no covariance with basaltic inputs. Seawater-like $^{87}Sr/^{86}Sr$ ratios (~0.70916) and PAAS-normalized REE patterns with pronounced negative Ce anomalies indicate a dominantly seawater-derived Fe-Mn oxyhydroxide phase. An Eu-anomaly mass-balance approach further constrains hydrothermal contributions to <0.1% of the authigenic REE inventory, confirming negligible hydrothermal bias.

Authigenic ε_{Nd} ranges from −7.9 to −6.2 and exhibits coherent glacial–interglacial and millennial-scale variability in abyssal circulation. More radiogenic ε_{Nd} during Marine Isotope Stage (MIS) 2 reflects the dominance of Antarctic Bottom Water (AABW), whereas less radiogenic values during MIS 1 and MIS 3 indicate increased penetration of North Atlantic Deep Water (NADW). On millennial timescales, ε_{Nd} tracks bipolar seesaw dynamics, with radiogenic excursions during Heinrich Stadials and Younger Dryas, and less radiogenic values during Dansgaard–Oeschger interstadials and Bølling–Allerød. Comparison with Atlantic ε_{Nd} records reveals systematic downstream attenuation of the NADW signal. During MIS 2, similar radiogenic ε_{Nd} values (~−6.5) across the South Atlantic and Indian Ocean indicate basin-scale dominance of AABW under weak Atlantic Meridional Overturning Circulation (AMOC). During MIS 1 and MIS 3, the western Arabian Sea remains more radiogenic than Atlantic records, reflecting limited NADW penetration (<15%) and weak ventilation. Together, these results identify the western Arabian Sea as a sensitive downstream archive of AMOC variability, capturing cross-basin teleconnections between the Atlantic and Indian Oceans.