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Tectonically restricted deep-ocean circulation at the end of the Cretaceous greenhouse

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The evolution of global ocean circulation towards deep-water production in the high southern latitudes is thought to have been closely linked to the transition from extreme mid-Cretaceous warmth to the cooler Cenozoic climate. The relative influences of climate cooling and the opening and closure of oceanic gateways on the mode of deep-ocean circulation are, however, still unresolved. Here we reconstruct intermediate- to deep-water circulation for the latest Cretaceous based on new high-resolution radiogenic neodymium (Nd) isotope data from several sites and for different water depths in the South Atlantic, Southern Ocean, and proto-Indian Ocean. Our new late Campanian to Maastrichtian data documents the presence of markedly different intermediate water Nd-isotopic compositions in the South Atlantic and Southern Ocean suggesting the presence of multiple, local water sources at nearly every site and a circulation system that was fundamentally different from the modern. In particular, a water mass with a highly radiogenic Nd isotope signature most likely originating from intense hotspot-related volcanic activity bathed the crest of Walvis Ridge between 71 and 69 Ma, which formed a barrier that prevented deep-water exchange between the Southern Ocean and the North Atlantic basins. The narrow geometry of the Atlantic Ocean together with tight to closed connections towards the Tethys and the Pacific Ocean limited volumetrically substantial deep-water exchange and promoted a local mode of deep oceanic convection in the Atlantic. Available Nd isotope data from the North Atlantic indicate the prevalence of different water masses in the abyssal plains and support a mode of ocean circulation that was maintained by down- and upwelling in various meso-scale eddies as proposed by Hay (2011, Sedim. Geol. 235, 5-26). Climatic cooling and the opening of gateways between 83-78 Ma may have initiated SCW formation in the southern hemisphere oceans. However, SCW formation did not drive global ocean circulation before gateway opening and mid-ocean ridge subduction further deepened ocean basins between 68-58 Ma. These consecutive plate-tectonic events played a crucial role in the global linkage of oceanic deep-water reservoirs and the establishment of a similar to modern global thermohaline circulation system.