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Long-term impacts of experimental deep-sea manganese nodule mining on the geochemistry and physical properties of deep-sea sediments in the Clarion-Clipperton Zone, Pacific Ocean

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Polymetallic nodules are targeted by industry for the development of new sustainable technologies. The nature and resilience of the abyssal ecosystem and effects of mining on the physical seafloor natural equilibrium is largely unknown, as is the temporal capacity to cope with and recover from any future mining impacts.

SMARTEX is a UK-funded project providing critical scientific understanding of ecosystems, biodiversity and geological processes associated with polymetallic nodules in the Clarion-Clipperton Zone (CCZ) of the Pacific Ocean. In 2023, Expedition JC241 investigated the biological, ecological and geochemical recovery following the 1979 experimental mining at the OMCO site. Four decades later, biological community abundance and seafloor physical impacts were still persistent[1].

Pore water and sediment geochemistry in the tracks and sediment redeposition zones directly affected were compared with a control area. Collector track sediment profiles show a persistent disturbance of the top 10-15 cm of sediment 44 years after removal, with shifts for elements such as Fe, Mn, Ni and Mo. Conversely, geochemistry of pore waters directly within the disturbance indicates that post-disturbance equilibration has been reached and has returned to baseline.

Geochemical profiles outside of the collector tracks are comparable with the control, even within the plume impacted area. Major differences between the control and disturbance areas are below 2 meters, where redox boundaries are influenced by basin geometry and basement depth. This highlights the importance of accounting for natural variability in explaining geochemical variance and establishing control points.

Physical property analysis and numerical modelling investigated effects of consolidation and changes in excess pore pressure over time resulting from the collector passage and sediment stripping. Modelled pore pressure equilibrates to hydrostatic pressure potentially within 1 year of the mining disturbance. Due to the hydrostatic pressure induced by more than 4 km of water, induced excess pressure is negligible on stability fields of mineral phases present within sediments, minimizing the release of metals associated with buried Fe and Mn oxides into pore waters expelled by compression.

[1] Jones et al., (2025). Long-term impact and biological recovery in a deep-sea mining track. Nature 642, 112-118 (2025).