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Iron Sources and Cycling over the Cenozoic: Evolution of the Iron Cycle in the South Pacific and Southern Ocean

LOGAN A TEGLER[1,2], TRISTAN HORNER[1], SUNE GRØNLUND NIELSEN[1], SILKE SEVERMANN[3], BERNHARD PEUCKER-EHRENBRINK[1] AND ANN DUNLEA[1]

[1]Woods Hole Oceanographic Institution
[2]Massachusetts Institute of Technology
[3]Rutgers University
Presenting Author: ltegler@mit.edu

Iron sources and cycling influence the productivity of marine ecosystems, especially in high-nutrient low-chlorophyll regions. Indeed, iron is the proximal limiting nutrient in large regions, reducing the efficiency of the ocean's biological carbon pump to sequester atmospheric carbon dioxide. Isotopic analysis of iron has emerged as a tool to understand how iron is sourced and cycled in the water column. Iron sources (dust, hydrothermal vents, and continental margins), exhibit characteristic isotopic signatures that enable their tracing.

To understand how marine iron cycling has changed over geological timescales, we analyzed the iron isotope and multi-element geochemistry of pelagic clays deposited in the South Pacific over the Cenozoic. Samples were collected from IODP Sites U1366, U1369, and U1370 in the South Pacific Gyre. We constructed age models for each site using a cobalt accumulation technique and Os isotope chronostratigraphy. The three sites contain 95, 58, and 65 Myr records. Backtrack paths indicate the sites were located in the Southern Ocean at the beginning of the Cenozoic and tectonically migrated into the South Pacific. Sediment samples (n=137) were leached to amplify the hydrogenous signal and leachates were analyzed for iron isotopes and 52 element concentrations. Applying Q-mode factor analysis to elements Fe, Ti, Ni, La, Mn, Ca, Mg, V, Co, Cu, Zn, Ce, and Pb we find that four factors account for 95 % of the total variability in the dataset. We interpret the factors as dust, an organically-bound distal background source, and near- and far-field hydrothermal activities, with each factor accounting for 47 %, 25 %, 18 %, and 5 % of the total variability, respectively. We used the VARIMAX-rotated factor loadings, which indicate the importance of each factor in each sample, to approximate the fractional contribution of each factor to the iron isotope value. We combine the components of our study—isotopic analysis, concentration measurements, and statistical modeling—to untangle the history of iron biogeochemical cycling in the South Pacific and the Southern Ocean through the Cenozoic. We find that the clays record dynamic Fe cycling as our study sites moved from near the mid-ocean ridges to downwind of Australian dust inputs.