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The biogeochemical balance that controls oceanic nickel cycling in the modern and past oceans

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Nickel is an important element in the oceans, utilized by enzymes involved in important marine processes including nitrogen fixation, uptake of fixed nitrogen, and methanogenesis. However, important questions remain about the processes which control the distribution of Ni in modern ocean, and the processes which control the global ocean Ni inventory on geological timescales. We have combined the analysis of Ni in field samples, in vitro lab culturing experiments, and modeling, in order to present a novel view of global Ni biogeochemical cycling. Two key features of the global Ni distribution are a deep concentration maximum reminiscent of Si, and surface Ni concentrations which never drop much below 2 nM. Common explanations for these features include a presumed presence of Ni within diatom silicate frustules, and the presence of ~2 nM non-bioavailable Ni in the surface oceans. However, neither supposition is consistent with our new data, which show very low Ni in diatom frustules, and the ability of phytoplankton to deplete Ni below 2 nM when provided sufficient macronutrients. Instead, we use the AWESOME OCIM modeling framework to explore alternative explanations for Ni distribution which are consistent with our data. We propose a new view of the Ni cycle in which surface ocean oligotrophic gyre Ni concentrations are set by high latitude nutrient uptake, with Ni being depleted slightly more slowly than macronutrients N and P, leaving 2 nM residual Ni after macronutrient depletion. We attribute the deeper depth maximum of Ni to reversible scavenging. This new view suggests that surface ocean Ni concentrations are highly sensitive both to Ni uptake in upwelling regions and to scavenging intensity. Both of these processes are expected to have varied in the past ocean, possibly leading to large and rapid fluctuations in surface ocean Ni concentrations, placing important ocean processes on a knife's edge between Ni feast and famine.