Why Ni Matters

The availability of transition metals has likely directed the course of evolution for a variety of life forms. Many global cyenzymes incorporate metals such as Mg in photosynthesis, Ni in methanogenesis and Fe in hemoglobin. As massive shifts in Earth’s atmosphere, ocean circulation and redox conditions occurred, the concentration of trace metals likely varied in the oceans and required biological adaptations. Determining how and when these shifts occurred would inform how life co-evolved with Earth.

Nickel is a bio-essential element for a variety of modern and ancient life and there were likely large fluctuations in its concentration in the oceans. [Insert sentence about residence time]. In the modern ocean, Ni has a nutrient like depth profile, meaning it is depleted in the surface and enriched through remineralization in the deeper waters. [associated with Si and P]. Nickel is essential to seven enzymes that regulate the global C, N, and O cycles. Because of Ni’s incorporation into these enzymes, marine Ni-dependent organisms, such as phytoplankton and foraminifera, are severely affected by fluctuations in ocean Ni concentrations (Schonheit et al., 1979; Dupont et al., 2010; Munsel et al., 2010; Twining et al., 2012; Smith and Goldstein, 2019). [ include a table listing important enzymes, their functions, and examples of life that have them, see table below to adapt]. [include Ni reliance graphs]

In the modern ocean, Ni is used by X, Y, Z. Diatoms, silica-shelled phytoplankton that produce around 45% of the Earth’s O and comprise ~1% of Earth’s biomass, rely on Ni because they use Ni-enzymes, urease and Ni-superoxide dismutase (Twining et al., 2012; Benoiston et al., 2017). [Insert study about Ni reliance] Foraminifera also exhibit a Ni reliance, potentially because of their use of urease as a pH regulator during shell formation (Munsel et al., 2010; Smith and Goldstein, 2019). In addition to Ni requirements, some of these organisms have been shown to have Ni toxicity limits. A study performed on a diverse group of foraminifera species showed that while the toxicity limits ranged, the general behavior was a slight increase in [Ni]SW (insert X nM) caused an increase in most foraminifera abundance whereas a significant increase (insert X nM) caused most foraminifera cell death (I need to find this study). The sources and sinks that regulate ocean Ni concentrations therefore also regulate the diversity and abundances of these organisms.

During the Archean, Ni was likely an incredibly important ingredient for early life. Methanogens likely dominated in the predominately anoxic ocean. One of the most notable biochemical uses of Ni is its incorporation into the cofactor f340 which is used by a crucial enzyme for methanogens, methyl-coenzyme M reductase. (Ragsdale, 1998; Cameron et al., 2009). [insert study about Ni reliance study]. Methyl coenzyme M reductase catalyzes the final step in methanogenic, and first step in methanotrophic pathways. [include sentence about the methane haze that likely kept the earth warm and how methane suppressed the rise of O] Clearly, there is and has been a biological need for Ni since the very beginnings of life. How ocean Ni concentrations have fluctuated would have large implications for the evolution of marine life’s diversity and abundance.

The shifts in ocean Ni concentrations appear to be quite drastic across Earth’s history. Using Ni/Fe data from banded iron formations (BIFs), Konhauser et al., detected a massive shift in the Ni concentration of Precambrian oceans from 400 nM to 200 nM approximately 2.5 Ga. [insert sentence about how this isn’t entirely conclusive because it’s one data set and has a large uncertainty]. Today, ocean Ni concentrations hover around 8 nM. As these shifts occurred, Ni-dependent life would have been greatly affected and either become more limited in abundance or evolved to exist with a lower Ni dependence. Again, determining the causes and timing of these shifts would help define pivotal moments when Ni-dependent life was challenged. However, before the past marine Ni cycle can be reconstructed, a fundamental modern marine Ni cycle needs to be established.



