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Understanding ancient nutrient limitation via a genomics approach

AYA S KLOS[1], BRYAN LE[1], ALEC LEONETTI[1], JOANNE S BODEN[2], EVA E. STÜEKEN[3] AND RIKA ANDERSON[1]

[1]Carleton College

[2]University of St. Andrews

[3]University of St Andrews

Presenting Author: klosa@carleton.edu

Nitrogen, iron, and phosphorus are all key nutrients essential to the productivity of life on Earth. Consequently, the bioavailability of these nutrients helped shape the scope and diversity of the biosphere, and the emergence of complex life. To further clarify the history of nutrient limitation and biological usage on Earth, we used a time-calibrated tree of life and gene tree-species tree reconciliations to estimate the timing of gene speciation, duplication, loss, and horizontal gene transfer events for genes involved in phosphorus, iron, and nitrogen cycling. Our reconciliations suggest the use of phosphate by microbes *before* the Great Oxidation Event (GOE). Phosphonate transport, metabolism and catabolism also emerged in the Archean, becoming more widespread in the Proterozoic with the evolution of PhnM, J, and H encoding broad spectrum C-P lyase. Fe(II) transport via *feoB* arose in the Archean but was likely not widely used by a diversity microbes until after the GOE. Uptake of siderophore-bound Fe(III) via the tonB-exbBE system likely became ecologically important shortly after the GOE (~2000 mya), while the more recent emergence of siderophore synthesis genes suggests that microbes may not have needed such energetically-expensive methods of obtaining Fe(III) until after the GOE. Nitrogen cycling genes involved in synthesizing the amino acid glutamate mostly had ancient origins (potentially due to the historic importance of amino acid synthesis) and are less indicative of nitrogen limitation. Taken together, our results add a phylogenetic perspective to geochemical reconstructions of nutrient availability on earth. An analysis on a more comprehensive set of genes, as well as consideration of competition and where gene events occur, will be necessary to further elucidate the picture of nutrient limitation on the early Earth and its effects on the evolution of life.