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Oxidizing Oases in the Paleoarchean Moodies Group, Barberton Greenstone Belt, South Africa

Objectives: Oxygenic photosynthesis has directly altered the Earth s atmospheric composition, prompting an evolutionary radiation of biosynthetic and metabolic pathways, and ultimately making multicellular life possible. Although atmospheric oxygen levels increased dramatically at 2.4 billion years ago (Ga), the timing of production of oxygen by phototrophs remains poorly constrained. Our primary objectives are 1) to locate the sites of iron oxidation on a 3.2 Ga coastal system preserved in the Paleoarchean Moodies Group of South Africa, and 2) to determine the presence or absence of oxygen production in those sites.

Methods: We will obtain unweathered samples by drilling through terrestrial and shallow-marine sandstone of the Moodies Group in collaboration with an international ICDP project. From these cores, we will select samples and perform detailed petrographic (polarized transmitted and reflected light, cathodoluminescence) and geochemical analyses of redox sensitive grains as well as early cements to document the mineralogy and redox conditions during deposition. Optical petrography will be supplemented by electron microprobe and EDS analyses. Geochemical analyses will include micro-X-ray fluorescence (micro-XRF) spectroscopy, Raman microspectroscopy and mapping, synchrotron X-ray analytical spectroscopy, laser-ablation inductively-coupled plasma mass spectrometry, and in situ Fe, C and O isotope analyses.

This proposal includes an appended Planetary Major Equipment and Facilities (PMEF) request to replace the micro-XRF instrument used in the project.

Perceived Significance: This project will contribute to the Early Evolution of Life and the Biosphere goal of the Exobiology program by investigating the evolution of photosynthesis and its effect on surface environments. Recent work has suggested that oxygen production began by at least the Mesoarchean without building up in the environment until hundreds of millions of years later. This work will allow us to probe sensitive recorders of oxidation state preserved in sedimentary rocks (including potential fossilized biological sources of oxidants) deposited in 3.22 billion-year-old coastal environments. Studying drill core samples collected from deep below the modern weathering profile will provide material minimally altered by oxidative weathering for constraining early biological and geochemical coevolution. Cores from this project and two other drill sites will be made available to the broader science community through the International Continental Drilling Program following a two-year science moratorium.

This project will also contribute to the Biosignatures and Life Elsewhere goal by developing mineral biosignatures of early oxidation. These results will be highly relevant to the Mars 2020 mission, as the Moodies deltaic sedimentary rocks to be explored are strong partial analogs to Jezero deltaic sedimentary rocks set to be explored by the Perseverance rover. In particular, the source terrains for both the Moodies Group and Jezero crater deltaic sediments had significant mafic components. Weathering and transport in both locations occurred in anoxic environments, likely under a high UV flux. This combination of critical environmental factors is rare in the surviving record of terrestrial deltas.

Moreover, the workflow for identifying and analyzing potential biosignatures will be similar to that used in the Mars 2020 mission. The geochemical screening tools for these biosignatures (X-ray analytical microscopy and UV and Vis Raman microspectroscopic mapping) will be similar to instruments on Perseverance (PIXL and SHERLOC, respectively). Results from these instruments will be used to sample for further analysis. We anticipate that results will be useful for designing measurements for in situ science and for selecting samples for return. The PI (Tice) is a PIXL Co-I and one of the Co-Is (Czaja) is a Returned Sample Science Participating Scientist.