

**MEASURING ANCIENT N<sub>2</sub> PRESSURE USING FOSSILIZED CYANOBACTERIA.** S. N. Silverman<sup>1,2,3</sup>, S. Kopf<sup>1</sup>, R. Gordon<sup>4</sup>, B. Bebout<sup>3</sup> and S. Som<sup>2,3</sup>, <sup>1</sup>Department of Geological Sciences (University of Colorado at Boulder, USA), <sup>2</sup>Blue Marble Space Institute of Science (Seattle, Washington, USA), <sup>3</sup>Exobiology Branch, NASA Ames Research Center (Moffett Field, California, USA), <sup>4</sup>Gulf Specimen Aquarium & Marine Laboratory (USA & Wayne State University, USA)

**Introduction:** Assessment of whether extrasolar planets are deemed habitable or uninhabited will be based on their atmospheric composition. Added insight regarding habitability will be obtained by comparing these exo-atmospheres to that of habitable Earth. Earth's atmosphere has remained habitable despite varying in redox state and total mass over geological time. As such, "snapshots" of Earth's atmosphere through the planet's evolution can provide a catalogue of different habitable atmospheres. At any timepoint in Earth's history, an upper limit can be placed on the number of possible air constituents by knowledge of atmospheric pressure at that time. Experimentally, this can be broken down by focusing on trends of specific gases over history.

Dinitrogen (N<sub>2</sub>) is thought to have been a major, though not necessarily constant, constituent of Earth's atmosphere throughout the planet's history. Despite its physical importance as a key component of the atmosphere and its role as the largest reservoir of nitrogen at the Earth's surface, only a few constraints exist for the partial pressure of N<sub>2</sub> [1], [2], [3], [4]. In this study we evaluate a new potential proxy for atmospheric N<sub>2</sub>: the physical spacing between heterocysts in filamentous cyanobacteria.

**Experimental background:** Heterocyst-forming filamentous cyanobacteria are some of the oldest photosynthetic microorganisms on Earth, and debated fossilized specimens have been found in sedimentary rocks as old as 2 Ga [5]. These organisms overcome nitrogen limitation in their aqueous environment through cellular differentiation along their filaments. The specialized cells that develop, known as heterocysts, fix the nitrogen and laterally distribute it to neighboring cells along the filaments.

Because the concentration of the dissolved N<sub>2</sub> available to the filaments correlates directly with the atmospheric partial pressure (Henry's law constant for N<sub>2</sub> gas in water is 6.1 x 10<sup>-4</sup> mol L<sup>-1</sup> atm<sup>-1</sup> [6]), any preservable physiological response of the organism to the changed N<sub>2</sub> availability constitutes a potential proxy for atmospheric N<sub>2</sub>.

**Experimental approach:** In the laboratory, we are quantifying the relationship between heterocyst distance and atmospheric pN<sub>2</sub> as well as examining whether the pN<sub>2</sub> is reflected in the isotopic signature of nitrogen fixation by subjecting the representative spe-

cies *Anabaena cylindrica* (in nitrate-free media) to different partial pressures of N<sub>2</sub> during growth at constant temperature and lighting. Future work will focus on the extent to which heterocyst spacing is dependent on species, water salinity, and water pH.

**Preliminary results:** We show experimentally that the distance between heterocysts reflects the nitrogen partial pressure experienced by *Anabaena cylindrica* organisms. As such, this renders them an ideal target to potentially record atmospheric nitrogen concentrations on ancient Earth. When heterocystous cyanobacteria fossilize, the distance between heterocysts should preserve information about the atmospheric N<sub>2</sub> partial pressure at that time. Application of this relationship to the rock record may provide a paleo proxy to complement the two existing geobarometers [1], [2].

**References:** [1] Som S. M. et al. (2016) *Nat. Geosci.*, 9, 448–451. [2] Som S. M. et al. (2012) *Nature*, 484, 359–362. [3] Marty B. et al. (2013) *Science*, 342, 101–104. [4] Berner R. A. (2006) *Geochim. Cosmochim. AC*, 65, 685–694. [5] Licari G. R. and Cloud P. E. (1968) *PNAS*, 59, 1053–1060. [6] Sander R. (2015) *Atmos. Chem. Phys.*, 15, 4399–4981.