BENTHIC MAT O_2 OASES: A MODERN ANALOG FOR EARLY EARTH. D. Y. Sumner[1], I. Hawes[2], T. J. Mackey[1], A. D. Jungblut[3], M. Krusor[1], and P. T. Doran[4], [1]Department of Earth and Planetary Sciences, University of California, Davis, 1 Shields Avenue, Davis, CA 95616, dysumner@ucdavis.edu, [2]Gateway Antarctica, University of Canterbury, Christchurch, New Zealand, [3]Department of Life Sciences, The Natural History Museum, Cromwell Road, London SW7 5BD, UK, [4]Department of Geology and Geophysics, Louisiana State University, Baton Rouge, Louisiana, USA 70803.

Introduction: Cyanobacterial photosynthesis produces an "oasis" of free O_2 in benthic mats below an anoxic water column in Lake Fryxell, Antarctica. Rates of photosynthesis are slow due to low irradiance, but O_2 production seasonally exceeds consumption and loss to the surrounding environment, and O_2 accumulates within the mat during summer. These transient O_2 oases provide the first known modern analog for formation of O_2 oases during Archean time, prior to oxidation of Earth's atmosphere. We hypothesize that once the first cyanobacteria evolved, they produced localized O_2 oases in benthic mats analogous to those in Lake Fryxell under a reducing atmosphere and surface waters. Then, as the efficiency of photosytem II increased and cyanobacteria evolved mechanisms to reduce photoinhibition, O_2 oases expanded within benthic mats and into the water column, eventually leading to oxidation of the upper oceans and the atmosphere. The presence of O_2 oases in benthic mats in terrestrial aquatic systems like those in Lake Fryxell may account for geological evidence for oxidative sulfate mineral weathering on land as early as 2.8 billion years ago.

Lake Fryxell: Lake Fryxell (75°35'S, 163°35'E) is a perennially ice-covered Antarctic lake. The stratification and ice-cover, inhibit mixing so that solute transport below 5 m depth is dominated by diffusion. An oxycline at ~9.5 m depth separates O_2 saturated water from deeper euxinic water. Irradiance is highly seasonal with six months of winter darkness.

Results: In November 2012, light transmitted through the ice and water resulted in 1 µmol photons/m^2s (the lower limit for net photosynthesis [1]) reaching 10.4 m depth in Lake Fryxell. However, the water column transitioned from O_2 supersaturated at 9.1 m to complete anoxia below ~9.8 m (Fig. 1). Net O_2 production in benthic mats at 9.8 m is demonstrated by a peak in O_2 at 1 mm depth in the mat (Fig. 2). The spatial distribution of O_2 indicates a flux to the water column of 0.04 µmol O_2/m^2s and into the sediment of 0.013 µmol O_2/m^2s. A net export of 0.05 µmol O_2/m^2s is consistent with expected local photosynthetic rates.

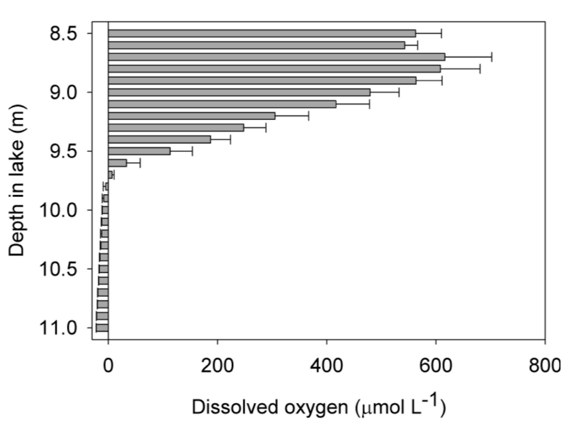

Fig. 1: O_2 with depth in Lake Fryxell. Error bars represent 1 standard deviation. Values below zero are artifacts of electrode calibration for high O_2 at shallow depths.

Implications: Archean terrestrial environments as old as at least 2.7 Ga contained benthic mats [2]. Once O_2 photosynthesis evolved, lakes likely hosted O_2 oases analogous to those in Lake Fryxell, providing microenvironments for oxidative weathering of pyrite, which could provide a mechanism for observed trace element fluxes [3]. Thus, local mat oases provide an alternative to whiffs of atmospheric O_2.

References: [1] Hawes I. et al. (2001) *Antarc. Sci. 13*, 18-27. [2] Buck R. (1992) *Science 255*, 74 –77; Rye R. and Holland H.D. (2000) *Geology 28*, 483-486. [3] Anbar A.D. et al. (2007) *Science 317*, 1903–1906.

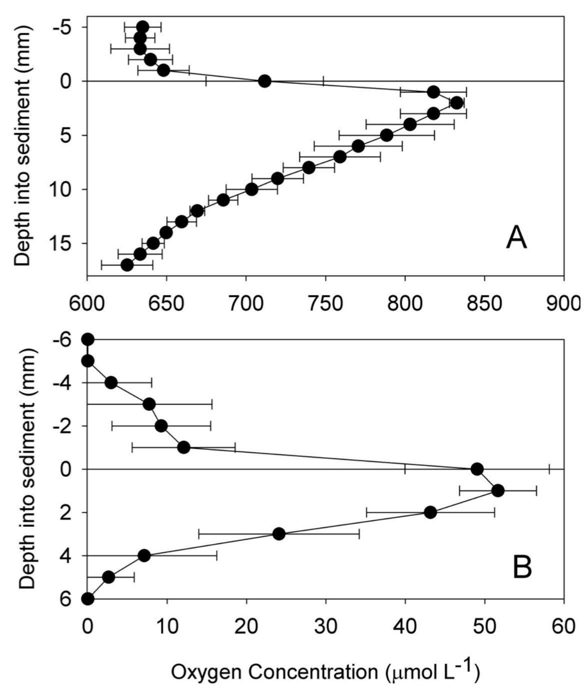

Fig. 2: Profiles of dissolved oxygen through mat-water interfaces in Lake Fryxell. A) The mean and one standard deviation of two replicate profiles through a mat in the oxic part of the water column (9.0 m depth). B) The mean and one standard deviation of 5 replicate profiles in the anoxic part of the water column (9.8 m depth).