A recipe for changing terrestrial air pressure 2.7 Gyr ago: redox states, biology and plate tectonics. S. M. Som[1,2], D.C. Catling[3], and R. Buick[3], [1]Blue Marble Space Institute of Science (1200 Westlake Ave N Suite 1006, Seattle, WA 98109 – sanjoy@bmsis.org), [2]NASA Ames Research Center [3]University of Washington, Department of Earth and Space Sciences, Seattle WA 98195.

Introduction: Air pressure constrains atmospheric composition, which, in turn, is linked to the Earth system through biogeochemical cycles and fluxes of volatiles from and to the Earth's interior. While the modern air pressure is known, there is little reason that this value has stayed the same through geological time due to major changes in climate and atmospheric redox states.

We calculate Archean barometric pressure using gas bubble size (vesicle) distributions in uninflated basaltic lava flows that solidified at sea level 2.7 billion years ago in the Pilbara Craton, Western Australia. These vesicles have been filled in by secondary minerals deposited during metasomatism and so are now amydules, but thin sections show that infilling did not change vesicle dimensions. Amygdule dimensions are measured using high-resolution X-ray tomography from core samples obtained from the top and bottom of the lava flows. The modal size expressed at the top and at the bottom of an uninflated flow can be linked to atmospheric pressure using the ideal gas law. Such a technique has been verified as a paleoaltimeter using Hawaiian Quaternary lava flows [1]. We use statistical methods to estimate the mean and standard deviation of the volumetric size of the amygdules by applying 'bootstrap'resampling and the Central Limit Theorem. Our data indicate a surprisingly low atmospheric pressure and a new upper-limit of 0.5 bars.

Nitrogen draw-down: In the absence of environmental oxygen, the fixation branch of the N-cycle is decoupled from the "fast" denitrification branch (requiring oxygen-derived nitrites and nitrates), and instead is coupled to the "slow" geological N cycle via subduction. The uptake and loss of marine ammonium to mineral species from the early anoxic ocean would draw down atmospheric pN_2.. Such sequestration of nitrogen could account for a low pN_2 in the late Archean compared to today.

We suggest that the atmospheric rise of oxygen at 2.4 Ga enabled the delivery of oxidized species into the mantle wedge via subduction (e.g., Ref [2]), shifting the redox balance to allow speciation of nitrogen from NH_4^+ to N_2 [3], which could then be released volcanically. Thus, we suggest that a rise of N_2 was a possible consequence of the Great Oxidation Event. Such an increase in pN_2 would necessarily be spread over a timescale of a few hundred million years and may be associated with a comparable timescale in the Paleoproterozoic before the Earth reached its new new stable state of Proterozoic climate and atmospheric composition.

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References:

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