Global silicate weathering: not always in control of climate, and not required to balance global degassing

BENJAMIN MILLS[1], ANDREW J. WATSON[1] AND TIMOTHY M. LENTON[2]

[1]School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, U.K.

[2]College of Life and Environmental Sciences, University of Exeter, Exeter EX4 4PS, UK.

Silicate weathering and carbonate deposition allows for net transfer of CO_2 from the atmosphere to the crust, and dependence of the rate on local temperature and CO_2 concentration stabilizes long term climate [1].

However, the operation of this process is considerably more complex than the simple kinetic relationships employed in current models. Limitation at the global scale via transport of cations is possible either under very high temperature/CO_2, such as following a snowball Earth event [2], or under very low erosion rates, such as during the Mezozoic. In both of these cases, climate stability may have been unattainable for long periods.

In the Precambrian, smaller continental area and lack of biotic soils likely provided harsh limitation of the silicate weathering flux, requiring the operation of an additional stabilizing mechanism to counter the higher degassing rates expected. Seafloor carbonatization appears to be a likely candidate [3], and additional climate regulation via this process decouples the the global silicate flux from CO_2 degassing rates.

The action of two independent stabilizing mechanisms allows for the global silicate weathering rate to increase permanently in response to biological or tectonic enhancements. We suggest that increasing rates of organic carbon burial over time (leading to planetary oxygenation), as well as changes in CO_2 dynamics, may be linked to a progressive increase in terrestrial chemical weathering rates.

[1] Walker, J.C.G., P.B. Hays, and J.F. Kasting (1981), *J. Geophys. Res.* **86,** 9776-9782. [2] Mills, B., *et al.* (2011), *Nature Geosci.* **4,** 861-864. [3] Caldeira, K. (1995), *Am. J. Sci.* **295,** 1077-1114.

Experimentally verifying the low oxygen demands of primitive animals

D.B. MILLS[1]*, L.M. WARD[2], C. JONES[1], M. FORTH[1], B. SWEETEN[1], A.H. TREUSCH[1] AND D.E. CANFIELD[1]

[1]Nordic Center for Earth Evolution, Institute of Biology, Univ. of Southern Denmark, 5230 Odense M, DK (*correspondence: daniel.brady.mills@gmail.com)

[2]Department of Geological and Planetary Sciences, Caltech, Pasadena, CA 91125, USA (lward@caltech.edu)

A rise of oxygen in the atmosphere and oceans is one of the most popular explanations for the relatively late and abrupt appearance of animal life on Earth [1, 2]. Multiple lines of geochemical evidence support an oxygenation and ventilation of the Ediacaran ocean (635–542 Ma), corresponding with the diversification of complex life, and supporting oxygen's role as the driving environmental factor behind the rise of metazoans [3, 4, 5, 6]. However, the critical concentration of oxygen required for primitive animals remains ambiguous. Therefore, in order to evaluate the oxygen-trigger hypothesis for animal origins, the minimum oxygen concentration supportive of animal life, in general, needs to be experimentally determined.

Our experiments show that modern demosponges, serving as analogs for early animals, can survive under low-oxygen conditions of 0.5-4.0% present atmospheric levels. Given that the last common ancestor of metazoans likely exhibited a physiology and morphology very similar to those of modern sponges [7, 8], its oxygen demands may have been met well before the marine redox shifts of the Ediacaran Period. Therefore, while animals certainly require oxygen, their origination did not necessarily require a contemporaneous rise in the oxygen content of the atmosphere and oceans. Our results, overall, suggest that the relatively late origination of animal life on Earth was not due to restrictively low levels of environmental oxygen that were finally lifted during the Neoproterozoic Era.

[1] Nursall (1959) *Nature* **183**, 1170-1172. [2] Knoll (1992) *Science* **256**, 622-627. [3] Fike *et al.* (2006) *Nature* **444**, 744-747. [4] Canfield *et al.* (2007) *Science* **315**, 92-95. [5] Scott *et al.* (2008) *Nature* **452**, 456-459. [6] Sahoo *et al.* (2012) *Nature* **459**, 546-549. [7] Sperling *et al.* (2009) *Mol. Biol. Evol.* **26**, 2261-2274. [8] Erwin *et al.* (2011) *Science* **334**, 1091-1097.

DOI:10.1180/minmag.2013.077.5.13