The evolution of weathering regimes

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Microbial communities, fungi, land plants and now humans have transformed weathering regimes and with that the composition of the atmosphere and oceans.

Land colonisation began as a microbial 'Matworld' in the Archean Eon, leaving geochemical signals of phosphorus weathering and localised oxidative weathering [1]. After the Great Oxidation Event ~2.4 Ga, in the Proterozoic Eon, global but kinetically-limited oxidative weathering of ancient organic carbon regulated atmospheric O_2 at low levels [2]. Conceivably the addition of eukaryotic algae and especially fungi to the 'Matworld' enhanced selective weathering of phosphorus, increasing ocean phosphorus levels and atmospheric O_2 in the Neoproterozoic Era.

The colonisation of the land ~450-350 Ma by non-vascular plants in the Ordovician followed by vascular plants in the Silurian-Devonian-Carboniferous revolutionised weathering regimes [3-5]. Weathering experiments and modelling suggests that early non-vascular plants lowered atmospheric CO_2, contributing to the Late Ordovician glaciations [3], and increased O_2 to levels >15% of the atmosphere, supporting combustion for the first time in Earth history [4]. The rise of vascular plants reinforced the decrease in atmospheric CO_2 and increase in O_2, oxygenating the deep ocean, and fundamentally changing the global oxidative weathering regime from kinetically-limited to transport-limited [2,5]. Regulation of atmospheric O_2 switched from its oxidative weathering sink to its source; phosphorus weathering and resulting organic carbon burial.

In this regime, pulses of vegetation evolution/expansion that increased phosphorus weathering have plausibly triggered some oceanic anoxic events (OAEs) e.g. in the Late Devonian. Conversely, I hypothesise that the widespread loss of forests at the end Permian extinction catastrophe suppressed biological weathering so much that the system was tipped into a stable high-CO_2 'hothouse Earth' state that persisted for millions of years through the early Triassic.

Now humans are creating a new and unusual weathering regime, massively increasing erosion rates and phosphorus input to the ocean and risking triggering a future OAE [6].

[1] Lenton & Daines (2017) *New Phytol.* **215**, 531-7. [2] Daines *et al.* (2017) *Nat. Comms.* **8**, 14379. [3] Lenton *et al.* (2012) *Nat. Geosci.* **5**, 86-89. [4] Lenton *et al.* (2016) *PNAS* **113**, 9704-9. [5] Lenton *et al.* (2018) *Earth Sci. Rev.* **178**, 1-28. [6] Watson *et al.* (2017) *Phil. Trans. A* **375**, 20160318.