A Paleozoic oxygenation event driven by the first land plants

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Land plants have transformed weathering regimes and with that the composition of the atmosphere and oceans.

It is widely accepted that the rise of rooted, vascular plants, including the first forests, through the Devonian-Carboniferous accelerated silicate weathering, causing a drawdown of atmospheric CO_2 and cooling the planet into the Permo-Carboniferous glaciations. Prior to that, the first non-vascular plants (mosses, liverworts and hornworts) colonised the land in the Mid-Late Ordovician. Weathering experiments have shown that a modern moss can amplify silicate weathering by a factor of 1.5 to 6 [1]. With a plausible estimate of the area covered by early non-vascular plants, they could have halved atmospheric CO_2, causing sustained global cooling of around 5 °C, and triggering the Late Ordovician glaciations [1].

Mosses were also found to amplify phosphorus weathering by a factor of up to 60. This could explain the extensive shallow water phosphate deposits, organic-rich black shale, and positive excursions in the marine carbon isotope record in the Late Ordovician. We predict a resulting rise in O_2 to levels >15% of the atmosphere, that could support combustion for the first time in Earth history. This is consistent with the appearance of the first fossil charcoal in the early Silurian, and with geochemical data that shows the deep ocean first became fully oxygenated sometime between the Ordovician and Mid Devonian [2]. The subsequent evolution of lignins with a high C/P ratio, further increased organic carbon burial and atmospheric O_2 [3].

Thus we argue for a 'Paleozoic oxygenation event' driven by the earliest land plants. Using an improved modelling framework, based on the 'COPSE' biogeochemical model [3], we predict the effects of early land colonisation and test them against geochemical data. We find that the increase in atmospheric O_2 caused by the rise of land plants fundamentally changed the global weathering regime from kinetically-limited oxidative weathering to transport-limited oxidative weathering [4]. With that the feedback mechanisms regulating atmospheric O_2 shifted from its sink to its source – i.e. from oxidative weathering to phosphorus weathering and the resulting organic carbon burial.

[1] Lenton *et al*. (2012) *Nature Geosci*. **5**, 86-89. [2] Dahl *et al*. (2010) *PNAS* **107**, 17911-5. [3] Bergman *et al*. (2004) *Am. J. Sci*. **304**, 397-437. [4] Daines *et al*. (2015) submitted.