

Land plants, weathering, and Paleozoic climatic evolution

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At the end of the Paleozoic, the Earth plunged into the longest and most severe glaciation of the Phanerozoic eon (Montanez et al., 2013). The triggers for this event (called the Late Paleozoic Ice Age, LPIA) are still debated. Based on field observations and laboratory experiments showing that CO₂ consumption by rock weathering is enhanced by the presence of plants, the onset of the LPIA has been related to the colonization of the continents by vascular plants in the latest Devonian. By releasing organic acids, concentrating respired CO₂ in the soil, and by mechanically breaking rocks with their roots, land plants may have increased the weatherability of the continental surfaces. The "greening" of the continents may also have contributed to an enhanced burial of organic carbon in continental sedimentary basins, assuming that lignin decomposers have not yet evolved (Berner, 2004). As a consequence, CO₂ went down, setting the conditions for the onset of the LPIA. This scenario is now widely accepted in the scientific community, and reinforces the feeling that biotic evolutionary steps are main drivers of the long-term climatic evolution.

Although appealing, this scenario suffers from some weaknesses. The timing of the continent colonization by vascular plants was achieved in the late Devonian, several tens of million years before the onset of the LPIA (Davies and Gibling, 2013). Second, lignin decomposer fungi were present at the beginning of the Carboniferous, 360 million years ago while the LPIA started around 340-330 Ma (Nelsen et al., 2016). Land plants have also decreased the continental albedo, warming the Earth surface and promoting runoff. Weathering was thus facilitated and CO₂ went down. Yet, temperature may have stayed constant, the albedo change compensating for the CO₂ fall (Le Hir et al., 2010).

From a modelling point of view, the effect of land plants on CO₂ consumption by rock weathering is accounted for by forcing the weatherability of the continents to rise by a factor of 6 (Berner, 2004). This factor has been inferred from studies of the weathering rate of rocks in young environments, such as recent lava flows colonized by the vegetation (e.g. Moulton et al., 2001). Nevertheless, present-day continental areas displaying a dense vegetal cover (equatorial forests) are characterized by low weathering rates (West, 2012). Indeed, the development of thick and depleted weathering profiles has shifted those systems into a supply-limited regime. The arising questions are thus: is the land plant effect on CO₂ consumption by weathering only transient, and if yes, how long does it last? Thousand, million, or tens of million years? Is a world fully vegetated weathering faster than a naked world?

Those questions will be investigated through a modelling study simulating the colonization of the continents by land plants in the late Paleozoic using a simple cellular automata algorithm, coupled to a weathering model accounting for the role of the regolith thickness on the weathering regime.