Subduction zones, CO_2 degassing, and recovery from the Cryogenian icehouse

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The Cryogenian Period (~720-635Ma) may have seen the coldest climates in Earth history, whilst the following Ediacaran and Cambrian periods (together 635-485Ma) saw the evolution and explosive radiation of the first animal life.

Proposed causal mechanisms for Cryogenian glaciations are often linked to the removal of CO_2 from the atmosphere by the global biota, or via terrestrial weathering events, e.g. [1]. However, such events have orccured during the Phanerozoic, and have not resulted in the return to global glaciation, hinting at an underlying step-change in surface conditions.

Here we analyze plate tectonic reconstructions in order to estimate changes in the global total length of subduction zones, from the Cryogenian through to the present day. Subduction zone length is a first-order control on the rate of CO_2 degassing at volcanic arcs, and recent work has shown that accounting for subduction zone length resolves mismatches between Phanerozoic model outputs and CO_2 proxy data [2].

Our reconstruction shows a dramatic increase in the total length of subduction zones during the Ediacaran and Cambrian periods, coinciding with the collisions that formed the Pannotia and Gondwana supercontinents. When combined with a simple carbon cycle model [3], this implies a background potential climate warming of ~5°C over these periods.

We conclude that whilst changes in carbon sinks may explain the onset of Cryogenian glaciations, it was the backdrop of low rates of subduction-related CO_2 degassing that allowed for the remarkably low temperatures during this period of Earth history. Long-term recovery from the Cryogenian icehouse appears to have been driven by a system shift towards greater subduction zone length. Moreover, this shift appears necessary for the evolution and development of the complex animal and plant biospheres that define the modern Earth system.

[1] Donnadieu et al. (2004) *Nature* **428,** 303-306. [2] Van Der Meer et al. (2014) *PNAS* **111,** 4380-4385. [3] Mills et al. (2014) *PNAS* **111,** 9073-9078.