

# Neoproterozoic Snowball Earth initiated by evolutionary advances in life on land

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Snowball Earth is a nickname for the Cryogenian Period, 717 to 635 Ma, when glaciers extended into tropical latitudes. Previous explanations were increased silicate weathering in tropics or of volcanics, or consequent marine plankton blooms. This study demonstrates enhanced chemical weathering and carbon sequestration due to evolutionary advances in life on land as cause of glaciation. Tonian paleosols of the Chuar Group in Arizona and Bitter Springs Group of Australia yielded fossils of increased soil microbiome diversity, including fungi and testate amoebae, and fragmentary, multicellular fossils. Three proxies for changes in the global carbon cycle come from paleosols. First, depth to carbonate nodules in paleosols is a proxy for late growing season production of respired soil CO<sub>2</sub>, and depths corrected for burial compaction show a significant increase from Tonian to Cryogenian (Fig.1). Second, tau analysis of paleosol profile geochemistry gives CO<sub>2</sub> consumption by silicate weathering of common alkali and alkaline earth elements. This can be converted to a rate with estimates of duration of weathering. Estimates of paleoprecipitation from paleosols then gives precipitation-normalized nutrient depletion rate ( $\mu\text{mol mm}^{-1} \text{a}^{-1}$ ), which in turn can be used with continental area and assumed near modern modal mean annual precipitation (764 mm) to estimate global annual carbon sequestration in picograms ( $=10^{15} \text{ g}$ ). The results of these calculations show increases in Cryogenian silicate weathering (Fig.2A). Third, tau analysis of paleosol profile depletion of phosphorus can be used in a similar way to derive precipitation-normalized depletion rates, as a basis for calculating global increases of carbon sequestration in biomass, and this showed significant increase (Fig.2B). Increased soil biomass, respiration, and nutrient depletion accelerated silicate weathering and carbon consumption, diminished CO<sub>2</sub> greenhouse, and ushered in Snowball Earth, just as during Ordovician rise of land plants, Carboniferous rise of forests, and Neogene rise of grasslands.

## References

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Fig.1. Paleosol productivity from compaction-corrected depth to Bk horizon.

Fig.2. Carbon consumption (A) and sequestration (B) on land from 1200-500 Ma.

