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Untangling planetary processes in the Neoproterozoic using cap carbonates and a geochemical carbon cycle model.

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The Neoproterozoic era is characterized by planetary-scale changes in Earth's surface environment: there were at least two "Snowball Earth" events where ice sheets reached low latitudes, the atmospheric oxygen abundance increased by several orders of magnitude, and large, complex life evolved in the Ediacaran. Knowledge of the evolution of Earth's surface environment during this era can help untangle the causes of, and relationships between, these changes.

The geochemistry of Neoproterozoic Earth's atmosphere and ocean is probed by "cap carbonates", layers of limestone or dolostone up to ~200 m thick that sharply overly the Snowball Earth glacial deposits in over 50 global locations. The presence of the cap carbonates suggests that there was an abrupt shift in climate following Snowball Earth events: from cold and ice-covered to hot and high CO_2; however, the exact mechanism that generated the required ocean chemistry and explains their formation has yet to be identified, but may involve enhanced continental weathering, stratification of the post-glacial ocean, microbial sulfate reduction, deep ocean upwelling, hyaloclastite formation on the seafloor, and more.

Here, we test potential cap carbonate formation mechanisms using a geochemical model of the Snowball Earth events. Our model tracks the evolution of the carbon concentration and marine carbonate alkalinity in the atmosphere and ocean as it is subject to processes of the geologic carbon cycle like continental weathering, seafloor weathering, and volcanic outgassing. We have modified our model to capture key aspects of the Snowball glaciation, such as the ice-covered syn-glacial ocean, the stratified post-glacial ocean, and the hothouse post-glacial climate. Thus, we have generated fully self-consistent geochemical evolution scenarios from pre- to post-Snowball.

Our results help distinguish between the possible mechanisms of cap carbonate formation and allow us to constrain the evolution of Earth's surface environment through the planetary-scale changes of the Neoproterozoic. This helps address key astrobiology questions about the rise of complex life on Earth, the survivability of global glaciation events, and the climate stability of potentially habitable exoplanets.