Terrestrialization of the Earth and its influence on the advent of complex life

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For the first 3 billion years of life's history on Earth single celled organisms were Earth's sole residents. In the Late Precambrian this record changed dramatically with the appearance of complex multicellular life (metazoans) that rapidly diversified and radiated. This radiation was likely triggered by planetary changes, though what those changes were, how they interacted with intrinsic (genetic) influence and which changes were causes and which effects constitute principal questions in geobiology with important implications for the conditions on other planets necessary to support complex life. Much of what we know of this transformation comes from the marine record because of a strong preservational bias relative to terrestrial sediments. It is evident from studies of the modern biosphere, however, that the terrestrial realm has a critical influence on the sustainability of complex life. While it is widely accepted that the early terrestrial surface of the Earth was inhospitable to life, and the timing of the greening of the Earth's surface remains poorly constrained, the infleunce of vascular land plants beginning in the Silurian is commonly believed to have been an important step in establishing the present Earth system. However an earlier more cryptic and simple biomass likely colonized and expanded across the Precambrain landscape, modifying physical and chemical weathering patterns, soil clay mineral production, marine and terrrestrial carbon burial, nutrient flux to marine systems and the hydrological cycle. It is reasonable to hypothesize that biogeochemcial systems, like clay mineral associated organic carbon preservation and burial, that play an important role in CO_2 sequestration and atmospheric oxygen production today, were intitated during this earlier transition. Secular changes in clay mineral composition of sediments through late Precambrain continental margin sediments show a distinct rise in phyllosilicates in support of this hypothesis. Alteration of the carbon isotopic composition of coastal carbonates by dissolved organic mater in meteoric waters also becomes a pronounced influence during this period of time, and finally new fossil discoveries also point to the terrestrial surface as being an important component in planetary transformation.

A continental amplifier for marine carbon sequestration in a greenhouse ocean

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Recent evidence has increased concern that future climate will be influenced by natural processes and feedbacks more common to a warm climate mode. It is well known from past greenhouse periods that anomalous concentrations of organic carbon were associated with disruption of marine ecosystems, widespread anoxia, and climate perturbations. While most models of black shale formation focus on oceanographic controls, findings on modern continental margin sediments also identify a strong landward influence on marine carbon burial that is also consistent with current understanding of hypoxic zone expansion. Here we show evidence for a direct land-sea mechanism that translates the effects of changing continental climate to carbon burial in deep marine sediments via the preservative effects of detrital clay mineral surfaces. We show a correlation (r^2=0.75) at cm resolution between mineral surface area (MSA) and abrupt (centennial or less) high magnitude shifts in TOC from 1% to 15% in pelagic sediments from the tropical Cretaceous Atlantic (ODP 959). Carbon burial was maximized by an enhanced flux of high MSA clay minerals formed in response to increased seasonality in tropical Africa that were exported to hypoxic shelf waters with high dissolved organic carbon concentration. Not only do these data identify a dominating terrestrial influence for back shale formation during one of the 'Cretaceous Oceanic Anoxic Events' ~ 85 ma (OAE3), but show that climate under greenhouse conditions can cross a threshold into a highly sensitive mode in which organic carbon burial efficiency is amplified, providing a negative feedback to pCO_2,