LIP-Induced Primary Positive CO_2-Feedback Loop and Its Associated Tipping Points, Running the Climate Show Throughout Earth's History

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Earth's climate is changing rapidly, primarily through CO_2 increase, and these changes are pushing Earth to critical tipping points (Lenton et al. 2008; Lenton 2013) where further small perturbations can trigger a large response with a long-term consequences. One of the most urgent tasks in modern climate change research is to predict, characterize and moderate the risk of crossing such climatic tipping points.

As a contribution to understanding modern tipping points, we review Earth's geological history of tipping points, representing sudden dramatic climatic changes, many of which are associated with Large Igneous Provinces (LIPs) (Ernst and Youbi 2017). Such events include Hothouse periods, major glaciations (including "Snowball Earths"), step changes in Earth oxygen level (the c. 2.4 Ga Great Oxidation Event (GOE) and Neoproterozoic Oxygenation Event (NOE)), Ocean Anoxic Events (OAEs), and mass extinction intervals, all reflected by rapid excursions of stable isotopes proxies, by anomalous isotope paleoenvironment proxies, and by sudden changes in sedimentary lithologies.

Consideration of Earth's climate history in terms of tipping points should allow identification of key climatic forcing functions (drivers) through time. The dominant one is CO_2 concentration and many tipping points are linked to positive feedback loops such as ice-sheet albedo, CO_2 drawdown through weathering, anoxia and oxia evernts. Other key climatic drivers are nutrient flux into the ocean from weathering, silicic pyroclastic eruptions, and hydrothermal flux from marine magmatism, along with associated biological effects and chemical sedimentation.

Refs: Ernst and Youbi 2017. How Large Igneous Provinces affect global climate, sometimes cause mass extinctions, and represent natural markers in the geological record: Palaeogeog., Palaeoclim., Palaeoecol., 478: 30-52. Lenton et al. 2008. Tipping elements in the Earth's climate system. Proc. Natl. Acad. Sci. 105:1786–93. Lenton 2013. Environmental tipping points. Annu. Rev. Environ. Resour. 1-29.