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Title: **Earth's early reduced atmospheres**

200 character summary:

Earth's early atmosphere evolved in response to cosmic impacts, photochemistry, hydrogen escape, mineral redox buffering, iron in the mantle, and crustal weathering and subduction.

Abstract:

Earth's early atmosphere evolved in response to cosmic impacts, photochemistry generated by the copious extreme ultraviolet radiation emitted by the young Sun, hydrogen escape, mineral redox buffering, the evolution of iron in the mantle, and the character of crustal weathering and subduction. No single chemical composition, surface pressure, or temperature was typical.

After the biggest impacts the temperature likely rose above 3000 K and the atmosphere held rock vapor. As the atmosphere cooled its constituents rained out: first the silicates, then the geochemical volatiles (such as salt), and last the water. Depending on the size of the impact, cooling took thousands to millions of years. Between impacts the atmosphere was thick with gases like CO₂, H₂, and CH₄ that do not condense at Earth but provide greenhouse warming that could easily have maintained surface temperatures in excess of 500 K.

At some point the early atmosphere must have been conducive to the evolution of organic chemistry and the origin of life. It was therefore --- at times --- dominated by reduced gases like hydrogen and methane. Hydrogen-methane atmospheres are easily formed thermochemically after major impacts if H₂O and CO₂ were present on Earth in quantities consistent with their inventories on Earth today – the key is high pressure. Hydrogen-methane atmospheres slowly break down over millions of years by hydrogen escape and photochemistry. At first methane decomposes into tars and nitriles that precipitate, but later as the atmosphere grows more oxidized from hydrogen escape the methane oxidizes to CO and CO₂, with a small fraction going to HCN. Impacts can also produce NH₃ directly from N₂ and H₂O, which is expected to rain out with the H₂O.

As impacts grew infrequent the climate cooled in response to the fixing of CO₂ as carbonate and carbonate subduction. Eventually the CO₂ was mostly removed to the mantle and the surface mostly frozen.