Upper limit on H_2 levels in the Archean atmosphere based on detrital magnetite

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The partial pressure of hydrogen on the early Earth is important because it has been proposed that high pH_2 warmed the planet [1, 2] or allowed prebiotic chemistry in the early atmosphere [3]. However, such hypotheses lack observational constraints. Here, we estimate an upper limit on pH_2 using a kinetic model of magnetite conversion given that detrital magnetite is found in Archean riverbeds (e.g., [4]).

A magnetite particle is converted and disappears on a timescale that depends on pH_2 and pH. Assuming a pH derived from reasonable estimates of the pCO_2 range in the Archean, the survival time is ~100 kyr when pH_2 is 10^{-2} bar, and decreases as pH_2 increases.

The residence time of a particle in long river systems is 100 kyr [5], so the observation of detrital magnetite particles in Archean river beds at ~3.0 Ga [4] likely indicates that pH_2 was below 10^{-2} bar. The uncertainty in kinetic rates favors a decrease in the timescale, so our value of pH_2 is a robust upper limit of pH_2 in the Archean atmosphere. This upper limit for pH_2 is consistent with that imposed on pH_2 by Archean ecosystems that include methanogens (e.g., [6]). However, the limit precludes both H_2 as a significant greenhouse effect via collision-induced absorption and a strongly reducing atmosphere at ~3.0 Ga.

References

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