A cold and alkaline ocean on Hadean Earth caused by impact ejecta weathering

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The origin of life remains a major unsolved problem. Constraints on the environment of the early Earth would help inform the conditions for the origin of life in addition to enabling a better understanding the chemical and physical evolution of the Earth itself.

The Earth's long term surface temperature is moderated by silicate continental and seafloor weathering, i.e., the carbonate-silicate cycle, as shown previously [e.g., 1]. Feedbacks in the cycle kept Archean atmospheric CO_2 (pCO_2) larger than today to compensate for the faint young Sun, which would decrease ocean pH. The same mechanism would operate in the Hadean, so the Hadean surface environment might be temperate and the ocean acidic. However, the Hadean Earth experienced intense impacts, which produced ejecta that were easily weathered [2]. Hence, some studies have suggested a cold early surface environment, although they did not consider the ocean pH.

In this study, we modeled impact ejecta weathering within a carbonate-silicate cycle with essential ocean chemistry. Results show that the Hadean impact flux decreases pCO_2 and surface temperature. Moreover, low pCO_2 increases ocean pH. Hence, the Hadean surface environment would be cold and the ocean weakly alkaline.

Such an environment is confined to the early Hadean under a high impact flux. However, if there was an interval of enhanced impact flux (i.e., Late Heavy Bombardment), a cold and weakly alkaline ocean is modeled around 4 Ga also. Such a cold and alkaline surface environment might be advantageous for a Hadean origin of life [3].

[1] Krissansen-Totton et al. (2018) *PNAS* **115**, 4104-4110. [2] Sleep & Zahnle (2001) *JGR* **106**, 1373-1399. [3] Bada & Lazcano (2002) Science 296, 1982-1983.