A model of ocean pH over Earth history

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The evolution of ocean pH has important implications for life's origins and biogeochemical cycling. All life on Earth obtains free energy from proton (pH) gradients across cell membranes, and pH gradients in hydrothermal settings have been suggested as a possible setting for the origin of life [1]. Bacterial biomineralization is also pH-dependent, and thus the pH of early Earth's ocean may constrain the emergence of complex life [2,3]. Additionally, ocean pH determines how CO_2 is partitioned between the atmosphere and oceans, and is therefore central to understanding the geological carbon cycle and Earth's long-term climate evolution.

Despite its importance, there is disagreement on the pH value of Precambrian oceans. It has been argued that the early Earth's ocean was basic [4], near-neutral [5], and acidic [6]. Here, we present a time-dependent model of ocean pH over Earth history to test these conflicting hypotheses.

Our simple box model computes ocean chemistry subject to changes in continental weathering, continental growth, and solar luminosity changes. Using lab data, we parameterize pH and temperature-dependent seafloor weathering, which is an important buffer of atmospheric CO_2 and ocean pH.

We validate our model using Cretaceous proxies, and we are able to reproduce the empirical results from [7,8] showing enhanced seafloor weathering in a hothouse Cretaceous climate. The model is then extended into the Precambrian. Uncertainties in current knowledge of carbon cycle processes are incorporated into the model parametrizations to produce a probability distribution for ocean pH over time. Finally, our results are contrasted against existing carbon cycle models of the early Earth.

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