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WEATHERING: EARTH'S INEXORABLE MILLSTONE

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Mere centuries from now, almost every physical object you've bought or wrought will have disappeared from the face of the Earth. Nature's forces will conspire to erase your archeological record. Unless you live in a stone manor, the foundations of your home will gradually crumble due to carbonic acid seeping into hairline cracks. Soil will migrate and turn over, shifting and consuming whatever *objets d'art* now grace your yard. Oxidation and sunlight will yellow and crack exposed plastic and paper. And everywhere, always, a teeming horde of plant roots, invertebrates, moles, and their microbial friends and relations will disaggregate and eat whatever they can. In the blink of a geological eye, almost your entire archaeological record will very likely be buried, broken down, and swept away.

Photo Credit: Larry Miller, CC BY-SA 2.0

But rejoice! As much as this fact might feel like a personal affront, it's a good thing. A miraculous thing. Mineral weathering is essential to the long-term buffering of atmospheric CO_2 at moderate levels, and, thus, can be thought of as a geochemical thermostat for Earth's climate over geological timescales. The harsh photooxidation of the surface environment clears methane and other reduced gases from the atmosphere and quickly degrades pollutants from soil and water surfaces. And the biosphere's capacity to reuse and redistribute carbon and nutrients is central to ecology at every scale. The inexorable grind of chemical and physical weathering is one of the key foundations by which the Earth's surface remains habitable.

But weathering comes in many forms. Looking at our celestial neighbors—the terrestrial planets, moons, and asteroids—we see that weathering, erosion and burial are ubiquitous in the solar system. But, weathering on our celestial neighbors comes in unfamiliar forms that we should be happy to skip: intense ultraviolet and cosmic-ray irradiation, ion sputtering, impact gardening, sublimation, and condensation of ices. It is Earth's distinctive mix of abundant liquid water, mild acids, atmospheric pressure, abundant oxygen, and living dynamic soils that turn the destructiveness of weathering and erosion into life-sustaining forces.

As we look back into geological time, we see long stretches of Earth's history where the modern norms of terrestrial weathering were mutated into unrecognizable and, for us humans, unwelcoming forms: frozen Earth where raw rock lay unconsumed by acid attack and CO_2 accumulated in the atmosphere; reduced Earths where the oceans were perfused with sulfide and undigested organic matter; Earths where life was confined to the oceans and unable to crack into the land's warehouse of rock-bound nutrients. We find ourselves surrounded, on every side in space and backward in time, with versions of the Earth where the processes of weathering and erosion bring destruction, yet with none of the rebirth.

And what of the future? Strange things are afoot in Earth's weathering surface. In just a few decades, anthropogenic emissions have charged the atmosphere with nearly double its geologically recent norm of CO_2. This now stands poised to get on with its business of silicate weathering. And our manipulation of the biosphere and soils has expanded to the point where our decisions about agriculture, construction, and industry could come to dominate the way that CO_2 is consumed by weathering. We find ourselves commanding both the driving forces of the silicate weathering system, and some of the gears by which it operates. Can these two unintended powers over the environment somehow be made to counteract one another?

This issue of *Elements* explores the past, present, and future of weathering on the Earth's surface, including its agents (the physics of fracture, the chemistry of water–rock reaction and the biosphere), its consequences (climate and landscape evolution), and our potential to harness it as a force for mitigating anthropogenic climate change. It is a fine example of the abilities of Earth scientists to reach across time, geography, and disciplines to get their arms around complex, dynamic, natural problems. It is also a window into the engines of geochemical and physical transformation that control our ultimate physical fates and render our world habitable.

John M. Eiler
Principal Editor