KELLY CLARKSON
STUDIO 3
IN LA VERNE
JULY 17 - AUGUST 13
$15-$25
Enjoy enhanced access: CLICK HERE FOR MORE
SEE ALL SHOWS AT SCIENCESTUDIO.COM
SCIENCESTUDIO

Feature | Climate Change
Volume 197 | Issue 7 | April 1, 2020

How powdered rock could help slow climate change

A method called enhanced rock weathering shows promise at capturing carbon dioxide from the air.

By Aris Aditi Davis
Ann Arbor, Mich.

On a hazy afternoon in rural Australia, a tractor-mounted machine harvesting fairy spheres crushed volcanic rock between rows of sugarcane. Eight thousand kilometers away, two young men in neutral India dust the leaves of a cashew tree with a powdery substance. Across the ocean, across a forest in Belgium, a spreader is pacing by hand onto tea grounds plants. Far to the north in Sugg Scotland, a pile of potatoes gets the same treatment, as do cattle pastures on sunny slopes in southern Brazil.

And from Michigan to Mozambique, farmers are scattering volcanic rock dust on their wheat, soy and corn fields with ag spreaders typically reserved for dispersing crushed limestone to adjust soil acidity.

Like this story?

Support high-quality science journalism and help us create more like it.

SUBSCRIBE

Across the continents, these farmers are experimenting with a technique called enhanced rock weathering, designed to improve degraded soil and to help combat climate change.

Enhanced rock weathering takes advantage of Earth's natural carbon cycle, which breaks down carbon dioxide in atmospheric rainwater, in water and soil. Volcanic rock naturally traps atmospheric CO_2 in a process that transforms the gas into a solid form. Like a thermostat, rock weathering can slowly moderate Earth's temperatures over millions of years by keeping atmospheric levels of CO_2, a greenhouse gas, in check.

Over the last two decades, scientists the world over have studied how to accelerate weathering as a potential climate solution. Grinding volcanic rock into powder increases the surface area available for trapping CO_2. While this rock dust can theoretically be spread anywhere, proponents typically target cropland, which offers easy access and multiple co-benefits.

Enhanced rock weathering is one of many carbon dioxide removal techniques that aim to pull greenhouse gas emissions from the atmosphere. Approaches that look up carbon dioxide could be key to meeting climate goals, according to the Intergovernmental Panel on Climate Change. Limiting global warming to 1.5 degrees Celsius above preindustrial levels – a target of the 2015 Paris Agreement – will probably require removing billions of metric tons of carbon dioxide annually by the end of the century, the IPCC says.

Enhanced rock weathering could put a substantial dent in that quantity, some of scientists' calculations. Spreading rock dust on every inch of Earth's planet, if applied to all arable lands on the planet, the method could remove up to 10 billion tons more the next 75 years, according to the team's computer simulations. That's a little of the IPCC's maximum estimate for needed removals.

"Crushing rocks – it's almost too dumb an idea. But it actually works," says Adam M. Wilshaw and chief executive officer of Eion, an enhanced rock weathering start up that appeared in *Time* magazine's list of best inventions last year.

Enhanced rock weathering may sound like a no-brainer. But it faces hurdles including high costs, lack of government incentives, uncertainties and the challenge of how to measure and verify the carbon removed. There's also concern that this relatively newcomer to climate change mitigation will divert money from longer standing priorities, like preserving forests and their carbon absorbing trees (DN 12:20).

Because some approaches to carbon dioxide removal have been embraced by the fossil fuel industry, critics also worry that supporting them will allow oil and gas producers to keep emitting rather than shifting to clean energy.

But the reality is that the world is far from achieving its climate goals without some form of carbon dioxide removal. Of course, both emission reduction and atmospheric carbon dioxide removal are needed now. The only sensible course is to stop engaging in fuel wars and immediately embrace all climate solutions – even newcomers, says Gabrielle Walker, an author and climate change researcher who founded multiple carbon dioxide removal ventures.

"If we don't build climate removals to gigatons scale by 2030," Walker says, "we cannot achieve our climate goals."

Sponsor Message

How does enhanced rock weathering work?

Rocks are composed of minerals that combine with carbon dioxide from the dissolves the breakdown and buildup of rock. Water droplets in the atmosphere combine with carbon dioxide to form carbonic acid. When the weak acid rains down on volcanic rock, silicate minerals in the rock dissolve. This weathering releases calcium, magnesium and potassium ions and transforms the carbon dioxide into bicarbonate (sodium with a net electric charge). The bicarbonate, HCO_3^-, traps the carbon from the atmosphere.

Heartbreaks flows from groundwater into streams and eventually the ocean, where ocean, clams and other critters use it to make their shells and skeletons. Upon dying, the shells and skeletons sink to the ocean floor, according to the team's computer simulations. That's a little of the IPCC's maximum estimate for needed removals.

"Crushing rocks – it's almost too dumb an idea. But it actually works," says Adam M. Wilshaw and chief executive officer of Eion, an enhanced rock weathering start up that appeared in *Time* magazine's list of best inventions last year.

Enhanced rock weathering may sound like a no-brainer. But it faces hurdles including high costs, lack of government incentives, uncertainties and the challenge of how to measure and verify the carbon removed. There's also concern that this relative newcomer to climate change mitigation will divert money from longer standing priorities, like preserving forests and their carbon absorbing trees (DN 12:20).

Because some approaches to carbon dioxide removal have been embraced by the fossil fuel industry, critics also worry that supporting them will allow oil and gas producers to keep emitting rather than shifting to clean energy.

But the reality is that the world is far from achieving its climate goals without some form of carbon dioxide removal. Of course, both emission reduction and atmospheric carbon dioxide removal are needed now. The only sensible course is to stop engaging in fuel wars and immediately embrace all climate solutions – even newcomers, says Gabrielle Walker, an author and climate change researcher who founded multiple carbon dioxide removal ventures.

"If we don't build climate removals to gigatons scale by 2030," Walker says, "we cannot achieve our climate goals."

Weathering in action

With enhanced rock weathering, companies spread volcanic rock powder on cropland (**Step 1 in illustration**). Carbon dioxide from the air dissolves in rainwater and forms carbonic acid (**2**). When that acid rains down on the rock powder, chemical reactions trap the acid's carbon in bicarbonate (**3**), which eventually flows into the ocean (**4**).

S. Harris

Since then, research has boomed. Much of it has been spearheaded by the Leverhulme Centre for Climate Change Mitigation at the University of Sheffield in England, which has conducted studies in the lab and the field on multiple continents.

Spurred by promising results, dozens of enhanced rock weathering companies have formed in the last five years. Although they started tiny, enhanced rock weathering, now are in the trial phase and some are little more than a catchy sell sheet. Some have disappeared or have expanded. They head South from mines or quarries, grind it, transport it to farmers and spread it on their fields. Some companies, like the Irish company Silicate Spreaders, specialize in rock dust logistics. Other companies provide the soil amendment to farmers for free, in exchange for the carbon credits that farmers can sell to companies in corporation such as Microsoft that want to offset their carbon footprints.

The Netherlands-based company greenhead takes a different approach. It sells its rock powder to farmers who use it in greenhouses, decorative stores and building material to keep artificial turf springy.

Other companies are exploring the possibility of spreading rock dust on beaches and ocean waters, which would absorb more dissolved carbon but potentially counter ocean acidification (DN 4/26/16).

What are the benefits of enhanced rock weathering?

Enhanced rock weathering has multiple advantages over other forms of carbon dioxide removal. Unlike tree planting, it promises to built on a natural process, which may help local credibility in the concept. It also holds an enticing industrial promiscuous — mining and agriculture — which can allow for rapid scale-up of commercially viable approaches.

All carbon dioxide removal methods require energy, land and water, and in these areas, enhanced rock weathering has a competitive edge over higher tech methods like direct air capture and bioenergy with carbon capture and storage (DN 10/19/18). Unlike the latter, the method involves growing crops such as potatoes, soybeans or sorghum and then burning the plants, capturing the released carbon for storage underground and harvesting the heat for energy.

Energy needs for rock weathering, mostly related to the grinding and transport of rock, vary widely depending on how far the distance from a farm and the firmness of the powder (rating rock dust left over from mining is easier than grinding up a hard rock). Some rock weathering typically requires only half as much energy as direct air capture, David Beerling, director of the Leverhulme Centre, and colleagues reported in 2021 in *Communications Earth & Environment*. The team studied carbon dioxide removal techniques in different countries.

A direct air capture plant uses machine fans and filters to suck CO_2 out of the air, then combines it with hydrogen to make fuel. The process may would require about 2,200 kwatssec hours of electricity. That's roughly three times as much electricity as the entire U.S. renewable sector generated in 2019.

> "Crushing rocks – it's almost too dumb an idea. But it actually works."
>
> – Adam M.M. Wilshaw and chief executive officer of Eion

In addition to energy savings, enhanced rock weathering can complement existing land uses. That's unlike some other carbon dioxide removal methods, such as bioenergy with carbon capture and storage. To achieve significant carbon removal, some researchers say that would require dedicating a large swath of land to growing fast-growing plants. Such a study published in February in *Science* concluded that ending up bioenergy with carbon capture and storage may "threaten food security and human rights, with potentially irreversible consequences."

Another benefit of enhanced rock weathering is that it requires only a tenth or a hundredth as much water as direct air capture, bioenergy with carbon capture and storage or other carbon dioxide removal strategies, Beerling and colleagues found.

Beyond climate benefits, enhanced rock weathering could help farmers. Modern agricultural practices — tilling soil, removing dead plant material, monocultures, heavy fertilizer and pesticide use and synthetic fertilizers — have damaged soil structure, contaminated fields and acidified soil. When soil becomes too acidic, essential nutrients can be locked up and unavailable to plants, causing crop yields to plunge. Decrease of nitrogen fertilizers can lead to the formation of nitrous oxide, a highly potent greenhouse gas (DN 12/19/18).

Farmers already add crushed limestone to fields to raise soil pH, counteract acidity and improve crop yields. Adding rock powder, chemical makeup, can remove more carbon from the atmosphere than limestone can. Volcanic rock powder can also release essential nutrients such as potassium, phosphorus and trace elements, potentially good news because crop production has to ramp up to feed a rapidly rising human population. Many of these benefits also come with regenerative agriculture techniques, such as no-till farming and the use of cover crops, that aim to improve soil health. Enhanced rock weathering is complementary, Beerling says.

What are the downsides?

Although the mechanics of enhanced rock weathering are well understood, the potential long-term risks are not. The most serious concern is the potential for heavy metal contamination in soils.

This concern was raised at last year's United Nations Climate Change Conference, COP25 (DN 12/12/19). Sonthalia Gaudenzio, chief scientist, author at the U.K. Department for Environment, Food and Rural Affairs, and other researchers studying enhanced rock weathering have published studies pass silicon, "Olivine has high trace metal content, including some toxics, and is a source of nickel, a potentially carcinogenic contaminant in fertilizers," Gaudenzio said.

Heavy metals in olivine rock so nickel can endanger health if absorbed at high enough levels by plants and ingested by humans or livestock, researchers have found. Other studies have raised concerns about heavy metals arise from the fact that enhanced rock weathering works best with repeat applications, which can increase levels of the metals.

The study showing a 250 billion ton reduction in atmospheric CO_2 over a 75 year period assumes annual application of 10 tons of basalt per hectare. But one study, which assumed a commonly used application rate of 1 ton per hectare, found that potentially toxic levels for that kind of application may be reached after only 50 years of repeat application.

Eion, with projects located in the southeastern United States, uses silicon. Wolf, the company's cofounder and chief innovation officer, points out that sod rolled levels is that silicon is not toxic to humans, and is actually recommended. In addition, silicon is absorb rocked more readily in acidic soil, something that silicon contains. "The impact is lower if has our sheets an actual toxicity problem," Wolf says, including one by Hindenburg.

Still, at least one start up isn't taking any chances. Wolfsplain, an affiliate of the climate think tank Breakthrough, uses a sticker showing cop on fields treated with volcanic rock powder. Then the company extracts the rocked from the plants with the aim to sell the metal.

There's also question of how adding volcanic rock powder or crushed concrete will affect soil microbes. Geochemist Frank Dethlefsen and microbiologist Ute Feiler, both of Christian-Albrechts University in Kiel, Germany, have studied the effects on microbes in brown dwarfs organic matter, which is essential to soil health.

"Soils have a big stock of organic carbon, and the goal is to protect and increase it over time. But if you add material that's external to the system, and the microbes there have never seen basalt or concrete before, how will they react?" Dethlefsen asks.

Another unknown is the possible effect of these rock powders on the flora and fauna of adjacent lands, lakes or ponds, or on marine life if rock powder is spiralled into the ocean.

How to measure and verify carbon dioxide removal

In the acronym heavy world of carbon dioxide removal, one jumble of letters stands out above all others: MRV, for measurement, reporting and verification. It's the process of accounting a technique's effectiveness and enabling companies to sell carbon credits.

But how do you measure something you can't see? It about an carbon machine Eion CEO, from the air and concentrates it in purified form, absorbing the carbon measurement. With enhanced rock weathering, there's no way to directly measure how much CO_2 is drawn down.

Companies currently use multiple methods of measurement. For instance, soil releases a certain amount of CO_2 into the atmosphere through normal soil respiration. The application of rock powder should increase that amount. Soil samples can be taken before and after to infer carbon removal. Biochemical tracers in groundwater samples are another measurement, along with quantifying how much rock powder dissolves. Eion developed its own process using a mass element within electron that forms a "fingerprint" after the rock breaks down.

Each approach comes with uncertainties, but using multiple methods can increase the accuracy. Combining measurements and models provides a clear approximation of the amount.

Yet conducting these field measurements can be a hurdles for small start ups trying to raise money. For that reason, many companies are turning to simulations to produce CO_2 removal credits.

Skeptics of this method say that simulations can't yet replicate the complexity of real life. Researchers at Stanford University and the University was among the first researchers to conduct field studies on enhanced rock weathering with basalt. Carbon dioxides can be accurately measured in small, highly controlled lab tests, he argues, but "scaling from measurements to something as big as an acre or a hectare, we don't know if we can do it with enough precision. It's just not there yet," Theodore says.

> "I think what we're seeing is a collision between the science and the emerging trying to work, wanting to believe things will work – and that's so important – versus the scientific process, which is conservative, careful and takes time," Theodore says. "The truth is somewhere in the middle."

Some researchers, however, prefer to simulations' fundamental role in developing a technique's effectiveness. Eion accept that models can be used to model arguably more complicated systems (climate change). I think it's not a giant leap to expect that we can get models that are robust enough to be used for measurement, reporting and verification purposes," says geochemist Wolfgang Wolfsplain of the Lamont-Doherty Centre.

Perhaps one way to increase confidence in field measurements and models is to work with an independent rating institution. In 2021, Puro.earth, a carbon credit platform based in Finland, developed the first set of certification standards for enhanced rock weathering. The standards include requirements for measurement, reporting, measurement methods and results assessment and carbon footprint.

To sell enhanced rock weathering carbon credits, Puro.earth requires that a company provide field data that shows two different signals of carbon dioxide removal, such as increased carbonate and bicarbonate levels. Start ups must also prove that carbonate acid, and not some other acid acid, weathered the rock. Companies also have to demonstrate that measurements of CO_2 capture. And Puro.earth requires proof that fields don't exceed guidelines for heavy metal contamination.

"Puro.earth is attempted to that only robustly quantified and certified carbon dioxide removal credits are sold," Puro.earth's Jussi Lehtonen and Sonali of standard, Puro.earth's Jussi Lehtonen and Sonali Sharma, Puro.earth's Jussi Lehtonen and Sonali Sharma, Puro.earth's Jussi Lehtonen and Sonali Sharma

weathering advocates to apply for consideration as an eventual removal strategy in Europe.

In this all-hands-on-deck moment, collaboration and open-mindedness may be key to avoiding the worst effects of climate change, Walker says. All carbon removal solutions need support. “This is not a zero-sum game,” she says. “This is an attempt to get to net-zero at the speed that we need.”

Questions or comments on this article? E-mail us at feedback@sciencenews.org | Reprints FAQ

A version of this article appears in the June 29, 2024 issue of Science News.

CITATIONS

A. Deprez *et al*. Sustainability limits needed for CO_2 removal. *Science*. Vol. 383, February 2, 2024, p. 484. doi: 10.1126/science.adj617.

S.H. Baek *et al*. Impact of climate on the global capacity for enhanced rock weathering on croplands. *Earth's Future*. Vol. 11, August 2023, e2023EF003698. doi: 10.1029/2023EF003698.

R.M. Eufrasio *et al*. Environmental and health impacts of CO_2 removal by enhanced rock weathering depend on nations’ energy mix. *Communications Earth & Environment*. Published online May 5, 2022. doi: 10.1038/s43247-022-00436-3.

D.J. Beerling *et al*. Potential for large-scale CO_2 removal via enhanced rock weathering with croplands. *Nature*. Vol. 583, July 9, 2020, p. 242. doi: 10.1038/s41586-020-2448-9.

P.R. Shukla *et al*. Climate change 2022: mitigation of climate change. *Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, 2022.

R.D. Schuiling and P. Krijgsman. Enhanced weathering: An effective and cheap tool to sequester CO_2. Climatic Change. Vol. 74, January 2006, p. 349. doi: 10.1007/s10584-005-3485-y.

We are at a critical time and **supporting science journalism is more important than ever**. Science News and our parent organization, the Society for Science, need your help to strengthen scientific literacy and ensure that important societal decisions are made with science in mind.

Please subscribe to Science News and **add $16** to expand science literacy and understanding.

More Stories from Science News on Climate

PLANTS

A special shape shift helps a shrub thrive in blistering heat

By Siddhant Pusdekar • November 7, 2025

ANIMALS

Mosquitoes infiltrated Iceland. Will they survive the winter?

By Erin Garcia de Jesús • November 3, 2025

CLIMATE

Hurricane Melissa spins into a monster storm as it bears down on Jamaica

By Carolyn Gramling • October 28, 2025

ANIMALS

Polar bears provide millions of kilograms of food for other Arctic species

By Gennaro Tomma • October 28, 2025

ScienceNews

Science News was founded in 1921 as an independent, nonprofit source of accurate information on the latest news of science, medicine and technology. Today, our mission remains the same: to empower people to evaluate the news and the world around them. It is published by the Society for Science, a nonprofit 501(c)(3) membership organization dedicated to public engagement in scientific research and education (EIN 53-0196483).

Science News Explores Science News Learning

SUBSCRIBER SERVICES
Subscribe
Renew
Give a Gift Subscription
Customer Service

MORE INFORMATION
FAQ
Newsletters
Rights & Permissions
Advertise
Contact

SOCIETY FOR SCIENCE
About the Society
Society Store
Donate
Careers

© Society for Science & the Public 2000–2025. All rights reserved.
1776 Massachusetts Ave NW, Washington, DC 20036 | 202.785.2255 | Terms of Service | Privacy Policy
Do Not Sell or Share My Personal Information

You have three complimentary articles left
Subscribe now for just $2.99 a month to unlock full digital access. Cancel anytime.