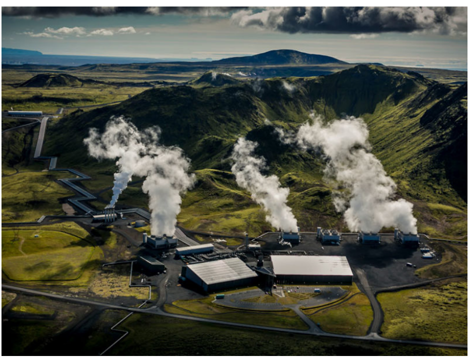
GEOHEALTH News

Basalts Turn Carbon into Stone for Permanent Storage

Scientists have shown that mineral carbonation can permanently capture and store carbon quickly enough and safely enough to rise to the challenge of climate change.



Iceland's Hellisheiði Geothermal Power Station, above, is the third largest geothermal power station in the world and the site of ongoing mineral carbonation experiments. Credit: Árni Sæberg

By Kimberly M. S. Cartier 20 March 2020

> "By mineralizing, we are permanently getting rid of the CO_2. We can walk away from it."

In carbon storage experiments tied to geothermal power plants in Iceland, 90% of injected carbon dioxide (CO_2) transformed into minerals in just 2 years. Standard carbon storage methods can take thousands of years to do the same.

"We are basing our methods on this natural process which is part of the big carbon cycle where all carbon on Earth derives from and ends up in rocks," said one of the lead researchers, Sandra Snæbjörnsdóttir. She is the head of CO_2 mineral storage at CarbFix.

"By mineralizing, we are permanently getting rid of the CO_2. We can walk away from it. We don't have to monitor it for the next decades or so. The permanent storage is the key here," she said.

Fast and Forever

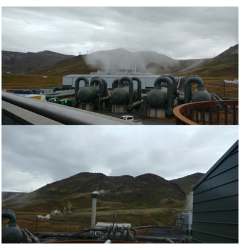
The Intergovernmental Panel on Climate Change reported that to keep climate change below 1.5°C, humanity must not only drastically cut CO_2 emissions but actively remove CO_2 from the atmosphere and keep it locked away. Most ongoing carbon capture and storage (CCS) projects seal captured CO_2 deep underground in sedimentary rock reservoirs to keep it from escaping. That carbon eventually seeps into small rock pores, dissolves in groundwater, and reacts with the rock to become carbonate minerals, trapping the carbon for good.

Carbon dioxide dissolved in water reacted with the basalt (black) in this core to create carbonates (white), trapping the carbon in solid form deep beneath the ground. Credit: Sandra Ó. Snæbjörnsdóttir

However, this method alone can't store a large enough volume of carbon or mineralize it fast enough to meet the carbon storage demand. It can take thousands of years from start to finish for all of the carbon to mineralize, and at any point, a shift in the rocks can cause some carbon to escape.

Climate researchers have long recognized that highly reactive basaltic rocks could be a solution to the carbon storage problem. In addition to being common around the world, basalts contain high concentrations of calcium and magnesium ions that chemically react with CO_2 to make calcite, dolomite, and magnesite. Moreover, dissolving the CO_2 in water aboveground and then injecting it into subsurface basalts bypasses the slower and less secure stages of conventional carbon storage.

Geothermal power stations, which sit atop basalt-rich volcano deposits, were a natural site for the new method's first field tests. Since 2012, the CarbFix project has partnered with Iceland's Hellisheiði Geothermal Power Station to capture the CO_2 released when drawing up hot water from the ground. The team dissolves the CO_2 in wastewater and injects it hundreds of meters deep into the basaltic ground. The team reduced the risk of induced seismicity by carefully surveying injection sites and adjusting injection rates as needed.



Hellisheiði Geothermal Power Station sits atop basalt-rich formations. Credit: Kimberly M. S. Cartier

Snæbjörnsdóttir and her team have been examining the injection sites using fluid sampling and tracers to quantify how well the mineral carbonation process works. The team found that over 90% of the injected CO_2 had been converted into minerals within 2 years of injection.

"We have demonstrated a very rapid mineralization of the injected gases," she said. "But also the way that we inject is that we dissolve the CO_2 in water prior to or during injection. This means increased security as well, because by dissolving the CO_2 we're killing the buoyancy of the CO_2. The CO_2-charged fluid is heavier than the groundwater in the formation where we are injecting, so it has the tendency to sink rather than to rise up. This increased storage security."

The team published these results in *Nature Reviews Earth and Environment* in January.

Expanding Around the Globe

Mineral carbonation has been gaining interest in recent years, Snæbjörnsdóttir said. "People often believe that this can only be done if you have geothermal [heat], but that's not the case," she said. "The things that you need for this to work are just a source of CO_2, [water], and reactive rocks."

A team in the United States found a similar mineralization rate on the flood basalts of the Columbia River. The European Union has sponsored future versions of CarbFix, and an international consortium has formed with the goal of using CCS to lower geothermal emissions.

Snæbjörnsdóttir's team is currently working to combine this process with direct air capture of CO_2 and researching other pathways to mineral carbonation.

"We know that basalts like we have here in Iceland are perfect for this method," she said, "but there might be rock types that are less reactive but still reactive enough. If some of those rock types are feasible to use for this method, we could broaden the applicability even more."

"For example, there's been a lot of work done in Oman where they have very reactive peridotites in connection with the ophiolites that are there," she said.

> "Using this method you can store CO_2 in areas you had not considered doing it before."

The team is also looking into how well offshore injections using seawater might work. Offshore injection would make this method an option in regions with limited freshwater resources or that might be prone to induced seismicity. If combined with direct air capture of CO_2, that could also bring this carbon storage method to areas that aren't strong CO_2 emitters.

"It expands the applicability of CCS in general because by using this method you can store CO_2 in areas you had not considered doing it before," Snæbjörnsdóttir said. "You're opening up new possibilities in addition to the conventional CCS that is already taking place."

—Kimberly M. S. Cartier (@AstroKimCartier), Staff Writer

23 March 2020: This article has been updated to clarify site sampling methods and other geographic areas of study.

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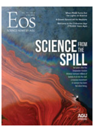

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Joe · 9 days ago · edited

Very nice. But I think a good number of people don't want climate change fixed and would be terrified by a cheap, effective solution. If they're politicians on the left, they want to use it to control the economy and engineer lives. If they're in business, they want to use it to displace fossil fuels and make money replacing them. The regular people who would want a cheap solution that allows life to continue and the economy to grow aren't the ones running things. I predict we hear very little about this in the future.

2 ^ | ˅ 3 · Reply · Share ›

smallbear (White Rose Society) → Joe · 4 days ago

Stuff your hate of those on the left. It's not productive and it's ignorant. This is a great solution and most people would be in favor of a permanent solution to the CO2 problem. Only an idiot would feel otherwise. There are also groups looking to convert CO2 into hard construction materials.

2 ^ | ˅ · Reply · Share ›

Joe → smallbear (White Rose Society) · 3 days ago · edited

I hope you're right and I didn't mean to suggest, or shouldn't have suggested, that the majority of those groups see it that way. But do you think Goldman Sachs or Al Gore, each w great piles of money invested in climate change, w welcome this? How about AOC's chief of staff, who was quoted in the WaPo saying ""The interesting thing about the Green New Deal is it wasn't originally a climate thing at all....Do you guys think of it as a climate thing? Because we really think of it as a how-do-you-change-the-entire-economy thing."

I'm 62 years old and a conservative. My daughter is a believer for environmental reasons. I don't think my view stems from hatred of the left. Over my lifetime people on the left have done a great job in identifying and addressing real problems. Now, however, a very large part of the left's environmental energy is devoted to climate change. There are a variety other problems that are extremely serious and potentially solvable, yet get only a small fraction of the money and attention climate change does. Bill Gates a couple years ago argued for more attention to pandemics. IQs are apparently falling worldwide and no one knows why. Endocrine disrupters appear to be fairly widespread, screwing up the lives of both girls and boys. Levels of testosterone have been falling at about 1% a year for at least the last 35 years or so. The prevalence of autism, allergies, and some chronic diseases continue to rise quite sharply. While longevity has risen, there are only about half as many people age 100 or above now as there were in...1820.

One thing these all have in common is that is hard to see how you can get rich or remake society as you'd like by fixing any of them. Another is that they concern merely human, as opposed to planetary, well being. But several of them could be actual existential threats and they may be more easily solved than climate change. I realize trends don't necessarily continue forever, but if a couple of these continued to worsen apace, what will it have meant to lower the temperature in 2100?

^ | ˅ · Reply · Share ›

smallbear (White Rose Society) ➦ Joe · 3 days ago

Conservatives are such great apologists for not addressing problems. Climate change is still (in spite of COVID-19) the Number One concern for the planet. If we lose the environment, then NOTHING else matters, because the planet will not be habitable. How does that not register with you?

⌃ | ⌄ · Reply · Share ›

Joe ➦ smallbear (White Rose Society) · 3 days ago · edited

What makes you think the importance of the environment doesn’t register w me? I just listed a bunch of things that I truly think are bad and that likely have an environmental cause. I’m not sure I’d be completely thrilled to if the world reached the year 2100 a degree cooler, but with human beings lacking what we regard as basic functionality. Do you disagree?

I think you are absolutely right — conservatives are great at not identifying and addressing certain problems. If you wanted to wade thru my posts, you’d see I (full-on Trumpian) have written exactly that before on conservative sites. The left, on the other hand, has been good at that. The problem is, they have been so fixated on climate change that they have failed to notice or pursue other problems that are arguably pretty serious, the kinds of things I mentioned above. This is a big departure from how environmentalists acted over the last 50 years, during which they had identified and sought to solve a wide variety of environmental maladies.

As to climate change being the absolute biggest problem, I am ignorant of the science, but think you may want to be skeptical. When compared to other environmental concerns, climate change seems to be where the money is. Look at Goldman’s $750b 10-year plans. The Democratic Party seems to pick its issues to please its donors: Why wd the basis of its concern for climate change be any different? It might be that the most attractive person at the party is also the smartest, kindest, and most loving, but I wouldn’t bet on it.

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smallbear (White Rose Society) ➦ Joe · 3 days ago

I am a scientist, both by nature and by training. I am always skeptical of the evidence, that's what science is, it constantly questions. Maybe you should look into the science. Knowledge is freedom. Never stop learning.

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Joe ➦ smallbear (White Rose Society) · 3 days ago · edited

I agree and hope you will do the same. I don’t see any evidence of your skepticism, let alone an ability to engage, but cognitive dissonance doesn’t bring out the best in anyone and scientists apparently aren’t immune. I appreciated our exchange.

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Wil Burns ➦ Joe · 4 days ago · edited

Your comments about what the environmental community wants are claptrap. Most of the major NGOs have called for radically deeper cuts in greenhouse gas emissions than politicos, and many have embraced CDR options such as this. Stop looking for black helicopters and grow up.

⌃ | ⌄ · Reply · Share ›

Joe ➦ Wil Burns · 3 days ago · edited

I don’t think I said anything about the environmental community, but thank you for your kind words otherwise.

⌃ | ⌄ · Reply · Share ›

Philip Orton ➦ Joe · 4 days ago

Congrats Joe on whining that people bring politics into things, by yourself bringing politics into a good scientific news story. In any case, you're wrong, unless you live on in the world of headlines, which are misleading.

Those of us paying attention to the science and policy know that carbon sequestration was and is the plan for a sizable portion of carbon mitigation and meeting the Paris Agreement goals. Sequestration in basalt is gaining a lot of attention and traction.

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Joe ➦ Philip Orton · 3 days ago

That’s great. Thanks. I don’t read about such things and will modify my curmudgeonly ravings accordingly.

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cbrowndde · 4 days ago

Photosynthesis is nature's way of removing CO2 from air, is this an improvement on that? We need to increase the green stuff and stop deforesting the planet. The research sounds very interesting, and sequesters CO2 as carbonates etc. The effects on groundwater quality need to be considered.

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Xiangqian Wu ➦ cbrowndde · 4 days ago

It does, but only temporarily. The green stuff will die and release the carbon back to air, in one year or longer, one way or another.

1 ⌃ | ⌄ · Reply · Share ›

cbrowndde ➦ Xiangqian Wu · 4 days ago

It does, but mainly if you burn it. Cellulose contains much of the carbon sequestered. Coal is the sequestered plant carbon from the carboniferous era. We are digging it up and burning it now, sending us back toward the carboniferous age.

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Xiangqian Wu ➦ cbrowndde · 4 days ago

Most carbon captured by plants goes back to the atmosphere by decay. Few burned. Even fewer through animals. And even even fewer fossilized.

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cbrowndde ➦ Xiangqian Wu · 4 days ago

Well, the carbon cycle is a cycle. Some fraction gets sequestered for days, weeks, or even eons. While the fossilization of carbon is slow, It did move us from the carboniferous age to the present. We're reversing that now at a high rate. Acids (e.g. acid rain) also unsequester carbon from carbonates as do cement factories. There may not be quick fixes given the rate of human population growth.

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