King City Asbestos Corporation Mine Carbon Mineralization Field Test

primary project goal

Lawrence Livermore National Laboratory (LLNL) is evaluating various approaches to carbon dioxide (CO_2) mineralization of asbestos-bearing serpentinite rocks/mine tailings to determine the most successful approach and to enable the U.S. Department of Energy (DOE) and project developers to make informed choices about this pathway of carbon removal.

technical goals

- Develop safety protocols to protect human health and the environment.
- Develop monitoring protocols to reliably and cost-effectively measure CO_2 uptake.
- Demonstrate enhanced weathering methodologies that increase the uptake of CO_2 by two to five times compared to the background rate.
- Achieve greater than 90% carbonation of brucite and labile magnesium (Mg).
- Show that the proportion of atmospheric carbon incorporated into newly formed carbonate minerals is significantly higher than the proportion of incorporated recycled bedrock carbon and/or biogenic carbon.
- Establish that the full life cycle CO_2 budget is net-negative.
- Develop and accelerate processes that result in CO_2 removal costs of less than $100/tonne CO_2.
- Demonstrate site restoration to the original condition or better.

technical content

Enhanced weathering is a technique that accelerates the natural process of chemical weathering in order to absorb atmospheric CO_2 more quickly than would occur naturally. The natural process of chemical weathering is shown in Figure 1, where broken-down silicate minerals chemically react with CO_2 to form new carbonate minerals that lock CO_2 away. However, this natural process captures CO_2 at about the same rate that it is released into the atmosphere by volcanic activity. The process of accelerated carbon mineralization through enhanced weathering aims to capture CO_2 more quickly than is possible through natural chemical weathering, whereby the carbon balance is shifted to net-negative. The process of accelerated carbon mineralization has three primary rate-limiting factors: the CO_2 supply, mineral dissolution, and carbonate precipitation. However, techniques, such as those in the ovals of Figure 2, can be used to speed up the natural carbonation process and thus result in enhanced weathering and accelerated CO_2 capture and storage (CCS).

The concept of accelerating carbon mineralization has been recognized as a promising approach to remove CO_2 from the atmosphere; however, the concept has largely been explored on the bench scale or in small field trails. Assessing the potential viability of this technology and advancing the field requires larger-scale field trials, as is the focus of this work.

program area:
Carbon Dioxide Removal

ending scale:
Small Pilot

application:
Enhanced Mineralization

key technology:
Novel Concepts

project focus:
Field Testing of Accelerated Carbon Mineralization Approaches

participant:
Lawrence Livermore National Laboratory

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FWP-FEW0278

predecessor projects:
N/A

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partners:
Natural Resources Agency of California; Bureau of Land Management; University of British Columbia

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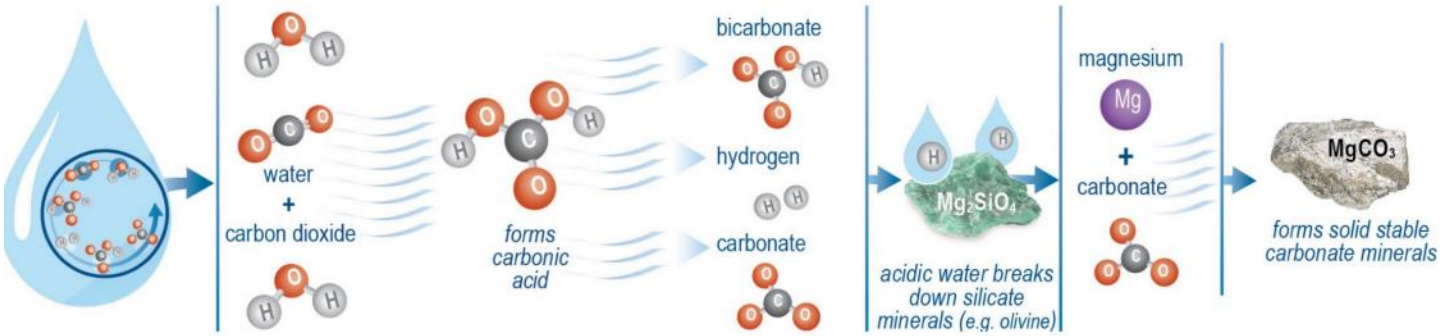

Chemical weathering draws down ~0.3 Gt CO_2/y, which over geologic timescales is approximately balanced by the amount of CO_2 released from volcanoes.

Figure 1: Natural chemical weathering and CO_2 capture.

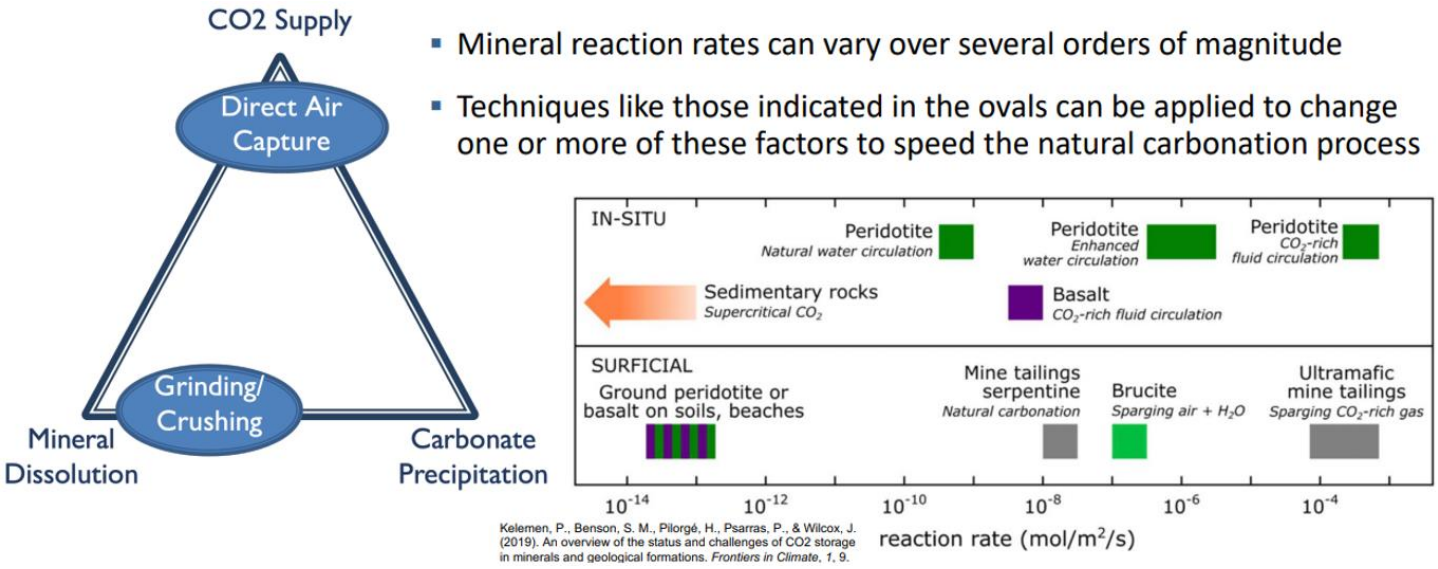

Figure 2: CO_2 mineralization influences and rates.

The former asbestos mine, King City Asbestos Corporation (KCAC) Joe Pit Mine, in San Benito County, California, has been chosen as the host site for this work as it is an ideal site for evaluating and conducting field trials for enhanced CO_2 mineralization due to the presence of serpentinite rocks and mine tailings. As shown in Figure 3, this site is located in the New Idria Serpentinite Body. Published literature indicates that the area has a brucite content of 7–8 wt% on average and 10–25 wt% in serpentinite boulders, while the magnesium oxide (MgO) content is about 40 wt%. The presence of these serpentinite minerals is highly favorable, as the potential for CO_2 mineralization is high; Figure 4 highlights the tons of CO_2 that can be stored per ton of dissolving and precipitating mineral.

California's ultramafic rocks, mostly serpentinite, cover surprising amounts of the state's land. Arrow points to the New Idria Serpentinite Body.

Figure 3: Location of California's ultramafic rocks (mostly serpentinite).

Tons of CO_2 sequestered per ton of dissolving and precipitating mineral

Dissolving Mineral \ Precipitating Mineral		Name	Magnesite	Hydromagnesite	Dypingite	Pokrovskite	Artinite	Nesquehonite	Lansfordite
		Formula	$MgCO_3$	$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$	$Mg_5(CO_3)_4(OH)_2 \cdot \sim 5H_2O$	$Mg_2(CO_3)(OH)_2$	$Mg_2(CO_3)(OH)_2 \cdot 3H_2O$	$MgCO_3 \cdot 3H_2O$	$MgCO_3 \cdot 5H_2O$
Name	Formula	CO_2: MgO ratio	1:1	4:5	4:5	1:2	1:2	1:1	1:1
Serpentine[a]	$[Mg_3Si_2O_5(OH)_4]$	-	0.48	0.38	0.38	0.24	0.24	0.48	0.48
Brucite	$[Mg(OH)_2]$	-	0.75	0.60	0.60	0.38	0.38	0.75	0.75
Forsterite	$[Mg_2SiO_4]$	-	0.63	0.50	0.50	0.31	0.31	0.63	0.63
Diopside[b]	$[CaMgSi_2O_6]$	-	0.41	0.37	0.37	0.30	0.30	0.41	0.41
Enstatite	$[Mg_2Si_2O_6]$	-	0.44	0.35	0.35	0.22	0.22	0.44	0.44

Modified from I. M. Power, A. L. Harrison, G. M. Dipple, S. A. Wilson, P. B. Kelemen, M. Hitch, G. Southam, Carbon Mineralization: From Natural Analogues to Engineered Systems. Reviews in Mineralogy and Geochemistry. 77, 305–360 (2013).

Figure 4: Amount of CO_2 stored per ton of dissolving and precipitating mineral.

Project Concept and Overview

LLNL is establishing the test design, test characterization, and baseline measurement methodologies at the test site located at the KCAC Joe Pit Mine, shown in Figure 5. Various approaches for onsite mineralization of CO_2 using serpentinite rocks and asbestos tailings are being tested and compared to gain information to enable DOE to make informed decisions regarding enhanced weathering processes, as well as regarding the human health and environmental safety factors. Furthermore, restoring the site to its original condition (or better) will be implimented and evaluated.

Figure 5: Location of test site at the KCAC Joe Pit Mine.

This work entails the development of an environmental, health, and safety (EH&S) plan for working at the KCAC test site. The handling of asbestos-containing material requires training and monitoring for all site users and the implementation methodologies established in this work will be informative to potential future developments. This work also involves establishing how baseline conditions and natural variability should be taken into consideration. For instance, the CO_2 flux, water cycling at the site, and aqueous chemical characteristics must all be understood in terms of baseline values considering seasonal variations. This information then informs the design of the carbon mineralization field experiements, which could be conducted using passive or more involved experimental methods, such as more frequently stirring reactive material to increase air contact or constructing purpose-built facilities to control the ambient conditions. It is anticipated that field experiments will be conducted on the scale of tons to tens of tons of reactive material. LLNL aims to advance the technology readiness from its current TRL 2 to TRL 5 during the course of this project.

technology advantages

- Accelerates the natural mineralization process to capture CO_2.
- Potential for a net-negative CO_2 budget.
- Potential for large-scale CO_2 storage.

R&D challenges

- Human health hazards due to exposure to asbestos-bearing serpentinite rocks/mine tailings.
- Environmental hazards due to disturbance of asbestos-bearing serpentinite rocks/mine tailings.
- Effective monitoring of CO_2 flux and uptake.
- Developing successful accelerated carbon mineralization experiments at low cost.

status

The project team is conducting initial site characterizations, is currently developing the EH&S plan, and is making progress toward determining a final evaluation design based on baseline measurements.

available reports/technical papers/presentations

"King City Asbestos Corporation (KCAC) Mine Carbon Mineralization Field Test," Project Kickoff Meeting, March 14, 2022. *https://www.netl.doe.gov/projects/plp-download.aspx?id=13020&filename=King+City+Asbestos+Corporation+(KCAC)+Mine+Carbon+Mineralization+Field+Test.pdf*.