Mechanochemical processing of silicate rocks to trap CO_2

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The problem

Hard to decarbonize industries emit CO_2 during chemical reactions and/or require very high energy intensity:

- Metal refining
- Chemical manufacturing industry
- Cement production
- Blue hydrogen production
- Asphalt

Microseismic induced mechanochemical reactions

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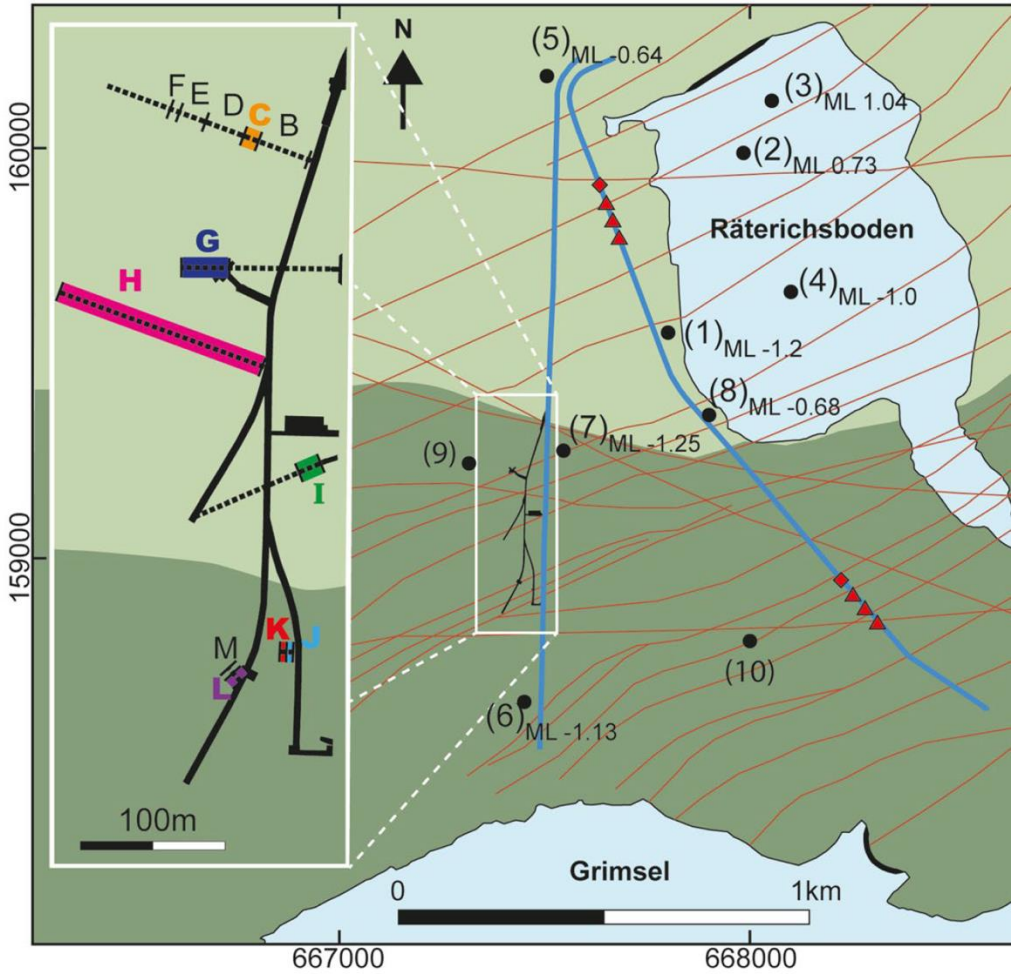
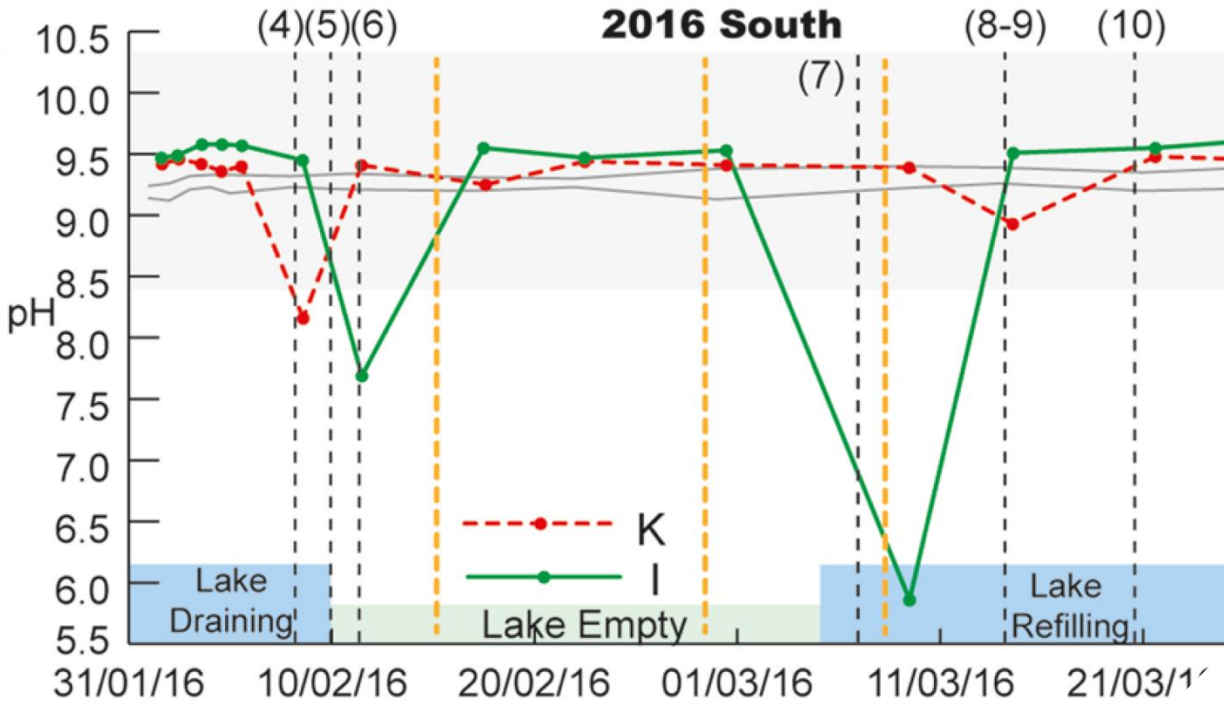
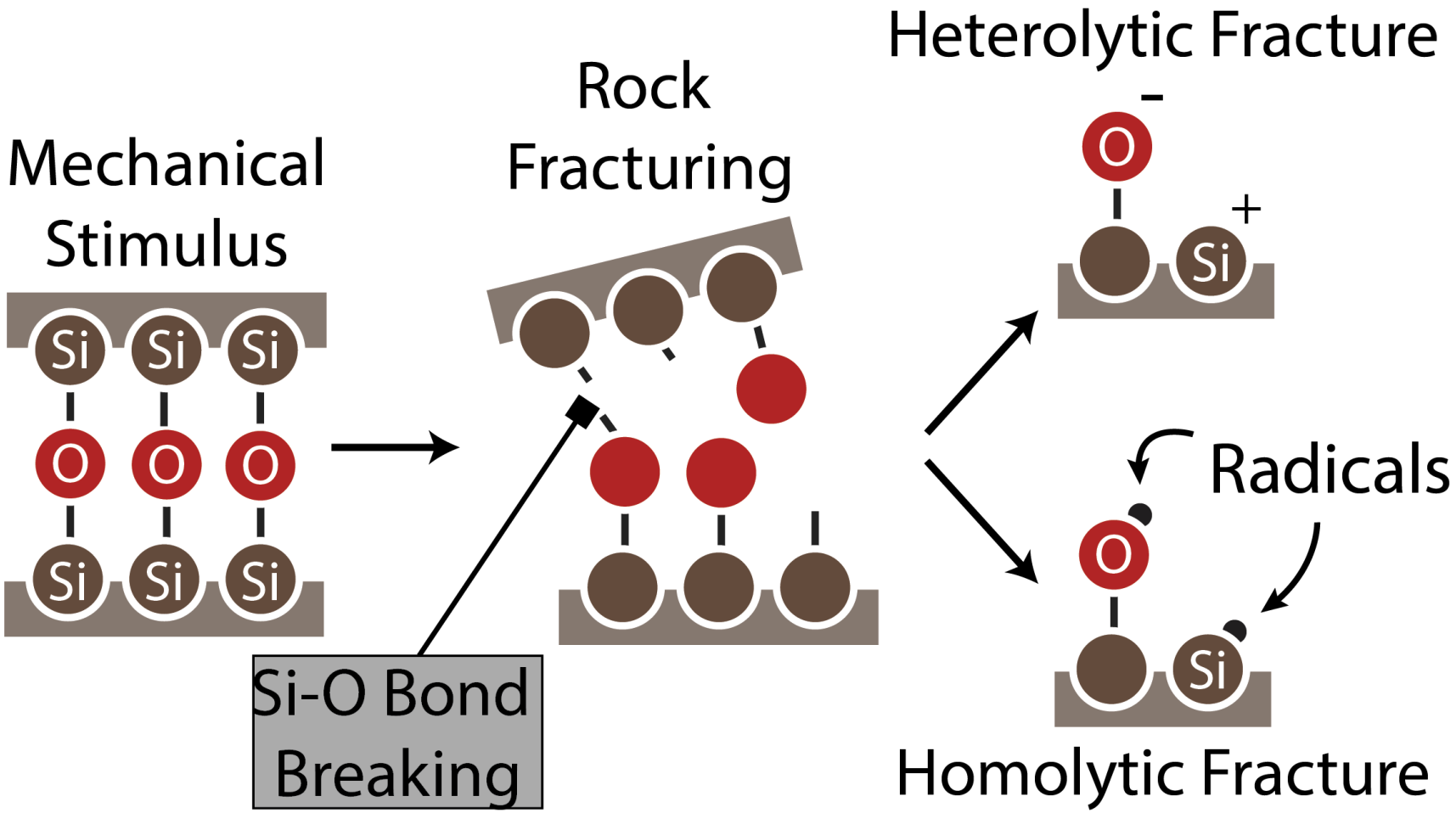
Microseismic induced mechanochemical reactions



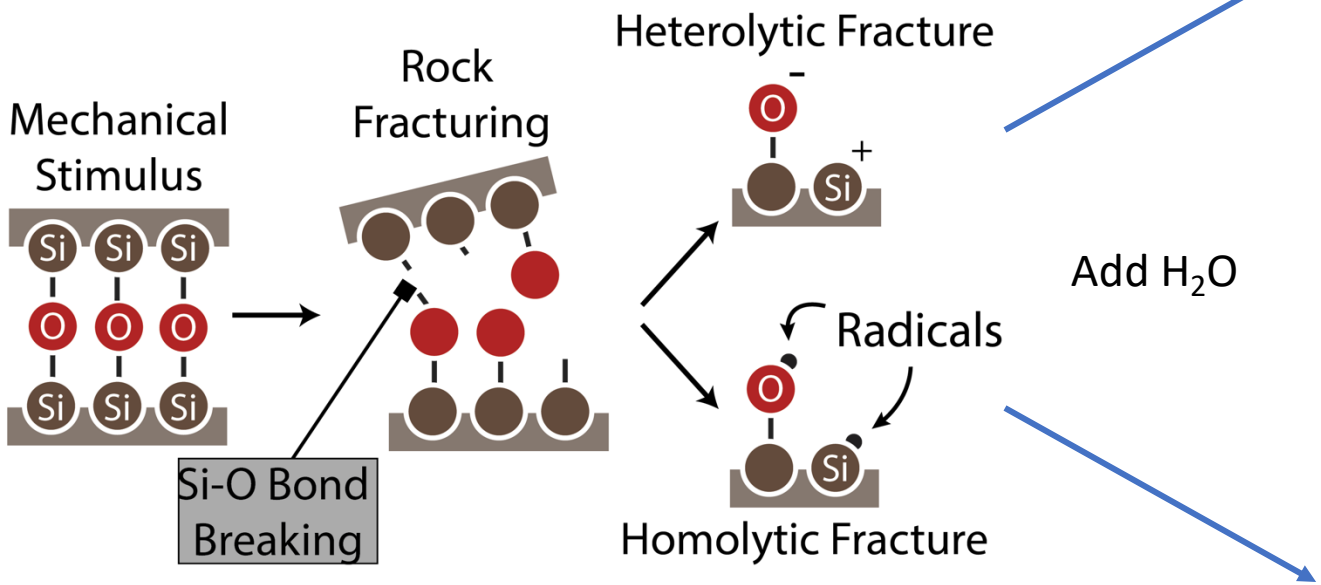


Stillings, M., Lunn, R. J., Pytharouli, S., Shipton, Z. K., Kinali, M., Lord, R., & Thompson, S. (2021). Microseismic events cause significant pH drops in groundwater. *Geophysical Research Letters*, 48, e2020GL089885. https://doi.org/10.1029/2020GL089885

Fracture-initiated Mechanochemical Reactions in Silicates



Mechanochemical Reactions in Silicates

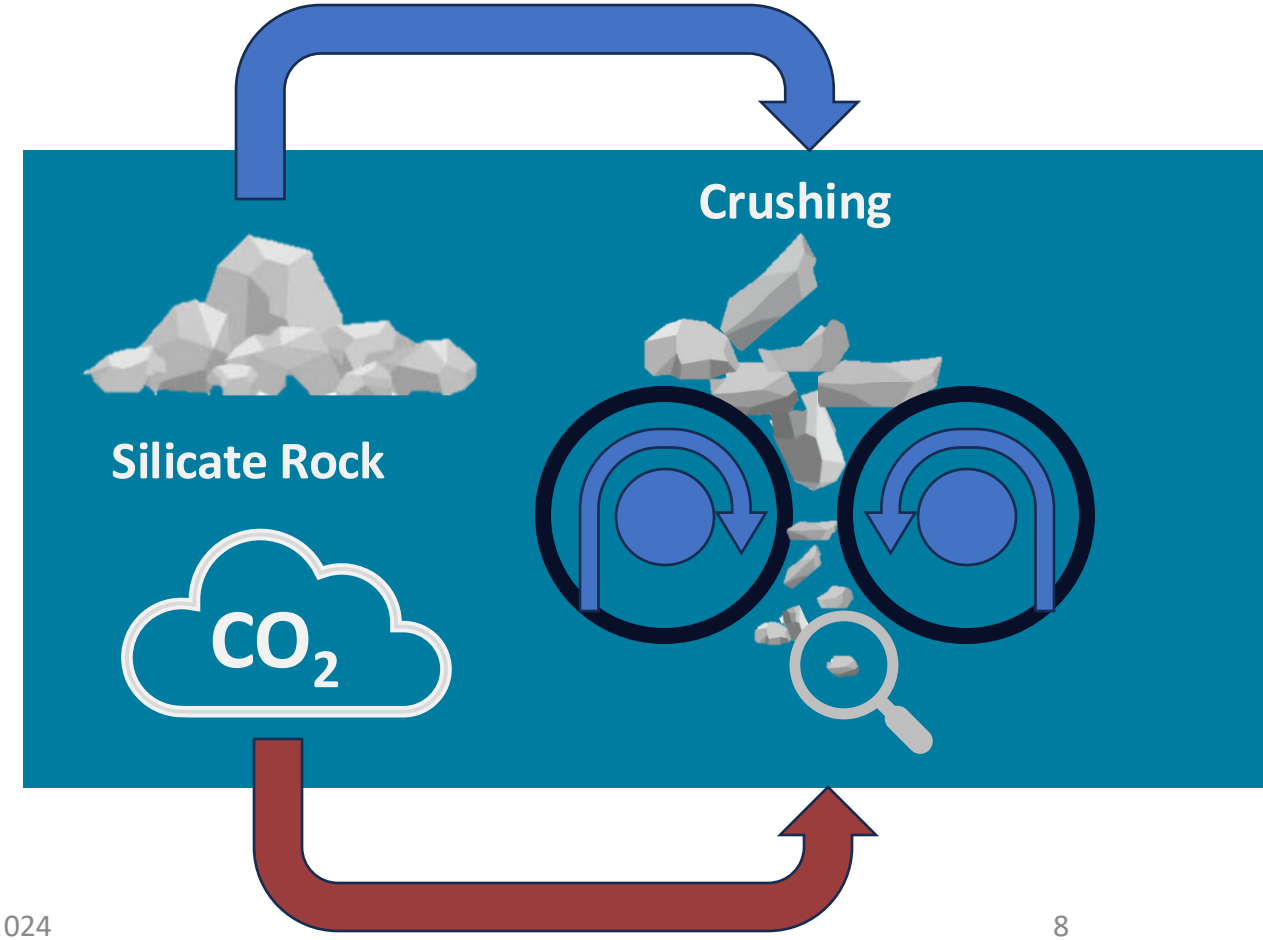


Produce H^+ ions lowering pH

Produce H· and OH· radicals
Which can form $H_{2(g)}$ and ROS

The idea

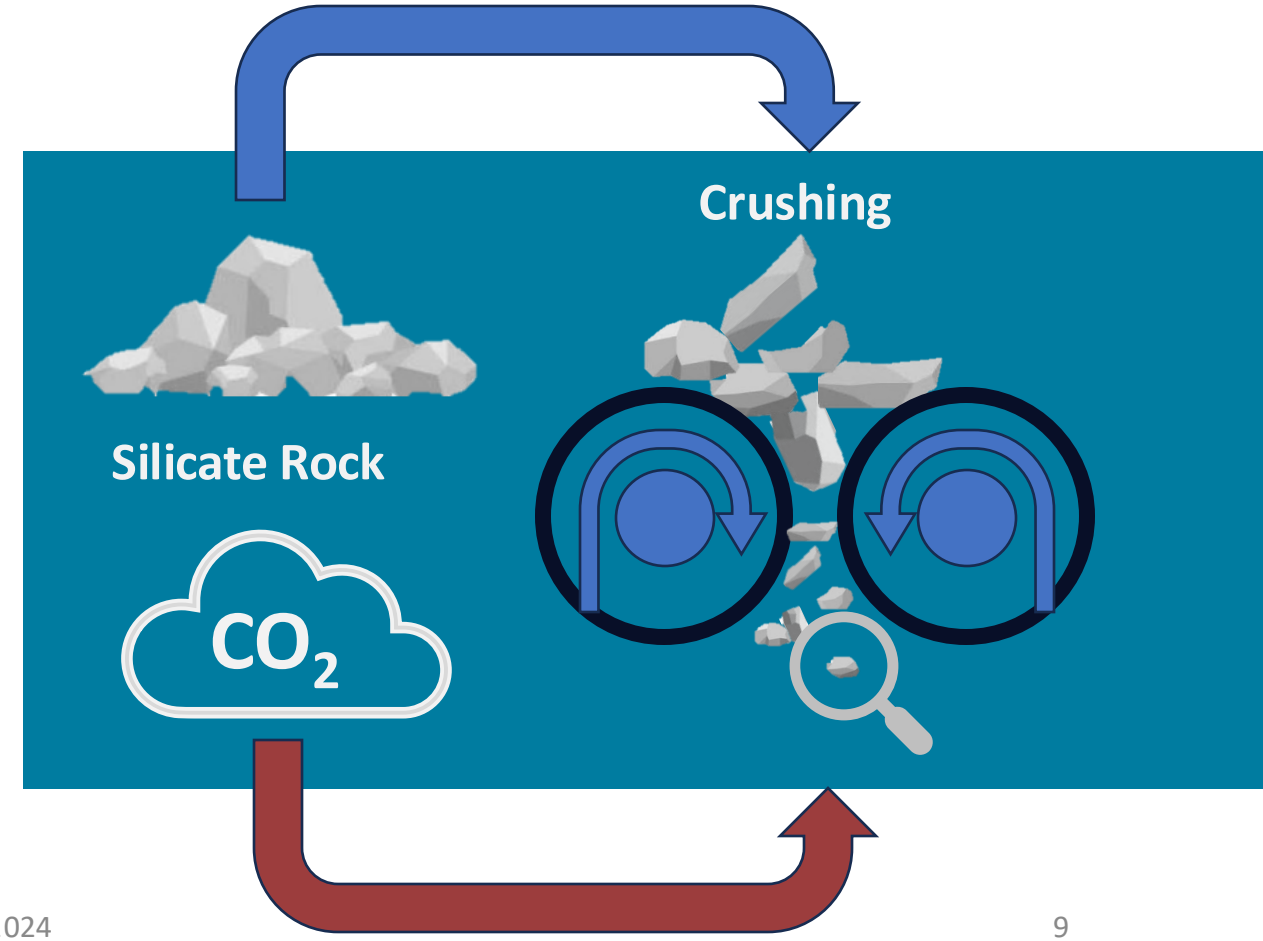
Mechanochemistry uses the energy released from breaking a bond to drive a chemical reaction



The idea

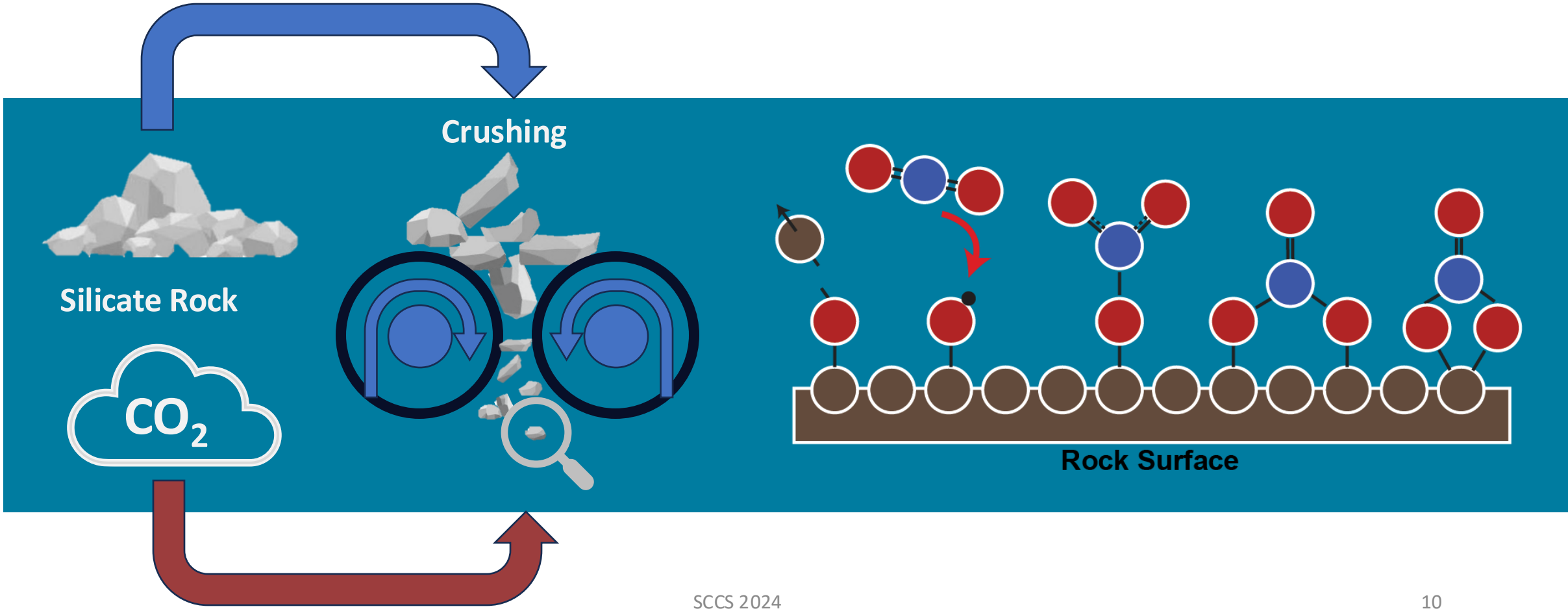
Mechanochemistry uses the energy released from breaking a bond to drive a chemical reaction

Can we use the mechanochemical energy released when we break a siloxane bond to capture CO_2 during rock crushing?

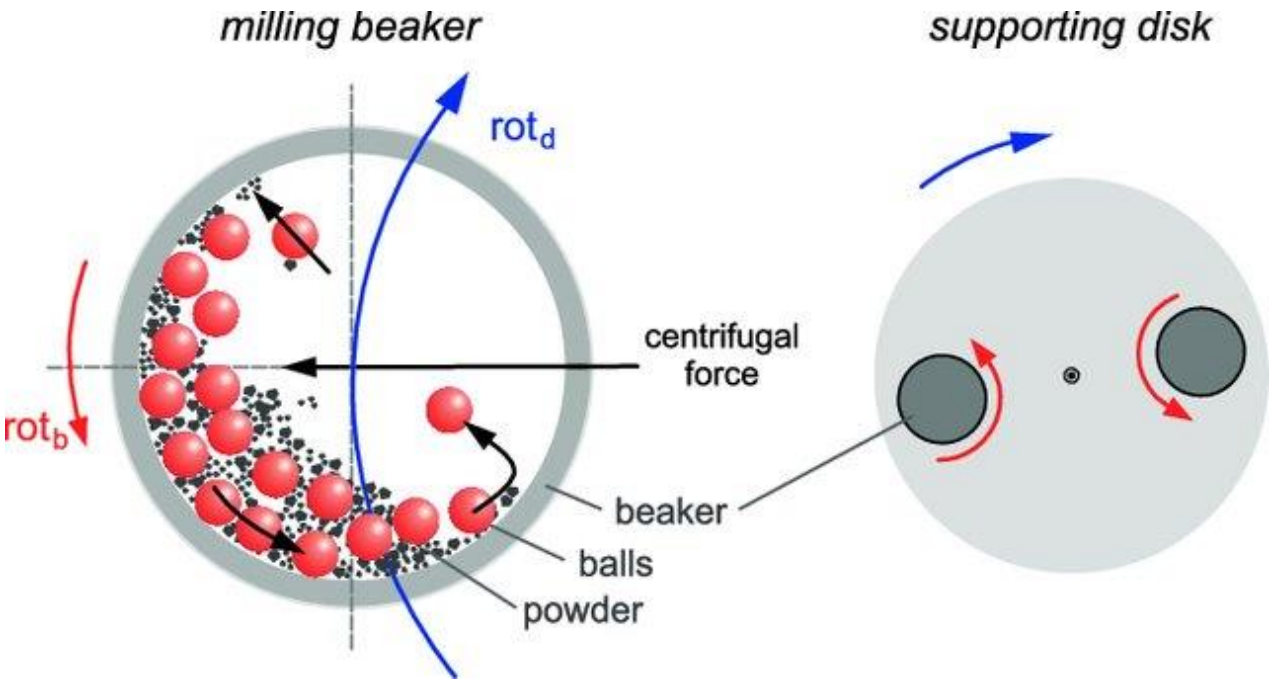


The idea

How stable is the trapped CO_2?
How is the CO_2 trapped?



Mechanochemical CO_2 Capture

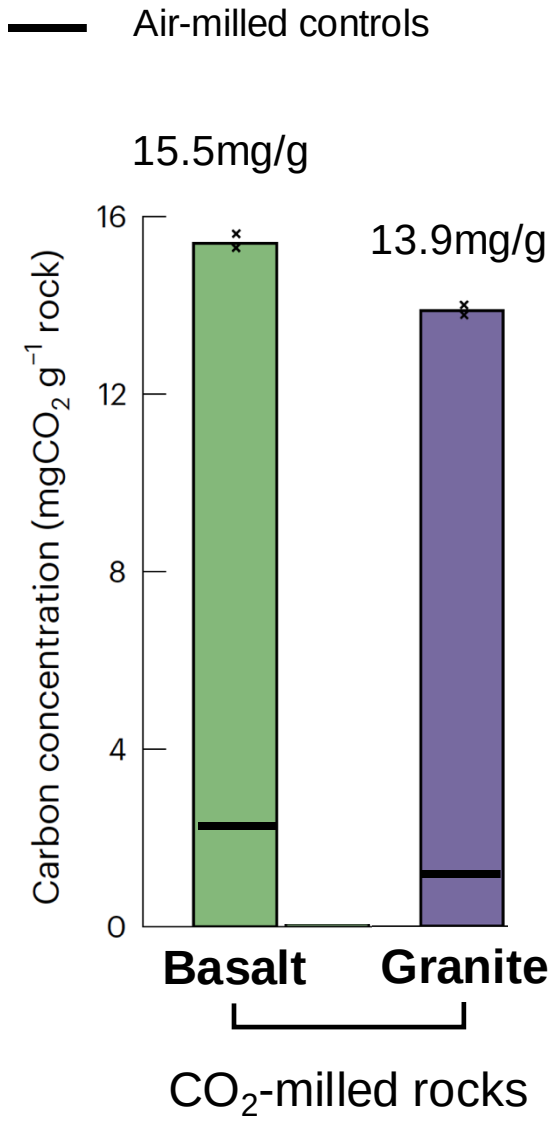


Wilkening, M., Düvel, A., Preishuber-Pflügl, F., da Silva, K., Breuer, S., Šepelák, V. and Heitjans, P. (2017) Structure and ion dynamics of mechanosynthesized oxides and fluorides. Zeitschrift für Kristallographie - Crystalline Materials, Vol. 232 (Issue 1-3), pp. 107-127. https://doi.org/10.1515/zkri-2016-1963

Experimental set-up:

- Planetary ball mill
- Pressurized with CO_2 gas (or air) during grinding

Laboratory demonstration
CO_2 Trapping



Milling rock to 15 µm grain size in CO_2 at ambient temperature

Granite and basalt selected as *end-member* mafic and felsic rocks

CO_2 trapped in both basalt and granite

Process not reliant on high Ca and Mg in rock?

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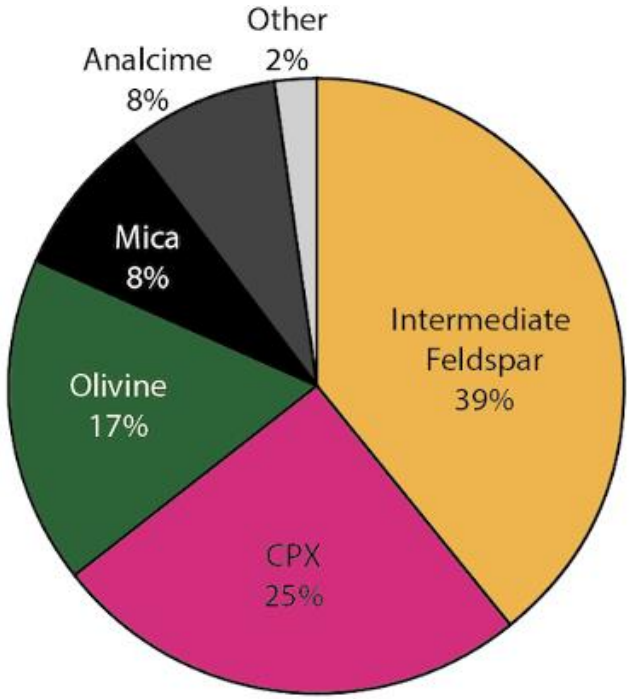
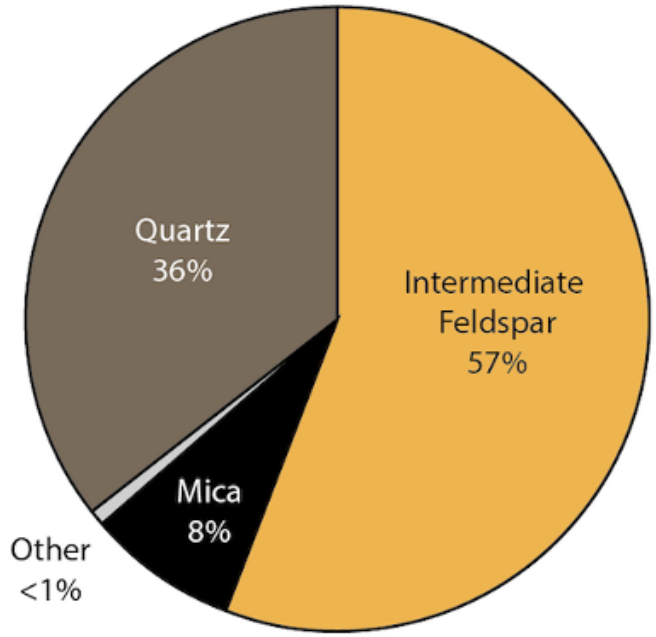
Whole-rock mineral composition

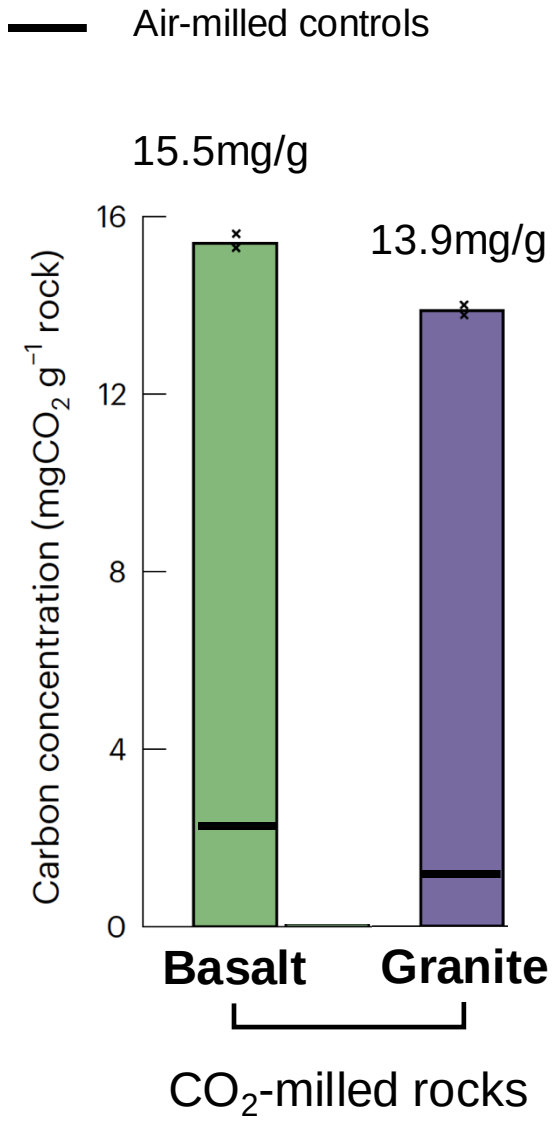


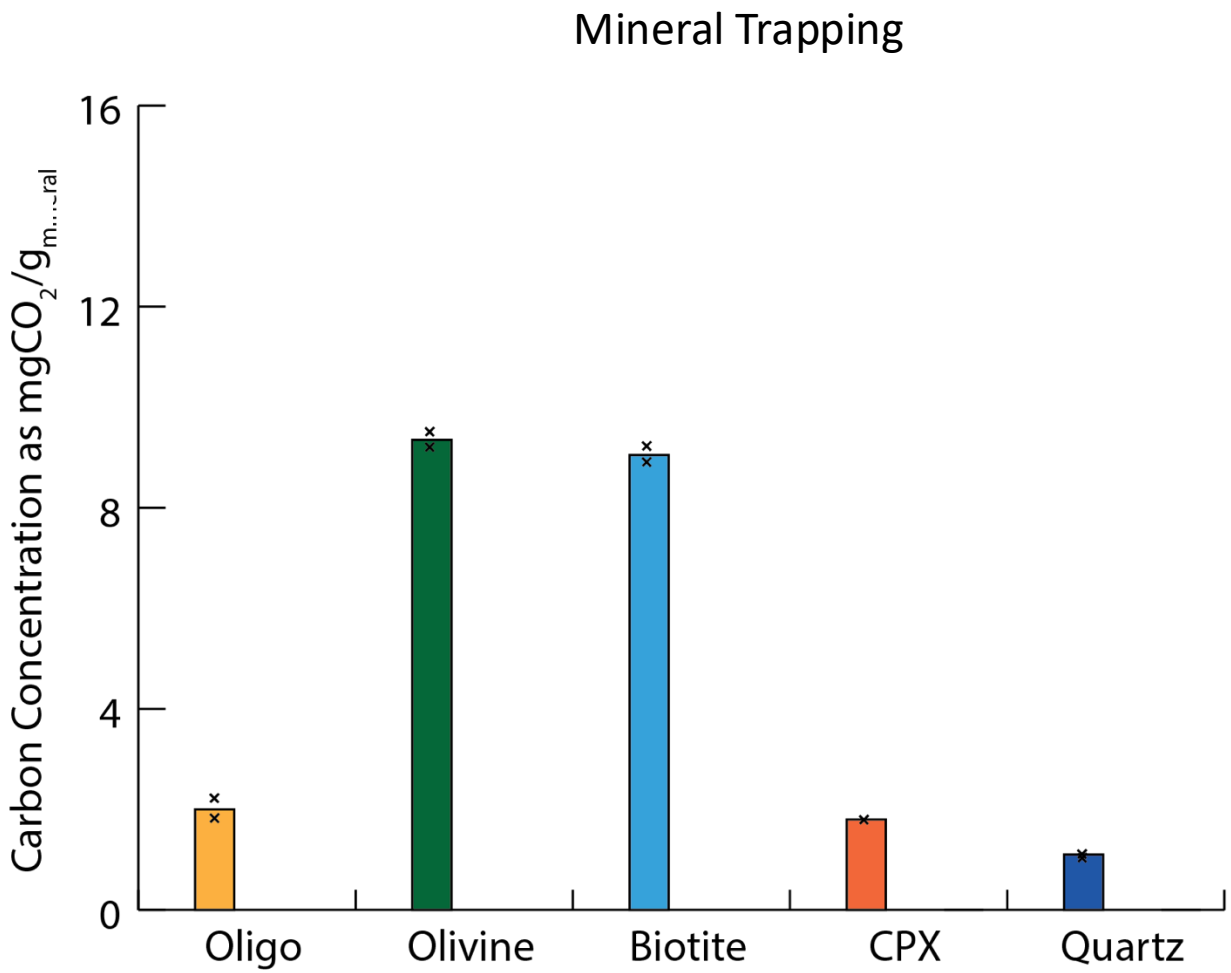
Basalt



Granite

Laboratory demonstration
CO_2 Trapping





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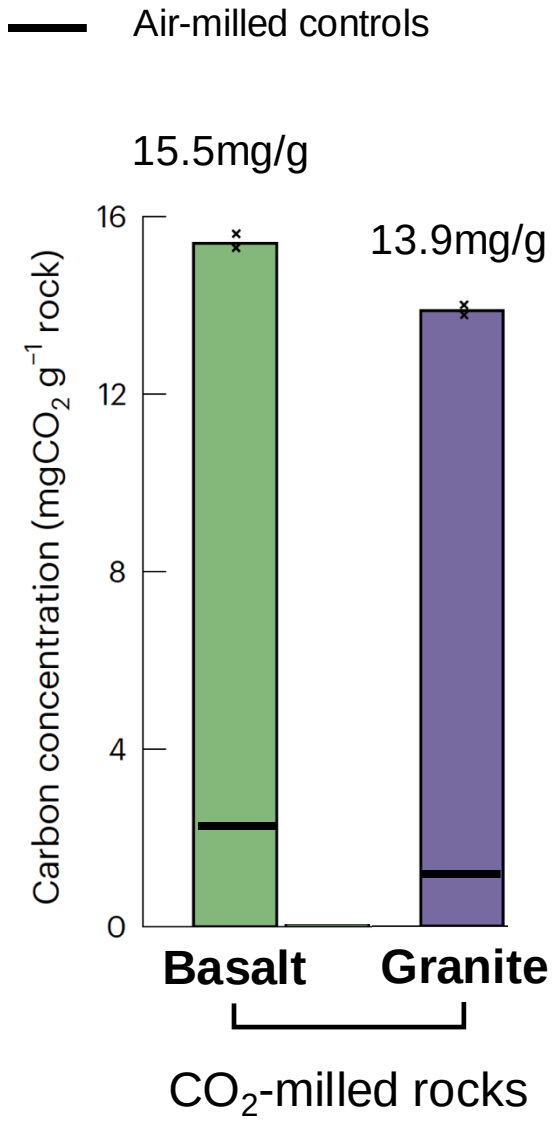

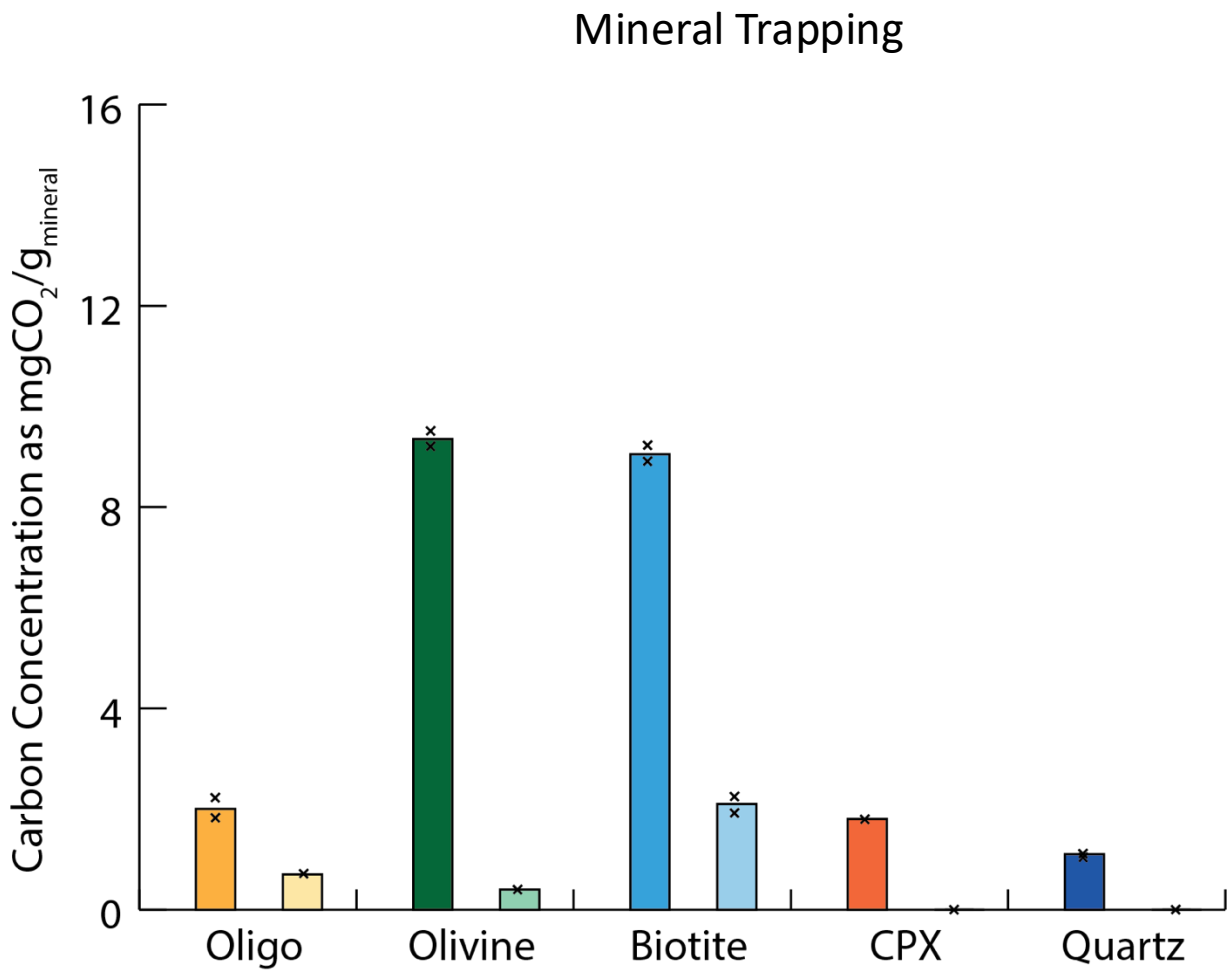

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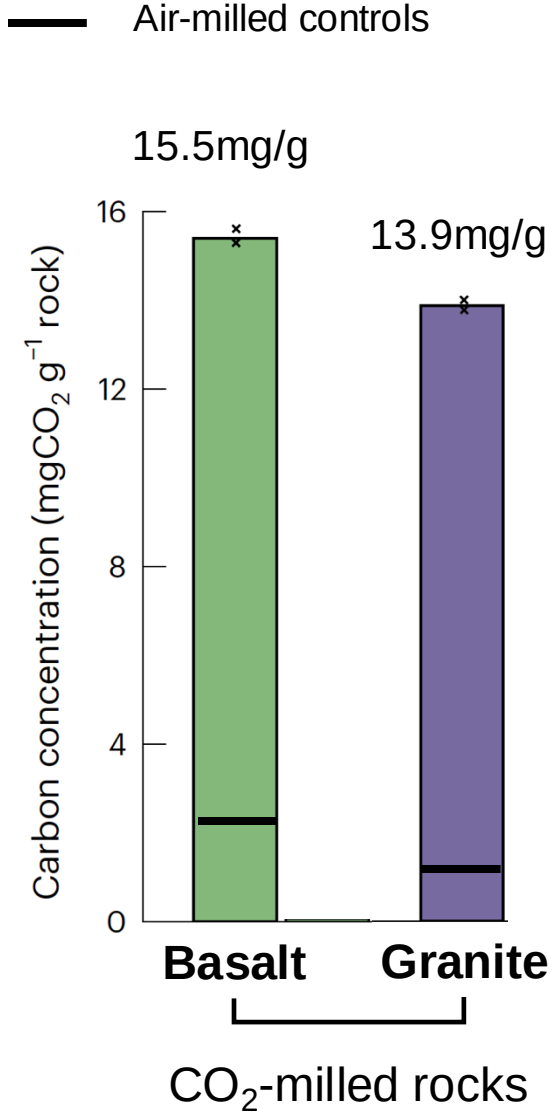
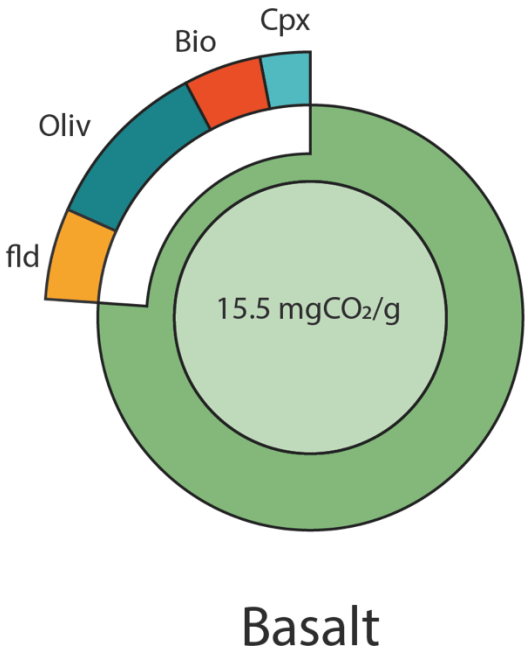
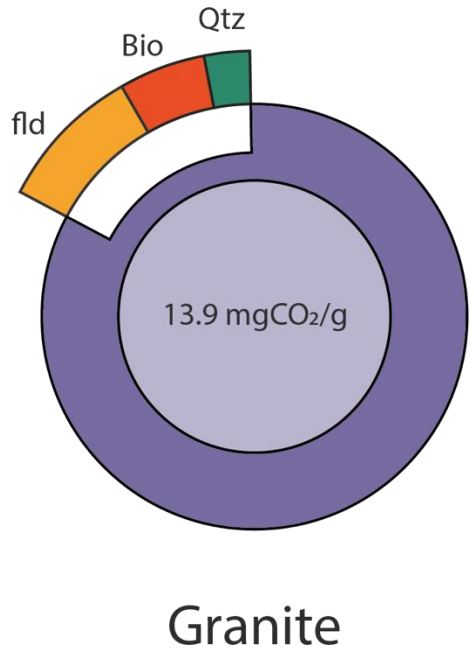
Comparing minerals with whole-rocks

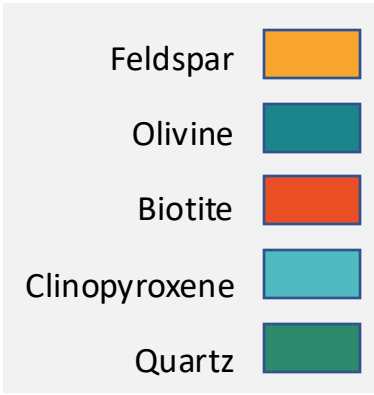


Basalt: 24% of CO_2 trapped by pure minerals

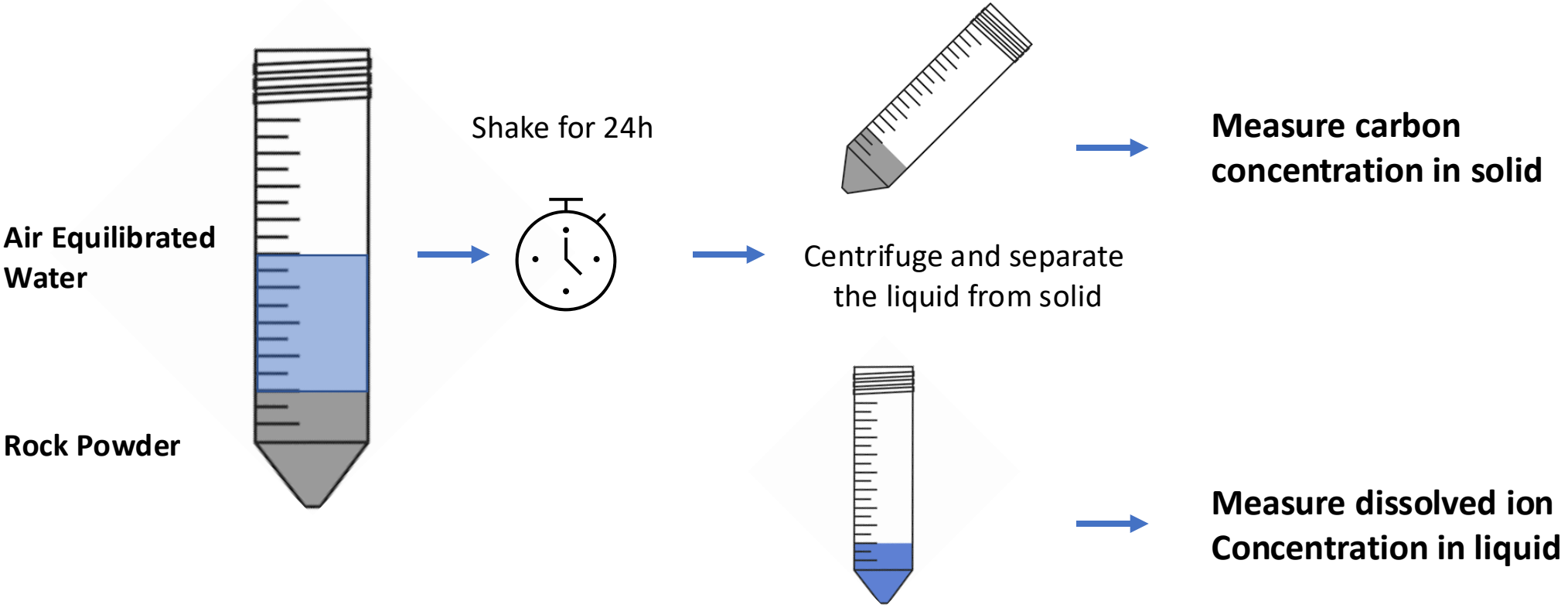


Granite: 17% of CO_2 trapped by pure minerals



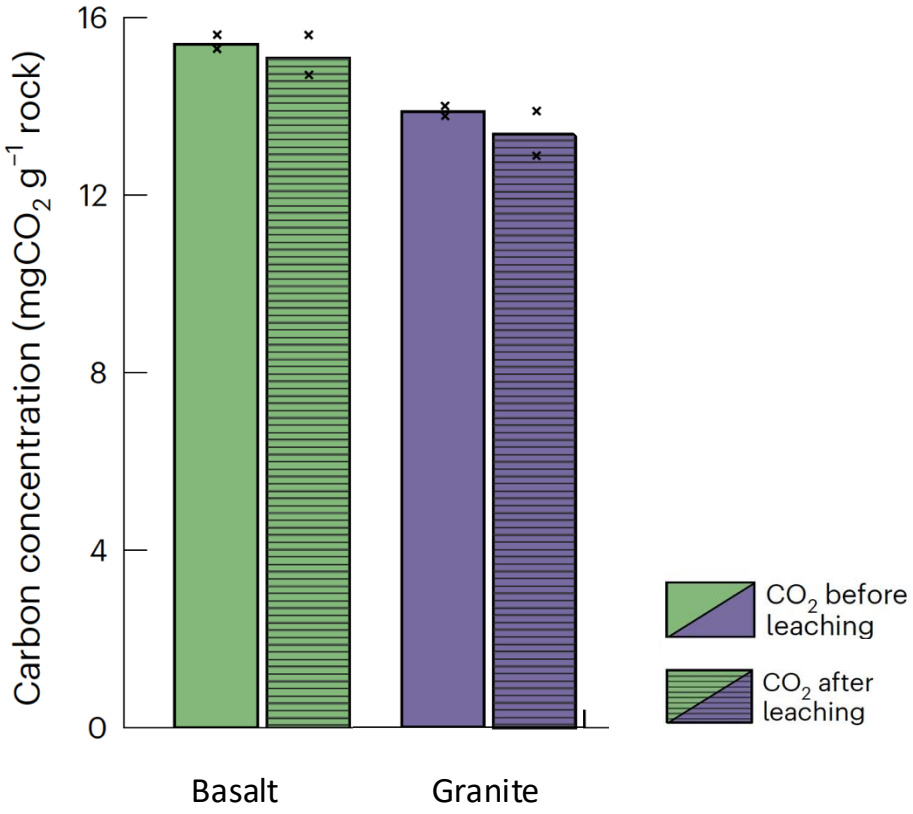


Determining CO_2 leachability

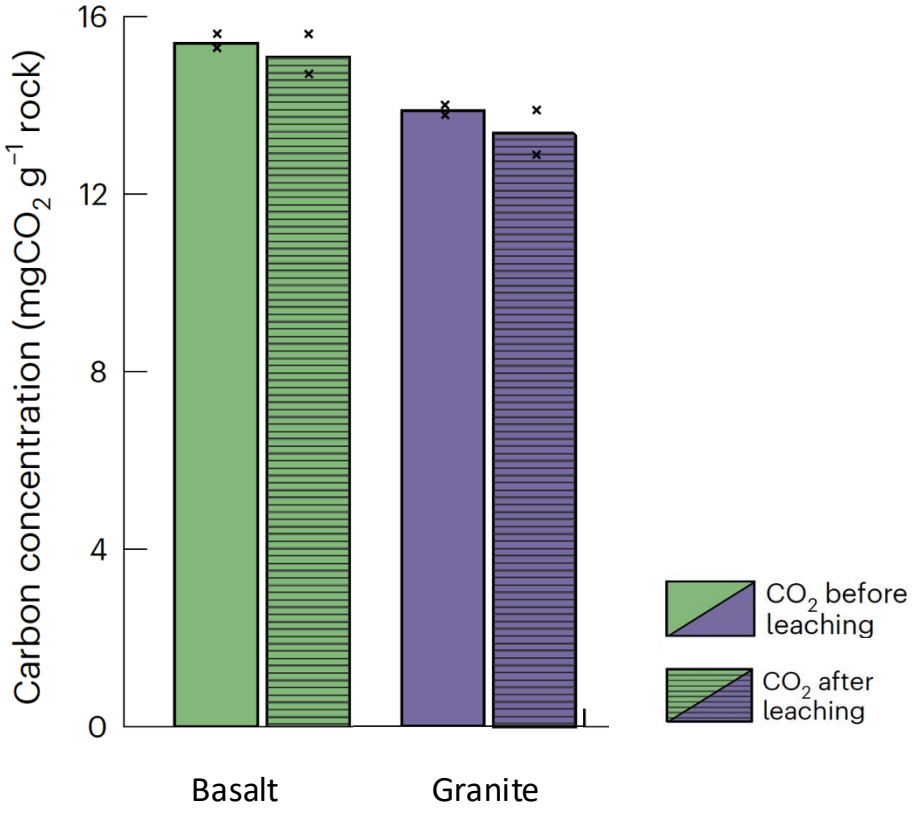


How much of the trapped CO_2 is insoluble?

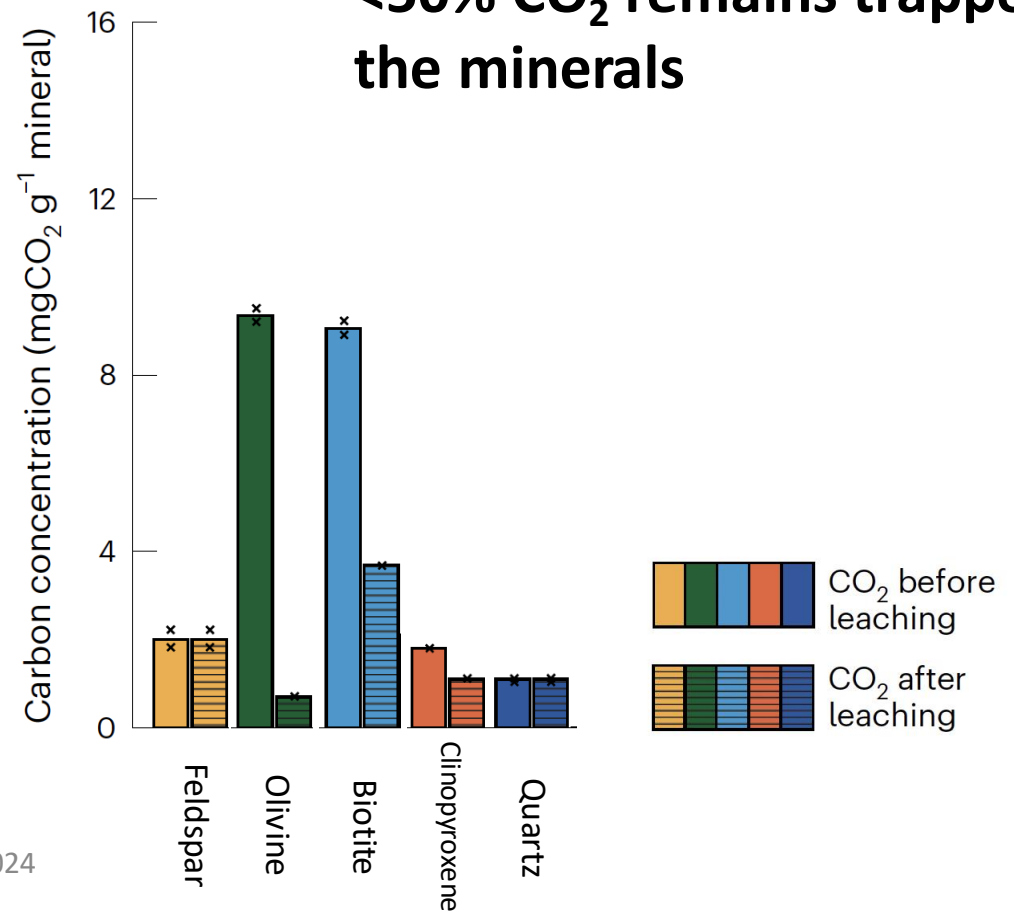
> 96% CO_2 remains trapped in basalt and granite



How much of the trapped CO_2 is insoluble?

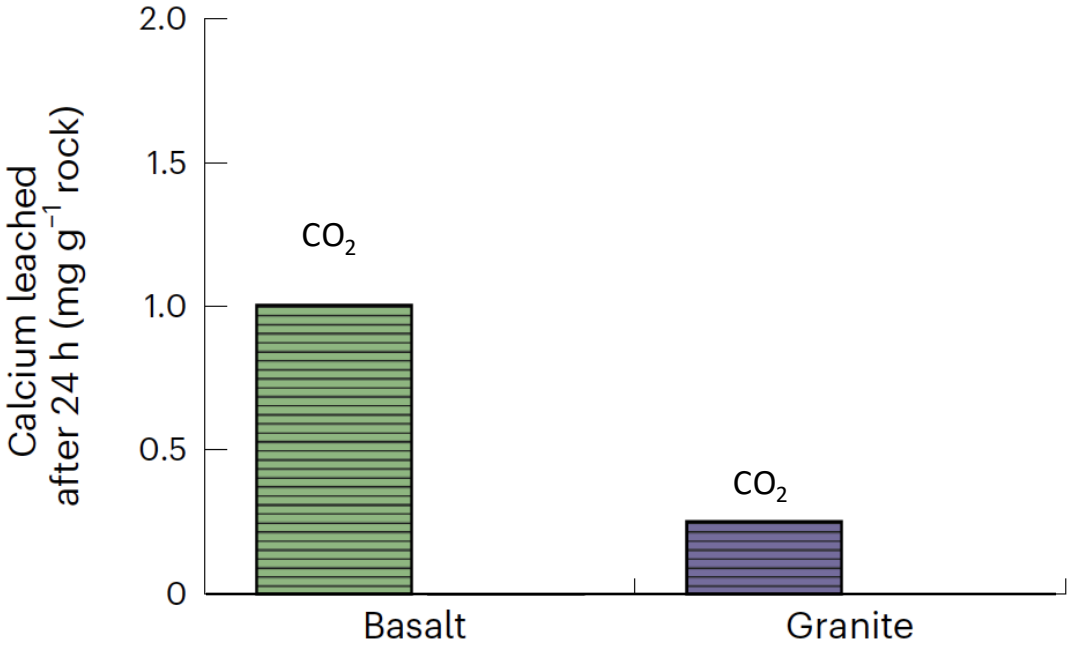


<50% CO_2 remains trapped in the minerals

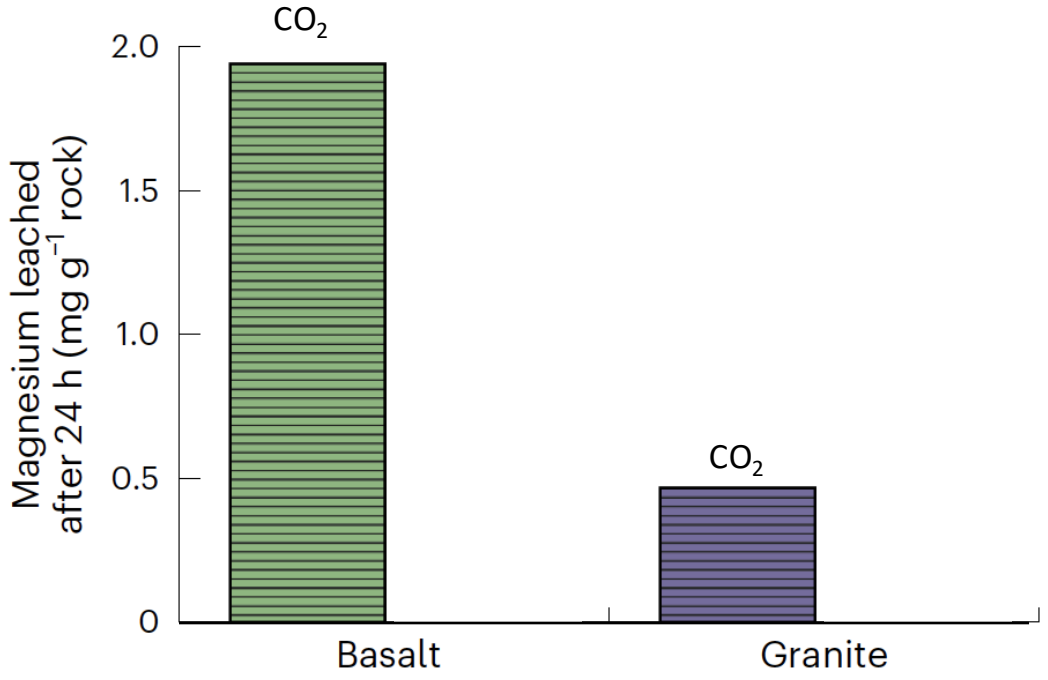


Ion leaching into solution

Calcium leached into solution



Magnesium leached into solution



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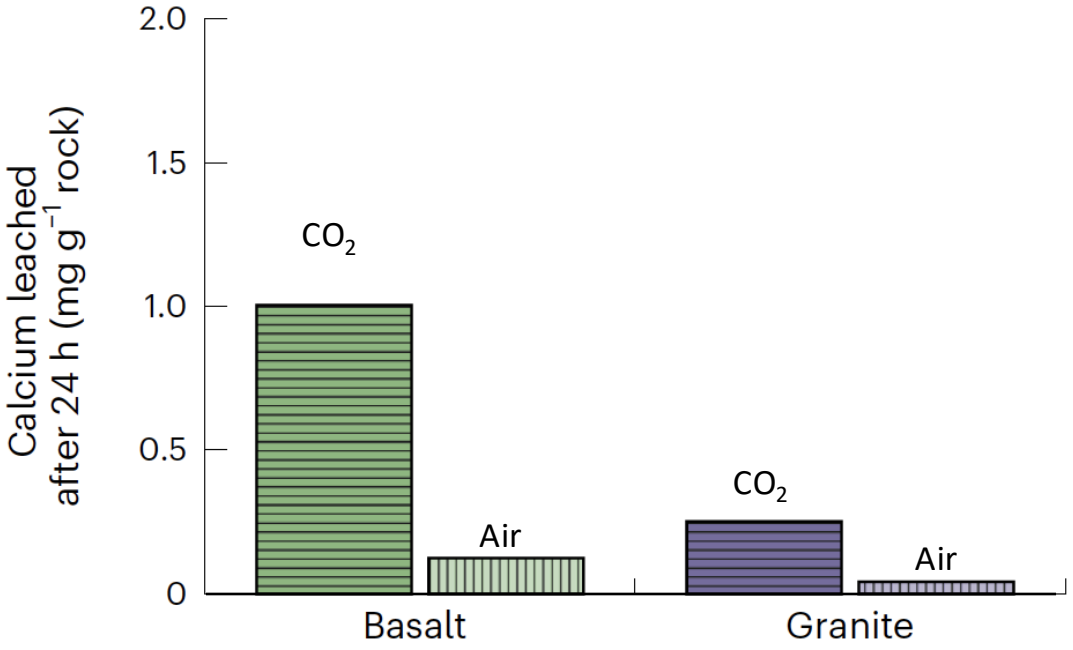

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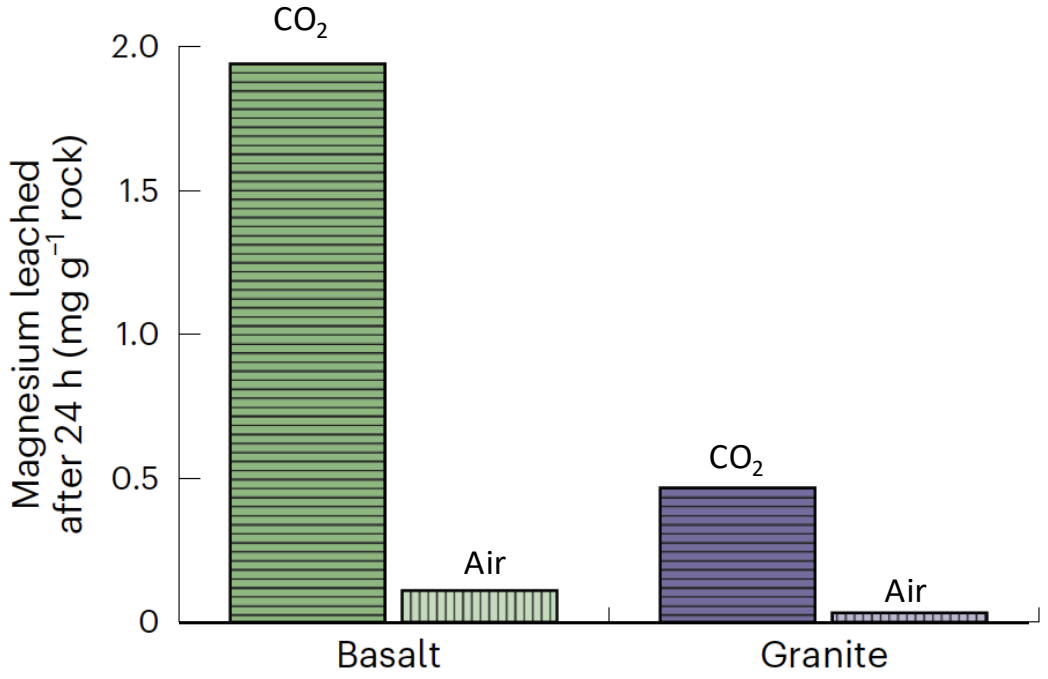

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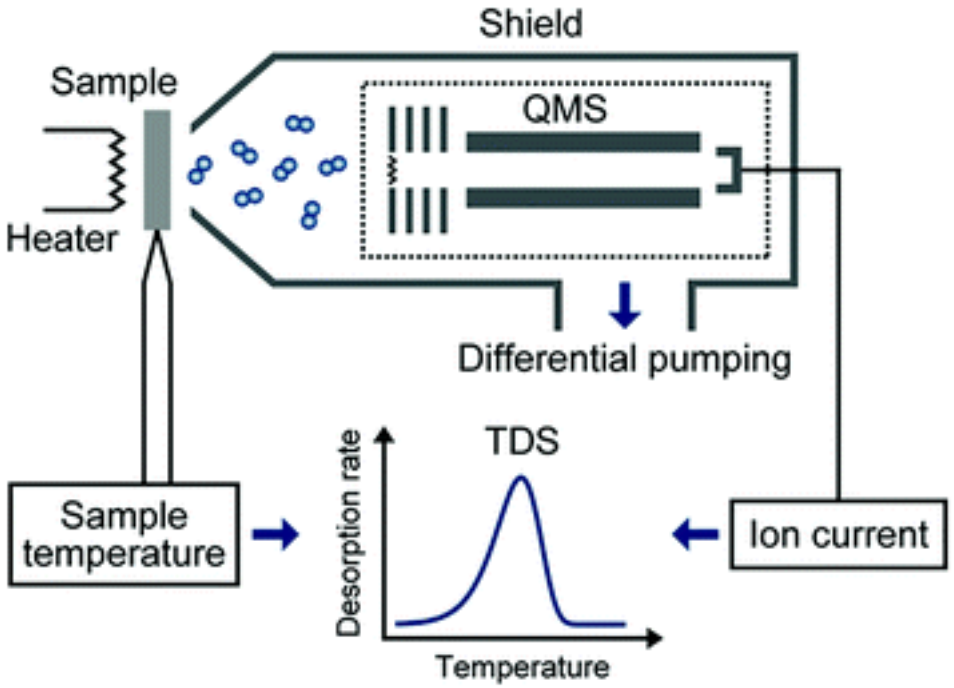
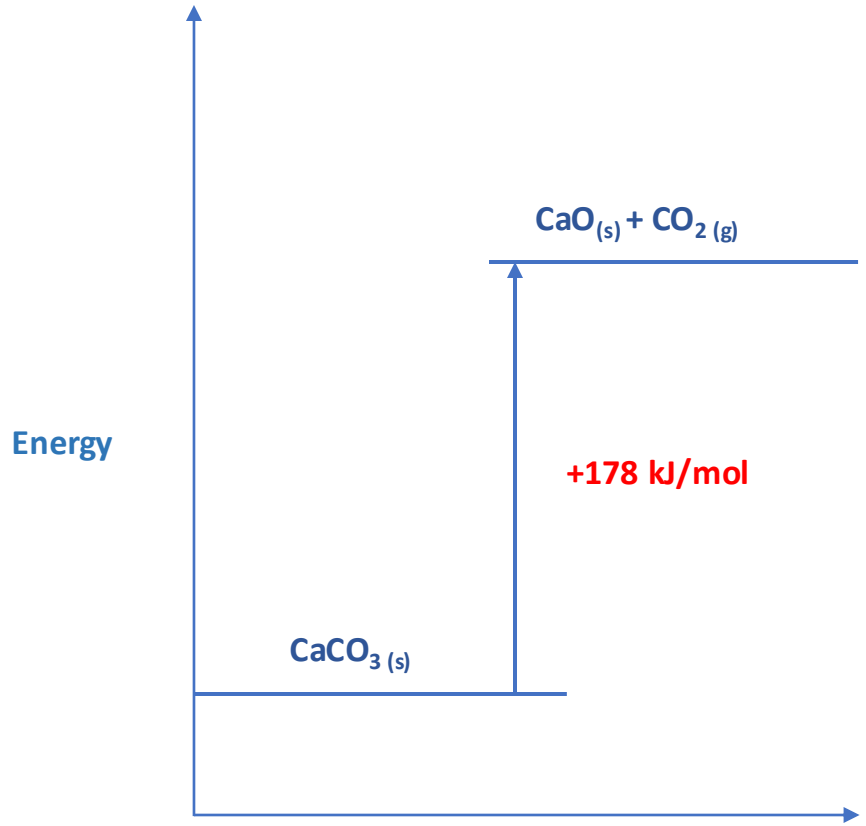
Thermal desorption

Evidence suggests we are not making metal carbonates

- thermal desorption experiments





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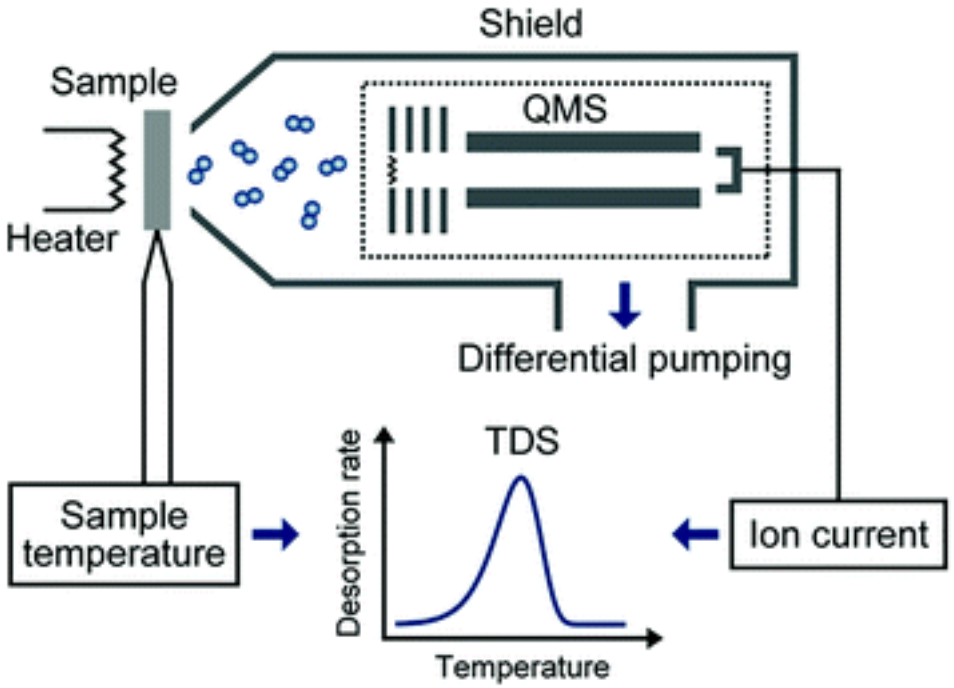

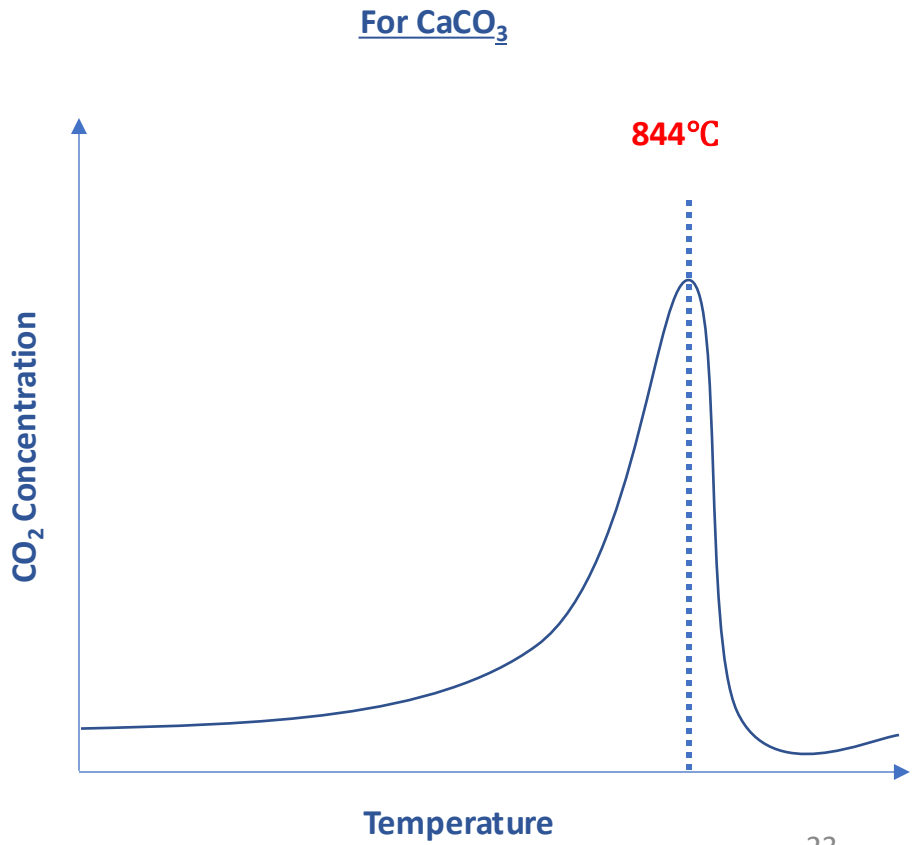

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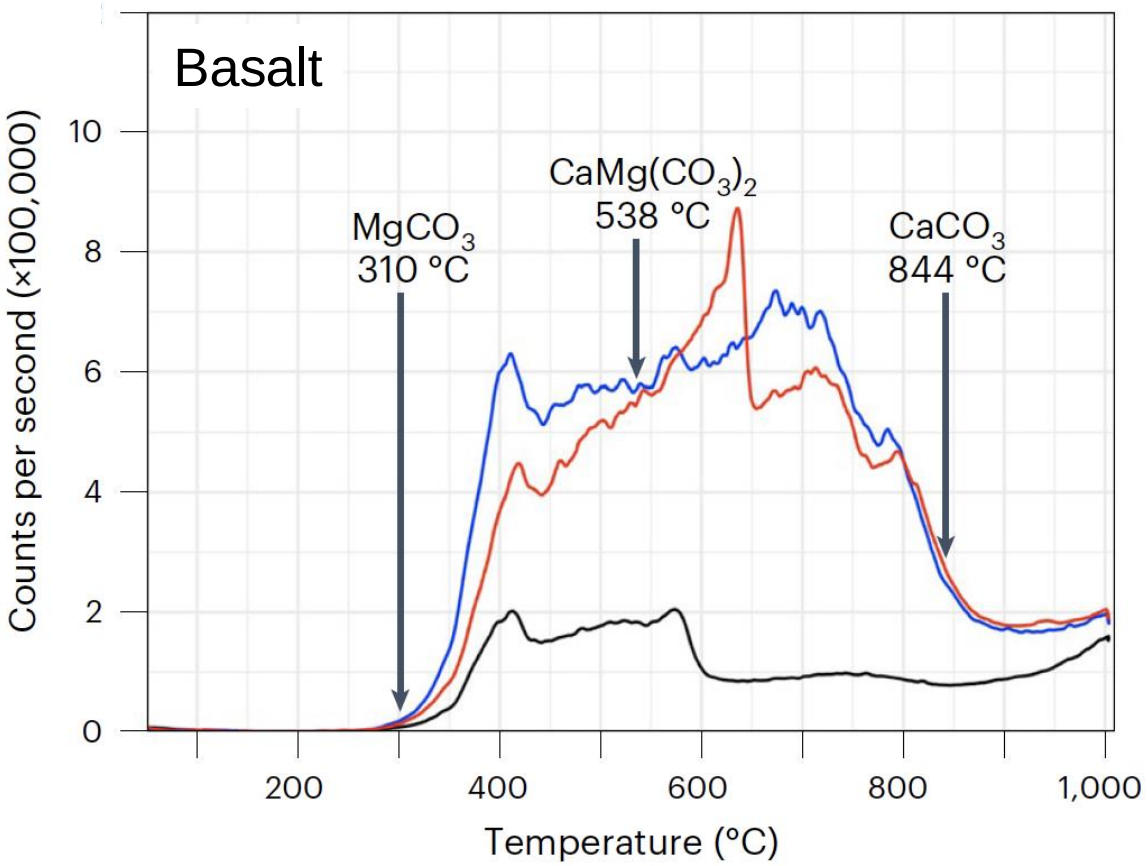

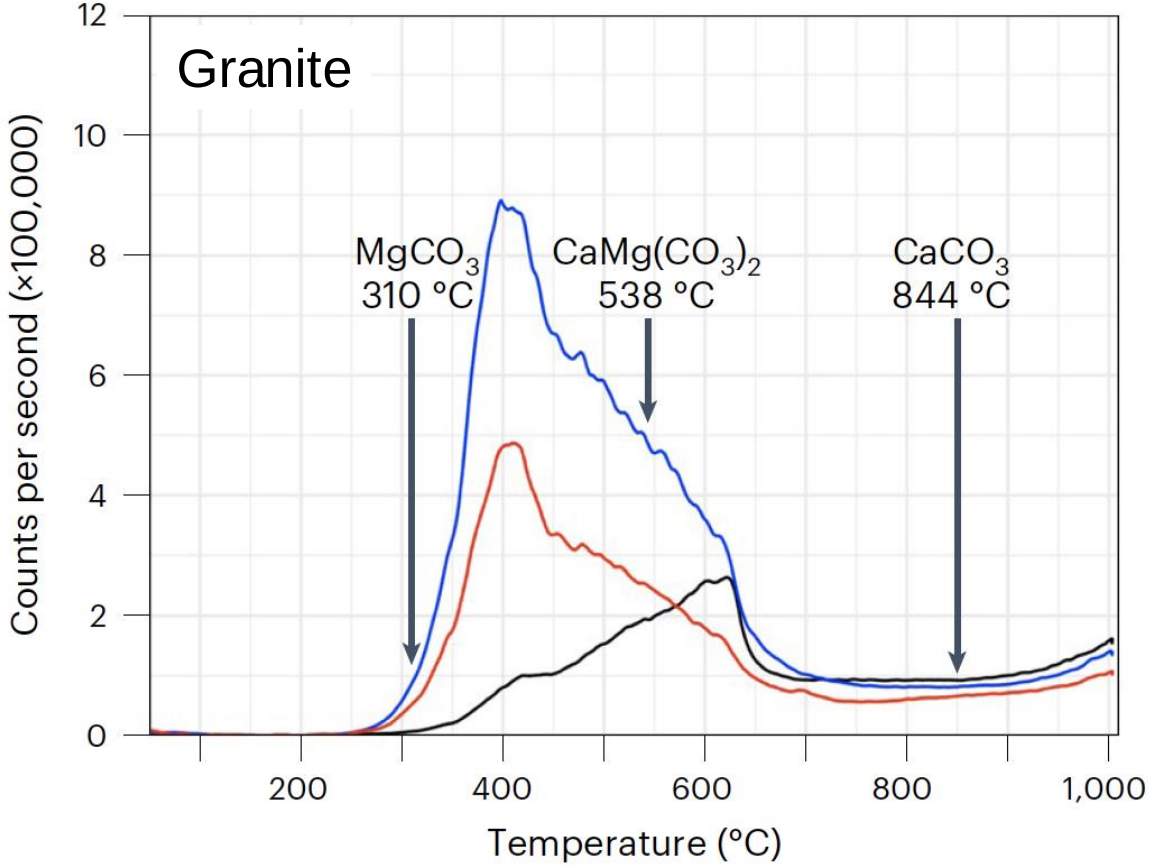

before leaching after leaching air-milled control

Summary

- Milling Silicate rocks in CO_2 mechanochemically captures the CO_2
- Captured CO_2 is thermally stable up to 300^{o}C and insoluble
- Trapping occurs differently in polymineralic systems compared to monomineralic
- Backed onto current mining processes ~2.8% of global emissions could be captured annually

Ongoing work

- Exploring trapping of other GHGs and realistic CO2 concentrations for effluent gases
- Identifying possible uses for carbonated powders
- Understanding how feedstock variability affects reactions
- Characterization of the trapped CO2