



Sequestration via CO₂ Mineralization

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Mineralization

- What is Mineralization?
- How does it work?
- What advantages does it offer?
- What is the current state of research?
- What is needed for the future?



Mineralization Research

Research efforts which seek to understand, refine and validate the conversion of CO_2 via reactions with metal oxides/hydroxides/silicates into an insoluble carbonate.

Mineralization of CO_2 has been mostly focused on the use of Ca, Mg, and to a much lesser extent on Fe containing materials.



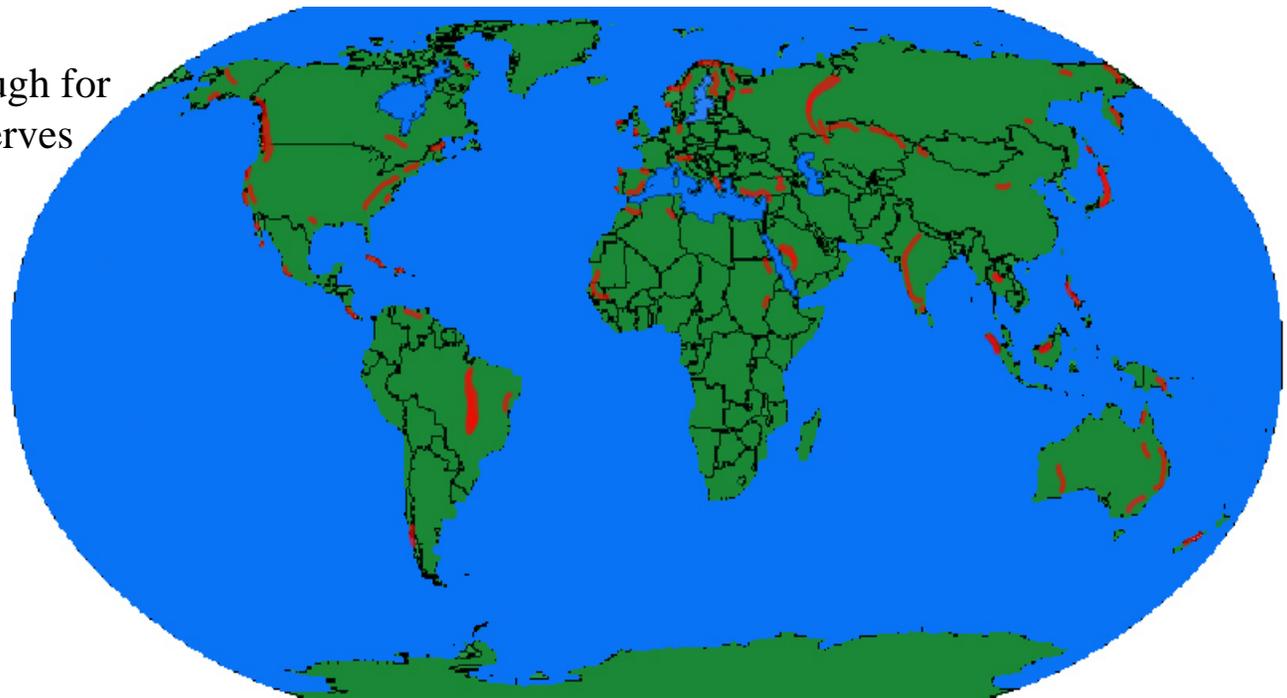
Advantages of Mineral Carbonation

- Long Term Stability
 - End product thermodynamically favored
- Ultramafic rocks are ubiquitous
- Process is exothermic
- Potential by-products or remediation value



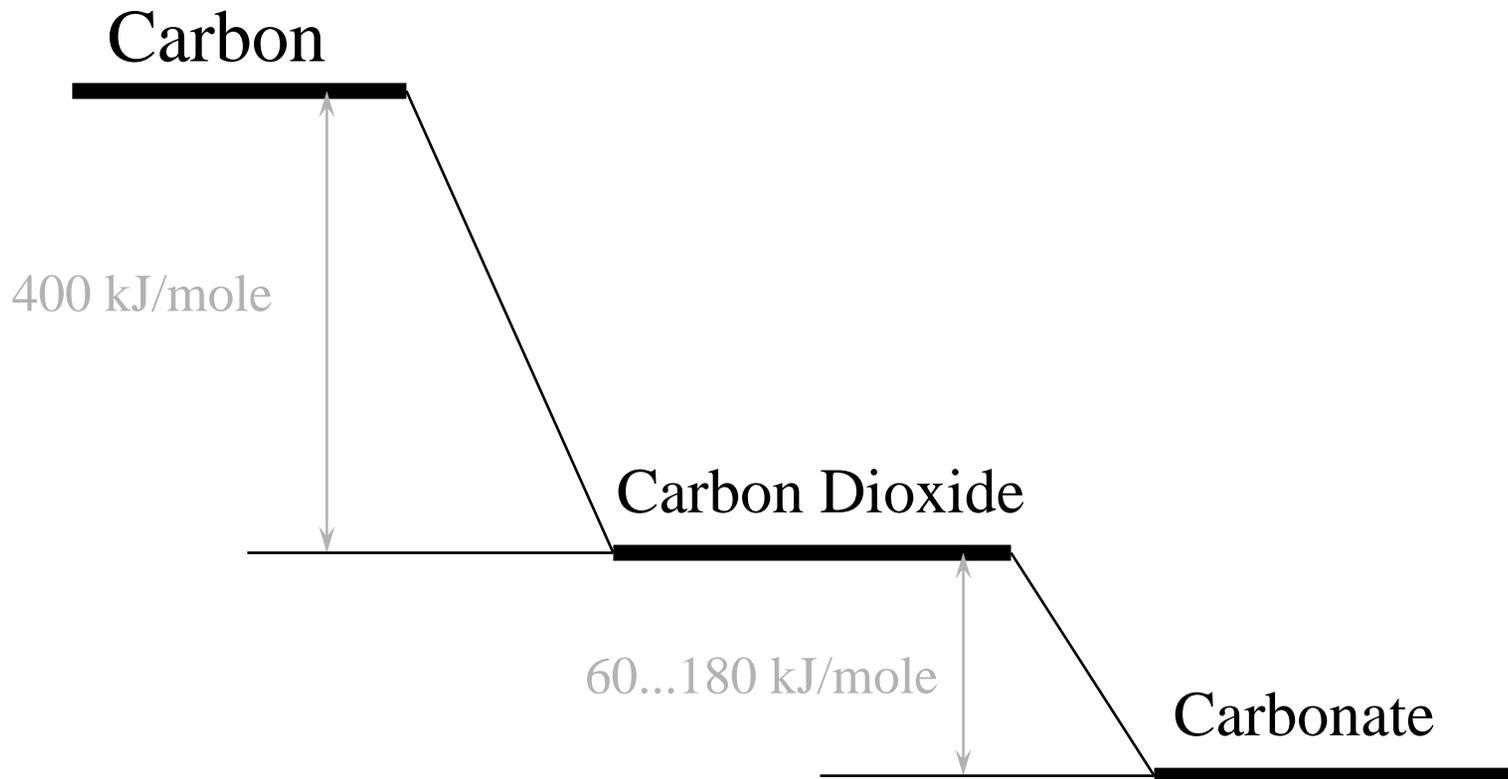
Global Ultramafic Resources

- Magnesium silicates occur in ultramafic sequences around the world
 - Resource large enough for worldwide coal reserves
- Major occurrences
 - Coasts of NA
 - Brazil
 - Northern Europe
 - Central Asia
 - India
 - Japan
 - Indonesia
 - Australia





Exothermic Reaction





R_{CO_2} Concept

$$R_{CO_2} = \frac{\text{Mass of Mineral}}{\text{Mass of } CO_2 \text{ Sequestered}}$$

MINERAL	R_{CO_2}
Olivine- Mg_2SiO_4	1.8
Serpentine- $Mg_3Si_2O_5(OH)_4$	2.1
Wollastonite- $CaSiO_3$	2.8
Fayalite- Fe_2SiO_3	2.1



In-Situ and Ex-Situ

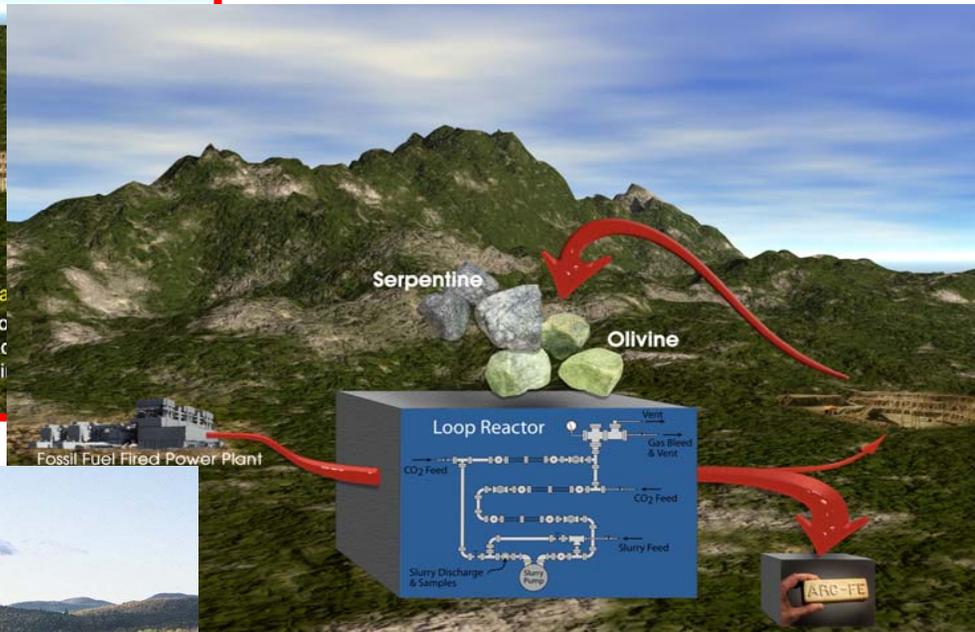
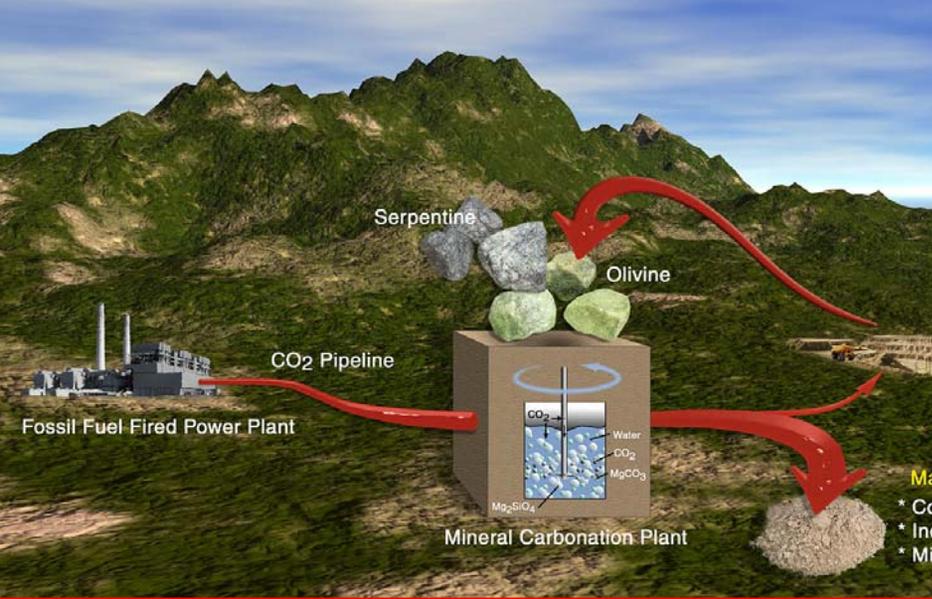
In-Situ refers to the injection of CO₂ into geological formations rich in potential carbonate formers.

Ex-Situ refers to the application of an industrial process to materials rich in carbonate formers.



Ex-Situ Critical Issues

- Pretreatment Issues which includes mining of minerals and preparation of solid, gaseous or liquid feedstocks
- Mineralization Reaction which includes mechanisms and reactor designs
- Post-Treatment Issues which includes separation of mineralization products, and disposal of process effluents
- Engineering Design, Assessment and Integration Activities which includes process integration, cost estimation, etc.

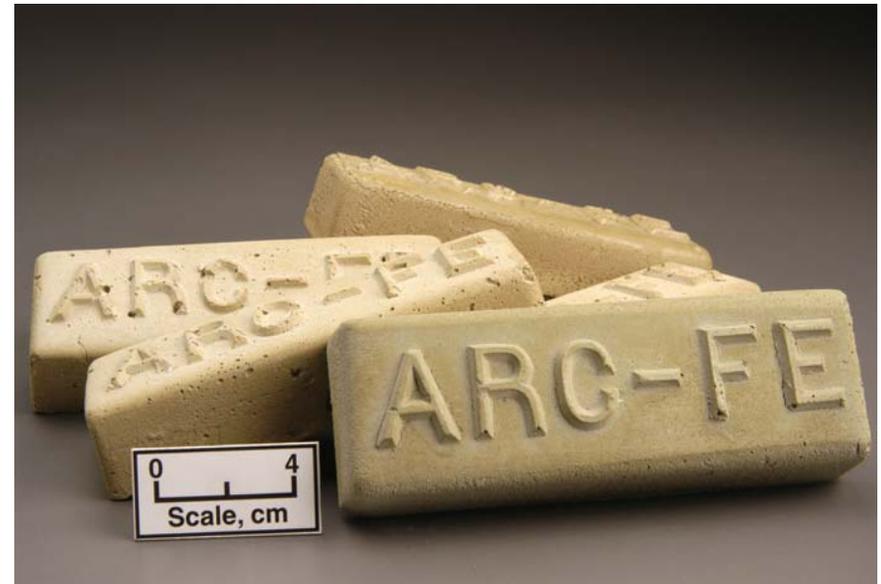




Carbonation Product



Product solids, ~30 wt pct CO₂
Carbonate in the minus 10 μm fraction



CO₂ "bricks," ~25 wt pct CO₂
Binder additions ~5 wt pct



Ultramafic Mineral Carbonation Regions





Cost Evaluation

Olivine Regions 1 & 5 (standard pretreatment)

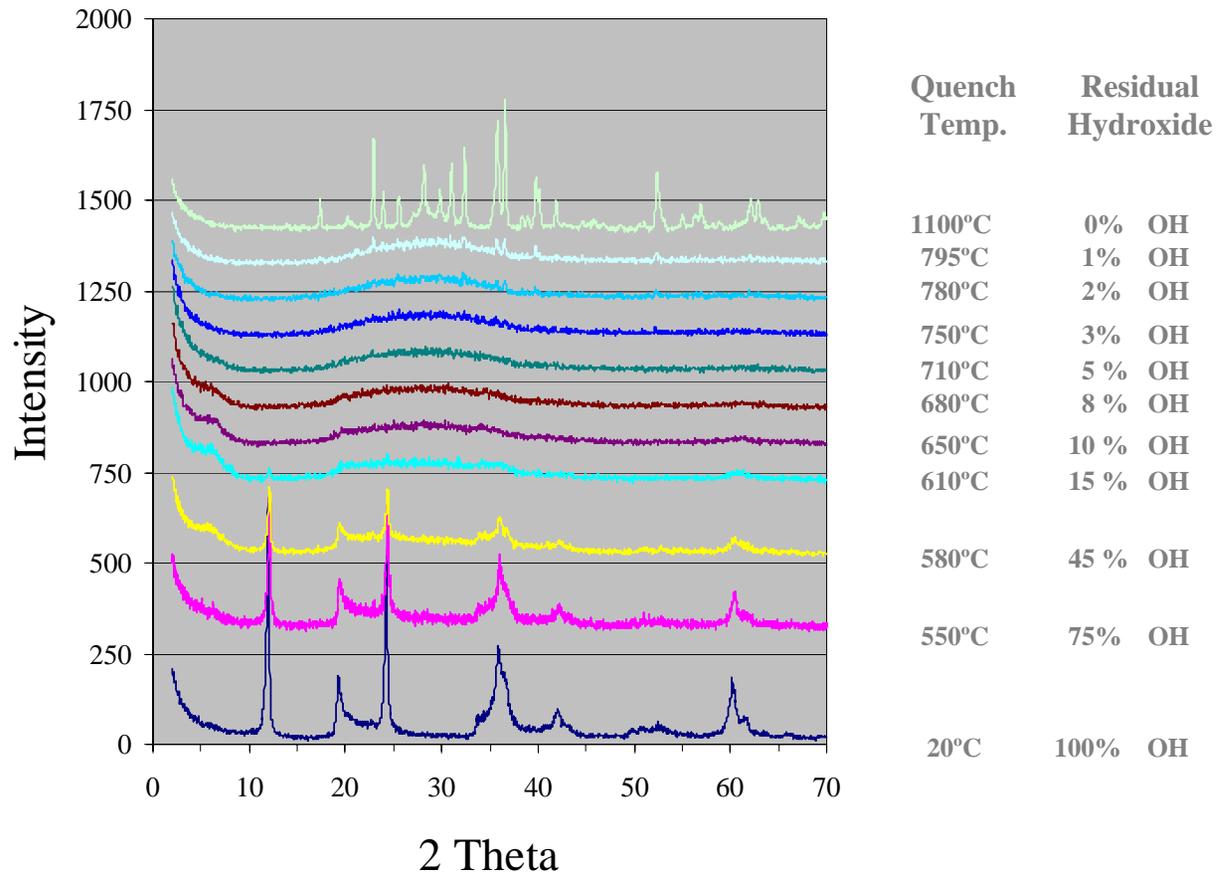
~\$54/ton CO₂ sequestered

~\$78/ton CO₂ avoided

CO₂ avoided: ~72% of CO₂ sequestered



X-RAY POWDER DIFFRACTION ANALYSIS OF LIZARDITE HEAT ACTIVATION



Chizmeshya et al.



Opportunity Materials

- Iron and steel slags
- Asbestos wastes and mine tailings
- Coal fly ash



In-Situ

- Advantages of CO₂ sequestration by mineralization as an in-situ process:
 - Elimination of mining/mineral processing activity
 - Independent of reaction rate
 - Potential for significant cost reductions



Direct injection into Mafic or UltraMafic Deposits

- Basalt Formations
- Active Fracture and injection into Massive Serpentine Formation

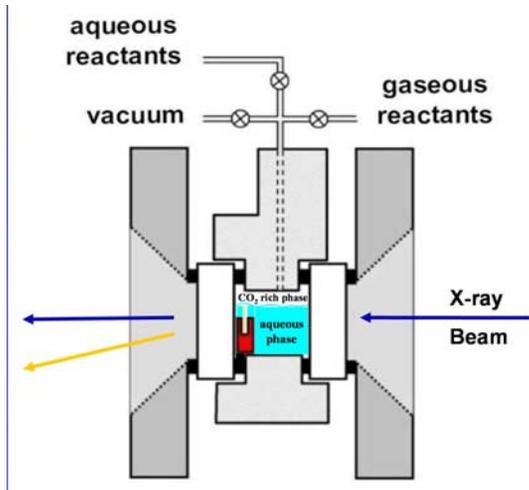


What Is Needed for the Future?

- Alternate approaches to conversion of Serpentine
- More focus on potential in-situ approaches.



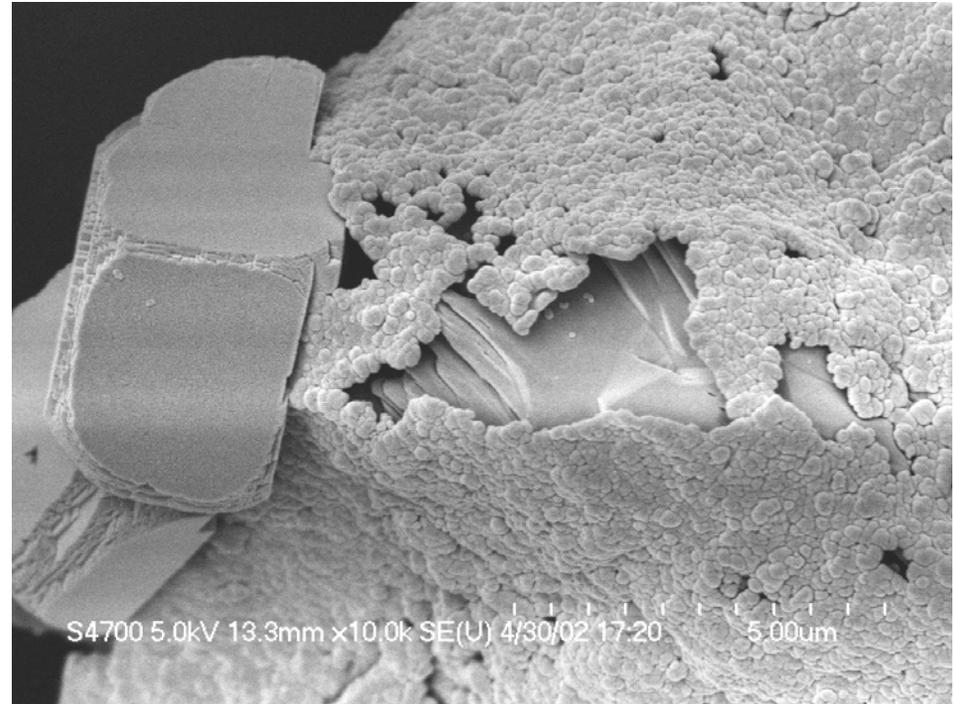
Fundamental Research



In situ techniques:

- Synchrotron X-ray Scattering
- Raman Spectroscopy
- Radiography
- Optical Microscopy

- Nuclear Magnetic Resonance (via the complementary NMR Probe)





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Thank You