CO_2 Mineralization for *in situ* Storage and *ex situ* Enhanced Metals Recovery Workshop Day 1

Tuesday July 13, 2021

Chemical Approaches

- Moderator: Jenifer Shafer, Program Director, ARPA-E Notes: Kalena Stovall, Tech SETA

A) *IN SITU*

1. Are there existing mining or drilling processes which can be readily adapted to incorporate CO_2 feeds?
2. How can modern ”fracking” technologies be used to improve *in situ* reaction rates and efficiency?

B) CHEMISTRY

1. Will lower purity CO_2 w/impurities (O_2, H_2S, H_2O, *etc*.) sources actually enhance or accelerate the conversion?
2. Are there other chemical reagents which might enhance dissolution to accelerate mineralization?
3. Can weathering be accelerated to the point that grinding needs can be reduced or eliminated?
4. How will mineralization impact the extraction of target metals? (purity, oxidation state, etc)

C) SCALING

1. What are the challenges associated with chemical mining and geo-mineralization, in terms of marketability and scale-up?
2. What engineering or chemical work or approaches are being done that should make chemical mining and geo-mineralization more profitable and scalable?

Chemical Approaches


- Moderator: Scott Litzelman, Program Director, ARPA-E Notes: Carlos Noyes, Tech SETA

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Electrochemical Approaches

- Moderator: Halle Cheeseman Program Director, ARPA-E Notes: Matthew Mattozzi, Tech SETA

A) *IN SITU*

1. Are downhole deployment of electrochemical approaches practical?
2. Are there existing mining or drilling processes which can be readily adapted to incorporate electrochemical manipulation of CO_2 feeds?

B) CHEMISTRY

1. Are there optimal concentrations for CO_2 to accelerate this process/ reaction?
2. Will lower purity CO_2 w/impurities (O_2, H_2S, H_2O, *etc.*) impact electrochemical processes?
3. Are there other chemical reagents which might enhance dissolution to accelerate mineralization?
4. Could electrochemical mineralization approaches reduce or eliminate comminution?
5. How will mineralization impact the extraction of target metals? (purity, oxidation state, etc)

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Electrochemical Approaches

- Moderator: Bob Ledoux, Program Director, ARPA-E Notes: Kate Pitman, Tech SETA

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Microbiological Approaches

- Moderator: David Babson, ARPA-E. Notes: Grace Ryan, Tech SETA

A) *IN SITU*

1. Availability of native microbial activity subsurface that mineralize CO_2?
2. Could surface microbes adapt to deployment at depth?
3. How to feed microbes at depth (and which families of microorganisms are most appropriate)?

B) "Bio-mining"

1. What are the mechanisms by which microbes and other organisms can simultaneously promote extraction and mineralization?
2. In what locations could microbes benefit both mining and geo-mineralization?
3. Can microbes accelerate weathering to the point that comminution would not be required or greatly reduced?
4. How will mineralization impact the extraction of target metals? (purity, oxidation state, etc)

C) SCALING

1. What are the challenges associated with microbe-based mining and geo-mineralization, in terms of marketability and scale-up?
2. What work is being done that can make microbe-based mining and geo-mineralization more profitable?

Microbiological Approaches

- Moderator: Marc von Keitz, ARPA-E. Notes: Jared Incorvati, Tech SETA

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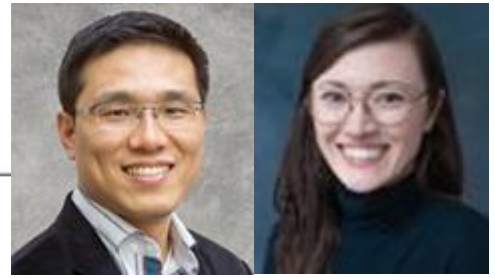
Phytomining Approaches



- Moderator: Phil Kim, Program Director, ARPA-E Notes: Laura Demetrion, Tech SETA

A) PLANT-BASED CARBONATION

1. What are the rates of silicate rock breakdown and carbonate formation in plant-based systems?
2. How quickly can plants extract metals from environments? What are the uptake rates, and how long can those rates can be sustained in a single generation of plants, or multiple generations?

B) BIO-ORES

1. What are the mechanisms by which plants and other organisms can simultaneously promote mining and mineralization?
2. In what locations could plants benefit both mining and geo-mineralization?
3. Can plants accelerate weathering to the point that comminution would not be required or greatly reduced?
4. Can bio-ores result in carbon-negative mining, upon taking harvesting and processing, etc. into account?

C) SCALING

1. What are the challenges associated with plant-based mining and geo-mineralization, in terms of marketability and scale-up?
2. What work is being done that can make plant-based mining and geo-mineralization more profitable and scalable?

Day 1 Takeaways

A) *IN SITU*

- Complex considerations: consistent/continuous access for reaction, fracture design, optimizing reaction
- Supercritical CO_2 used, but instead of pumping underground, may be better used in other processes

B) CHEMISTRY

- Extraction is a 2-step process: dissolve then precipitate. Acid/base process. (pH becomes bigger problem at scale)
- Impurities pros / cons specific to process
- Impurities will be biggest impediment to electrochemistry processes
- Electrochemical processes limited to surface reactions
- Heat advantages / disadvantages / limitations need to be considered
- Controlled kinetics are important
- Additional information needed to make modeling more useful
- Ways to accelerate reaction: catalyst, microbes. Note: microbes hard to get underground

C) SCALING

- Cost / value will be partly driven by which elements are removed in a given process
- Adding electrochemistry increases cost. Mitigate by speeding up process, value of elements extracted.

PHYTOMINING

- Carbon benefits could be more significant with *in situ* extract from the plant (vs. burning)
- Time frame from lab success to real-world success is long: engineer plants, plant growth time, etc.
- Accelerate with right agricultural environment and plant choices