Conversion of calcium carbonate into methane and multi-carbon compounds by a novel microbial consortium

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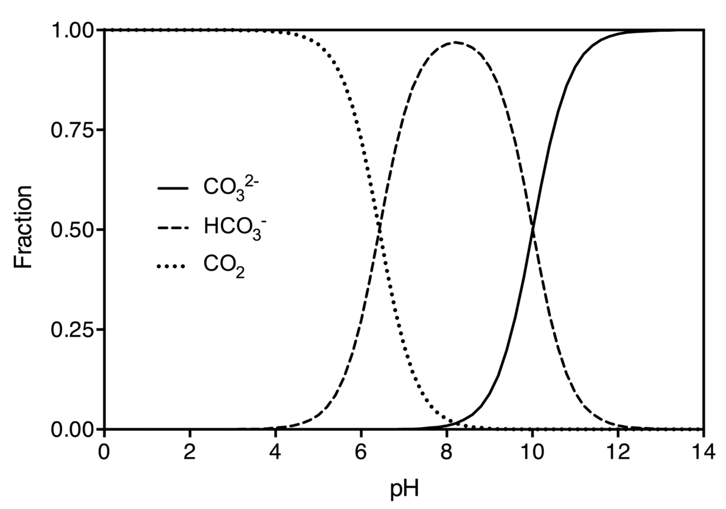
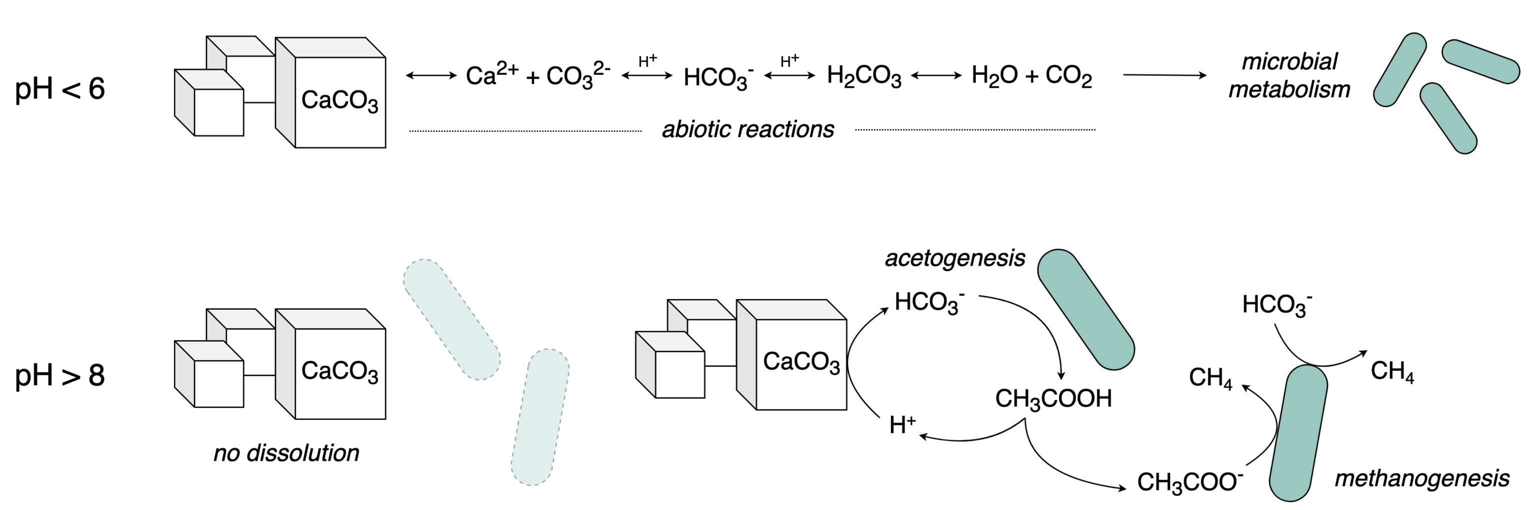
ABSTRACT

The microbial conversion of CO_2 into methane or multi-carbon compounds offers an alternative approach for renewable energy storage and bio-product production. Here we present preliminary results assessing the conversion of sequestered CO_2 in the form of carbonate minerals into methane and acetate using a microbial consortium enriched from the saline, alkaline wetlands near Lincoln, NE. The enrichment was maintained at an alkaline pH (8.3) under anoxic (100% Ar) conditions when provided with calcium carbonate and either electric current or H_2 as an electron source. With optimization, this process could be used to address the storage limitations of wind and solar power by producing methane gas or multi-carbon compounds.

BACKGROUND

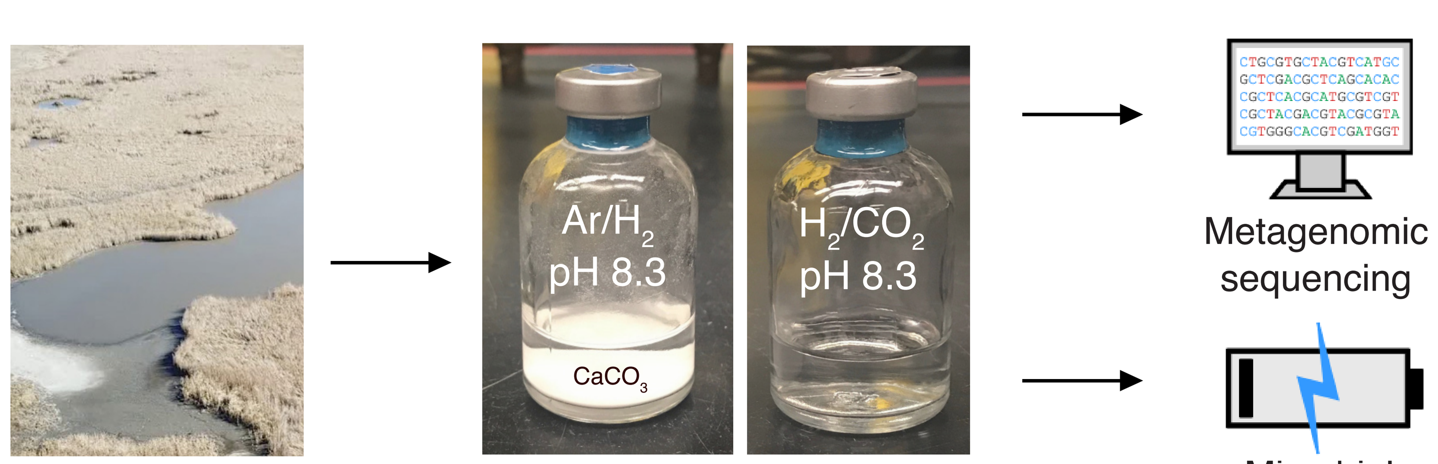


Bjerrum plot indicating **relative proportions of carbonate species** at equilibrium as a function of pH (left) and carbonate dissolution chemistry with **hypothesized mechanism of microbially-catalyzed dissolution** at alkaline pH (below).



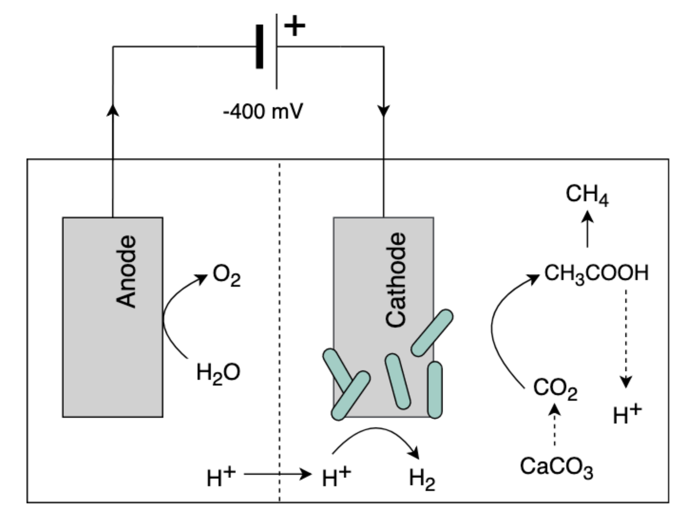
OBJECTIVES

1. Identify microorganisms and metabolic pathways catalyzing the dissolution and conversion of calcium carbonate to acetate and methane at alkaline pH.



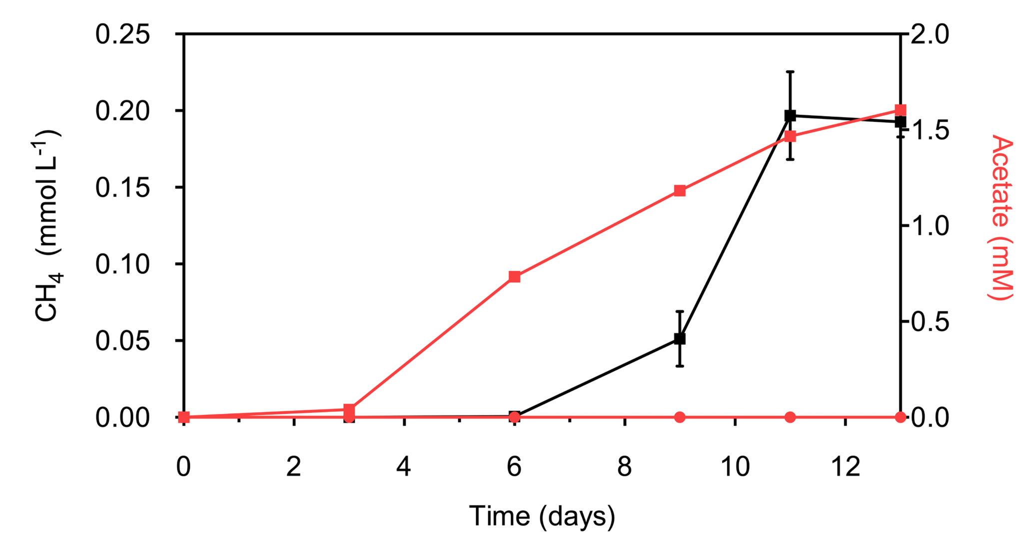
Saline wetland Lincoln, NE

Anoxic culture vials with minimal saline alkaline medium

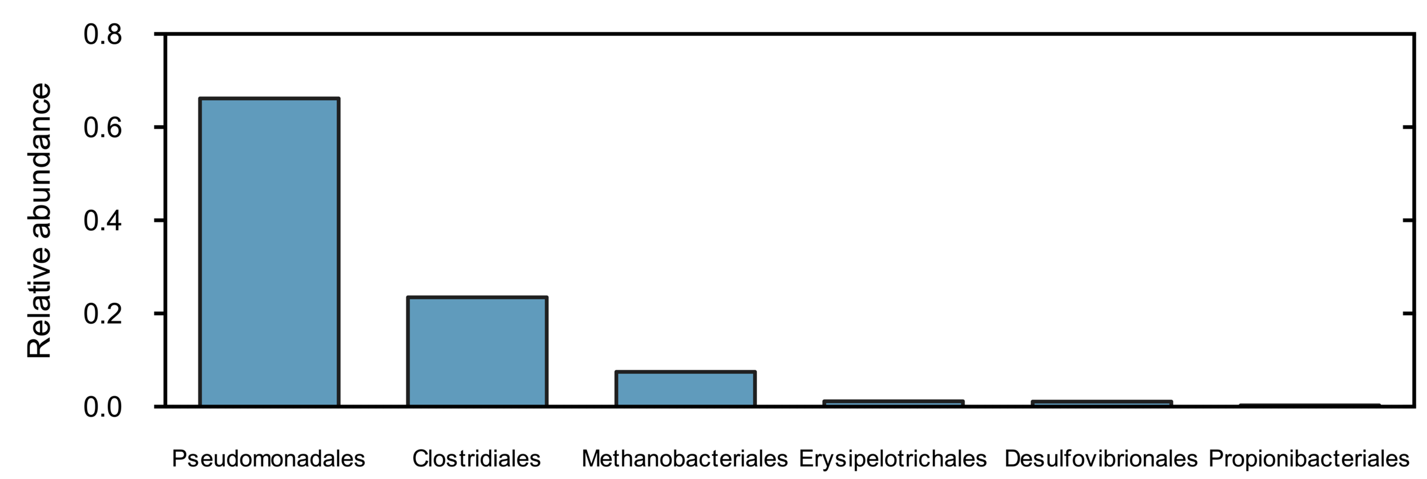


2. Determine electrosynthetic capability of the enrichment consortium and evaluate its potential for use in the microbial electrosynthesis of methane and multi-carbon compounds from calcium carbonate and renewable energy (wind or solar).

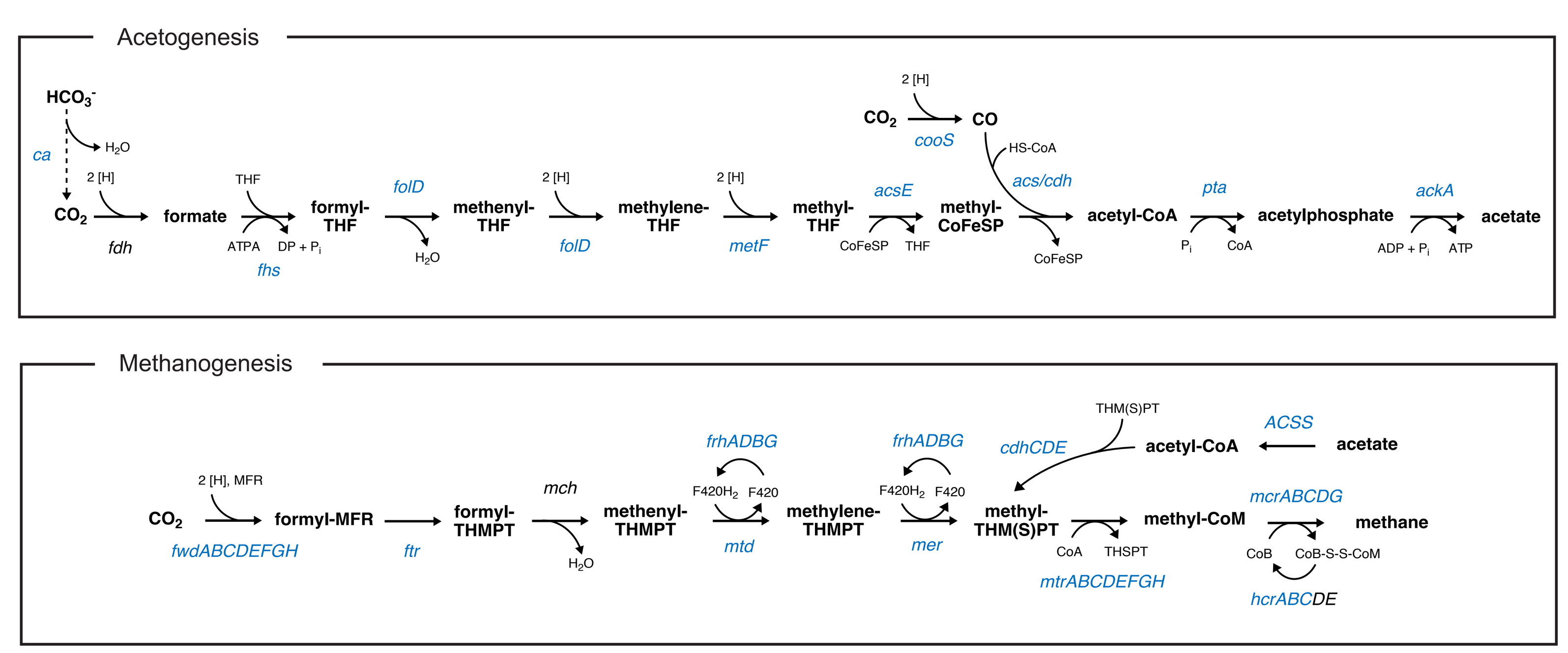
RESULTS



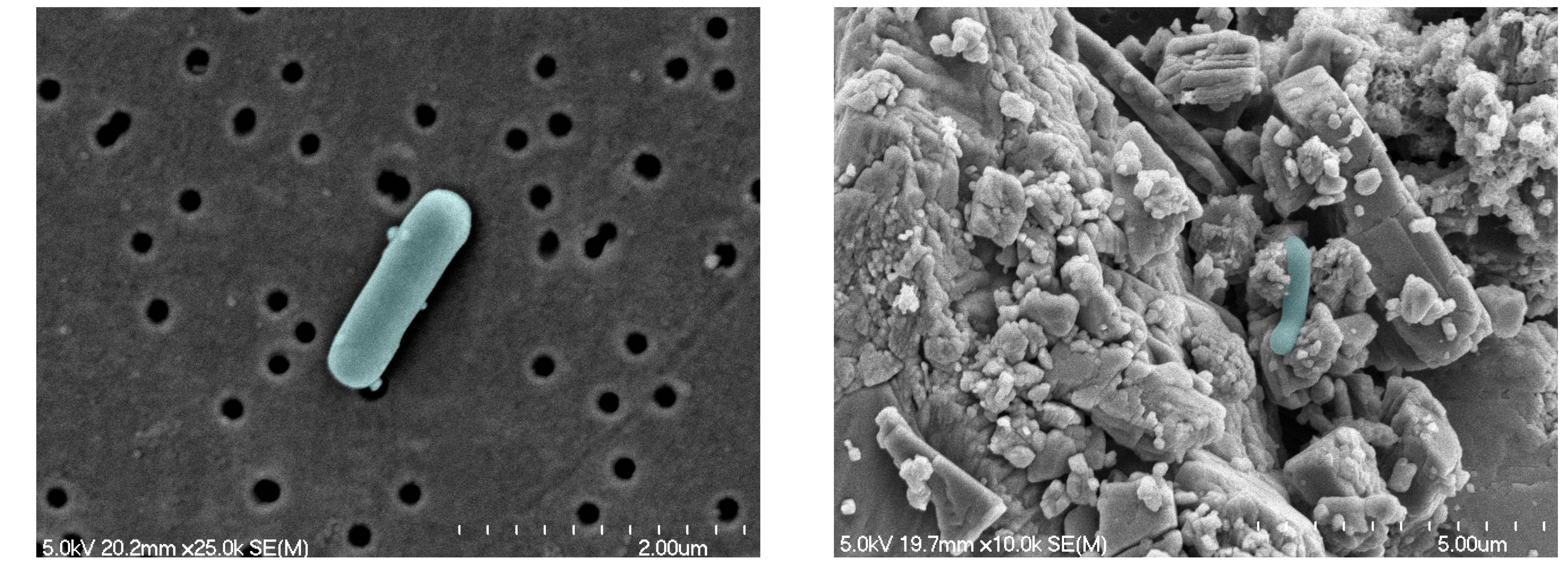
Methane and acetate production in anaerobic microbial cultures (■, live cells) amended with $CaCO_3$ relative to a negative control (●, heat-killed cells). Standard error of measure of triplicate cultures is denoted by error bars. Error bars not visible are smaller than the symbol.



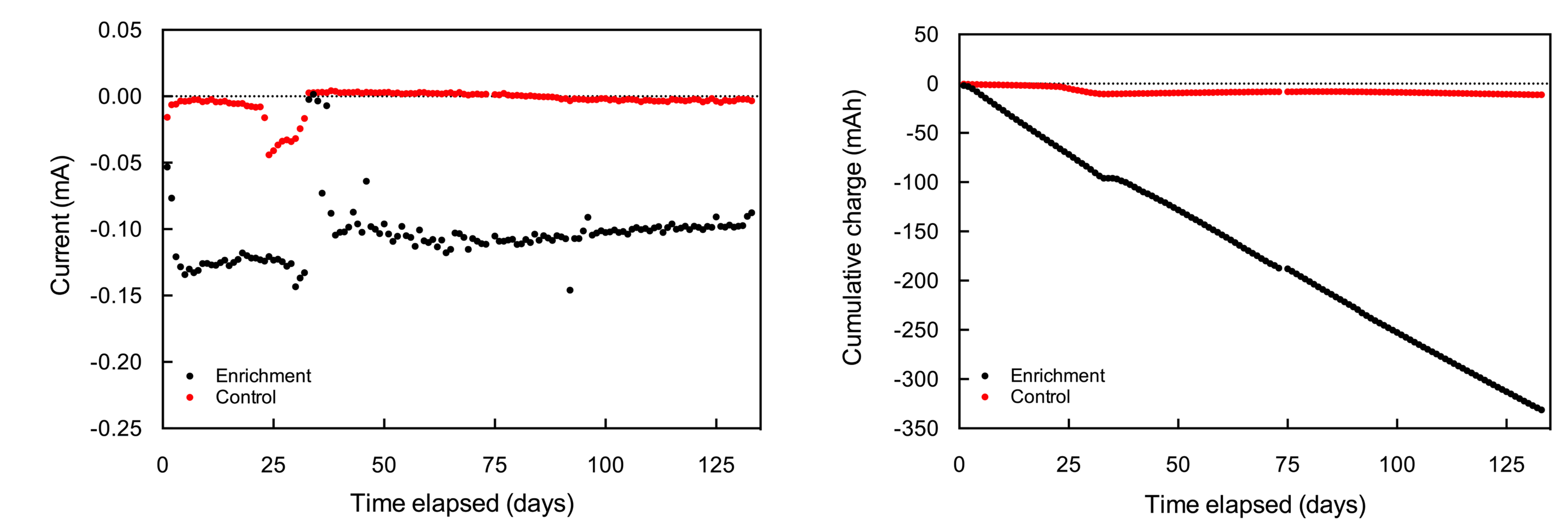
Shotgun metagenomic sequencing of the alkaline carbonate enrichment. Taxonomy and relative abundance of the assembled 16S rRNA gene sequence as assigned by EMIRGE using the SILVA database.



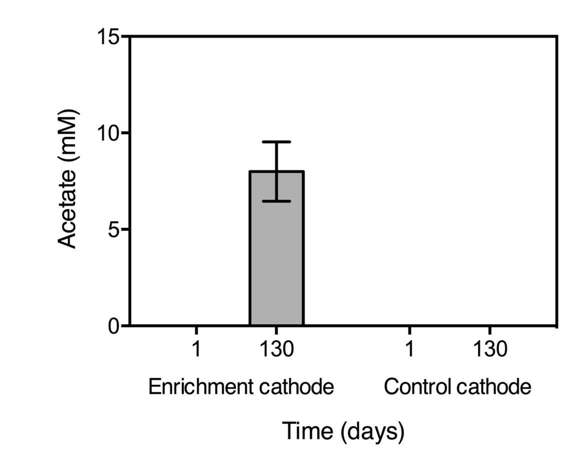
Metabolic pathways identified in shotgun metagenomic sequence assembly linking taxa to acetogenesis and methanogenesis. Reconstructed from KEGG reference modules. Genes in blue have been positively identified in the assembled metagenome.



Scanning electron micrographs of enrichment organisms (pseudocolor) cultured on CO_2 (left) or $CaCO_3$ (right) as carbon sources.



Current consumption by enrichment organisms cultured in H-cells with a cathode potential of -400 mV and calcium carbonate as the sole carbon source. Values are relative to a silver chloride reference electode.



Acetate production in cathodic chamber of enrichment-based microbial fuel cells. Standard error calculated based on deviation of acetate standards from a previously generated standard curve. Methane production has been monitored, but has not yet been observed.

CONCLUSIONS

1. Alkaline enrichment acetogen and methanogen have near-complete pathways for acetogenesis and methanogenesis (both acetoclastic and hydrogenotrophic), confirming metabolic potential for the hypothesized mechanism of carbonate dissolution and conversion.

2. Enrichment consortium is able to consume electrons directly from the cathode of a microbial fuel cell, supporting the electrosynthetic potential of the carbonate-based fuel cell system.

ACKNOWLEDGEMENTS

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