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Preferential Utilization of Calcium Carbonate Polymorphs by a Hydrogenotrophic Methanogenic Microbial Community

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Carbonate minerals, a significant carbon reservoir on Earth, are considered metastable under alkaline conditions. However, we recently demonstrated that calcium carbonate can serve as a sole source of inorganic carbon to sustain hydrogenotrophic methanogenesis at moderately alkaline conditions (pH 7.6-8.5) in a microbial enrichment culture [1]. Hydrogen consumption and methane production were observed concurrent with an increase in dissolved calcium, indicating microbially mediated mineral dissolution within the enrichment culture. Genome-resolved metagenomics of the enrichment community confirmed the presence of a methanogen (*Methanobacterium* sp.) with the metabolic potential for hydrogenotrophic methanogenesis in addition to five bacterial community members (*Tessaracoccus lapidicaptus*, *Nitratidesulfovibrio* sp., *Stutzerimonas stutzeri*, *Acetoanaerobium noterae*, and an uncultured genus in *Erysipelotrichaceae* (UBA2212 sp.)). Minerals able to sustain hydrogenotrophic methanogenesis and cell growth were further tested using commonly occurring natural and synthetic carbonate-bearing minerals (calcite, aragonite, dolomite, siderite, magnesite, and synthetic calcium carbonate). After one month of incubation, calcium carbonate minerals (calcite, aragonite, and synthetic calcium carbonate) were identified to produce a significant amount of methane and support cell growth demonstrating these minerals are preferential substrates for the microbial community. Whereas cultures amended with dolomite, siderite, and magnesite did not produce methane significantly different than the control, nor was cell growth observed. Geochemical modeling indicates that use is not solely a function of mineral solubility. Together, these results demonstrate that calcium carbonate polymorphs are a preferential source of inorganic carbon for hydrogenotrophic methanogenesis by the enrichment culture. Consequently, these results have significant implications as they suggest that microorganisms could compromisethe long-term stability of sequestered calcium carbonates and subsurface hydrogen storage in reservoirs dominated by calcium carbonate. Understanding these mineral-specific challenges will be important to consider for optimization of carbon and energy storage.

References:

[1] Fiore NA, Kohtz AJ, Miller DN, Antony-Babu S, Pan D, Lahey C *et al*. Microbial methane production from calcium carbonate at moderately alkaline pH. *Communications Earth & Environment*. 2025;6**:** 85.