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Carbonation and cementation of ultramafic mine wastes

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Ultramafic (Mg-rich) mine wastes are produced in vast quantities, are of no economic value, and their storage impoundments can be susceptible to catastrophic failure.¹ Carbon dioxide (CO₂) mineralization of these wastes to form carbonate cement can reduce greenhouse gas emissions² and assist in de-risking storage impoundments through physical stabilization.³ CO₂ mineralization and cementation have been documented at asbestos,⁴ nickel,² and diamond mines, occurring unintentionally over long periods (e.g., decades).^{2,4} This research aimed to 1) better understand carbonation and cementation processes by examining historic kimberlite mine wastes from diamond mines and 2) accelerate these processes in experiments using brucite-bearing serpentinite mine wastes.

We collected physical, mineralogical, and geochemical data of cemented historic kimberlite wastes 70 to >110 years old. Analysis of cemented fine- and coarse-grained residues from the Voorspoed and Cullinan diamond mines (South Africa) revealed the presence of a fine-grained (<63 μm) cement matrix with greater total inorganic carbon (TIC; +0.08–0.34% relative to clasts), secondary clays (e.g., Mg-Al silicates), and some minor carbonates (e.g., calcite). Unconfined compressive strength varied considerably between fine- and coarse-grained wastes (UCS; 0.13–4.45 MPa). Furthermore, kimberlite clasts and cements were isotopically distinct, suggesting that mineral weathering by meteoric water drove cementation over decades after the deposition of these wastes.

In experiments, coupling organic and inorganic carbon cycling accelerated carbonation of synthetic tailings that contained brucite [Mg(OH)₂], a minor yet reactive mineral. In cylindrical test experiments (2.5 × 5 cm; 40 weeks), waste organics were either mixed (0–10 wt.%) or kept separate from brucite-bearing serpentinite mine wastes to provide an additional source of CO₂. In the mixed cylinders, brucite consumption ranged from 3–30% and was limited by CO₂ generation, as evidenced by minor increases in TIC (+0.02–0.22%). Compressive strengths amongst the cylinders reached 0.51 MPa with few cylinders becoming sufficiently stabilized; however, in experiments that exposed cylinders to CO₂ generated from organics separate from cylinders, brucite carbonation (64–84% consumption) and compressive strengths were substantial (0.4–6.9 MPa).³ Our research demonstrates the role of long-term weathering for sequestering CO₂ within ultramafic mine wastes, and how coupling organic and inorganic carbon cycling can accelerate CO₂ sequestration and physically stabilize these wastes.

References:

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