

# Microbial CO<sub>2</sub> removal into carbonate sediments using cation exchange leachates from kimberlite mine residues — Results from Project CarbonVault

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Kimberlite mine residues are suitable rocks for carbon dioxide removal (CDR) due to their high Mg and Ca contents. The reactivity of smectite-rich residues can be enhanced in two steps: (1) liberation of Mg<sup>2+</sup> and Ca<sup>2+</sup> from residues through adding a cation exchange amendment and (2) carbonation of the resulting Mg and/or Ca-rich leachates using a source of CO<sub>2</sub>. Here, we tested this approach by conducting one-year-long field experiments using kimberlite residues from the Venetia Mine (South Africa). The kimberlite residues consist of a complex mineral assemblage dominated by serpentines and (Mg,Ca)-rich smectites. The fast reactivity of these residues can be accessed using cation exchange reactions that liberate Mg<sup>2+</sup> and Ca<sup>2+</sup> from the interlayer spaces of smectites in exchange for less desirable species/cations (NH<sub>4</sub><sup>+</sup>, K<sup>+</sup>) introduced in leaching amendments.

The field experiments consisted of several reactors, each comprising ~850 kg of kimberlite residues. Cation exchange amendments of either 1 M ammonium acetate (NH<sub>4</sub>-acetate) or 1 M ammonium chloride (NH<sub>4</sub>Cl) were applied to each reactor weekly for six weeks. A control system employed tap water. Leachates from each of the three experiments were drained into two 1,400 L leachate troughs: an abiotic control system to assess physical processes and a microbial system using a consortium cultured from the Venetia open pit. Four months after the first amendment, solid samples were collected at the bottom of each trough. Powder X-ray diffraction analyses coupled with scanning electron microscopy and energy dispersive X-ray spectroscopy revealed the formation of sediments dominated by Mg-calcite with a dumbbell morphology in the NH<sub>4</sub>-acetate leachate troughs. Very high Mg-calcite (also called protodolomite) dominated in the sediments from the NH<sub>4</sub>Cl leachate troughs and no carbonate minerals formed in the control troughs. Given the low solubilities of Mg-calcite and very high Mg-calcite, these results suggest that the field experiments provided biogeochemical conditions leading to CO<sub>2</sub> storage which will

