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Investigating microbially-mediated mineral carbonation during acid leaching of processed kimberlites: Results from Project CarbonVault

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Ultramafic mine tailings such as processed kimberlite can be used as feedstocks for mineral carbonation due to their Mg- and Ca-rich composition and high surface area [1]. In this study, processed kimberlites from the Venetia mine (South Africa) were used for an acid leaching field trial. Treatments of 0.12 M HCl were applied weekly for six weeks to processed kimberlite within a 1-m^3 reactor. Equal volumes of leachate were collected into two photosynthetic, 1400-L bioreactor troughs and carbonation reactions were monitored for 1 year. The microbial consortium cultured from the Venetia mine pit was employed in one trough for microbially-mediated carbonation whereas the second trough served as an evaporative control. A combination of quantitative X-ray diffraction (XRD) using Rietveld refinements, inductively coupled plasma optical emission spectrometry (ICP-OES) and scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDXS) were used to investigate the amount of mineral carbonation.

Our results show that calcite (7.2 wt%) is abundant in the initial processed kimberlite and acts as the main source of Ca in the leachate. In contrast, Mg is extracted mainly from dissolution of phyllosilicate minerals. Very high magnesium calcite (VHMC, also called protodolomite) and low-Mg calcite formed as a result of microbially-mediated carbonation. Although calcite dissolution decreases the mineral carbonation potential, our preliminary results suggest liberated Ca is being recarbonated and that the leached Mg is sequestering additional atmospheric CO_2.

Treatment pathways used for enhanced weathering and carbonation should be dictated by the specific mineralogy of each ultramafic rock type and/or each kimberlite facies. We also studied the influence of the specific mineralogy of residues on mineral carbonation in a laboratory-based acid leaching experiment using three different ultramafic rocks. Our results show that the combination of acid leaching and microbially-mediated carbonation is best employed for calcite-poor ultramafic mine residues. For ultramafic mine tailings rich in calcite, cation exchange using mild treatments such as NH_4Cl and NH_4-O-acetate is a new approach to extract Mg and Ca from clay minerals while avoiding primary carbonate dissolution.

[1] Wilson, S.A. et al. (2009). Economic Geology 104 (1): 95–112.