

Cation exchange: a new strategy for mineral carbonation of smectite-rich kimberlites

Nina Zeyen¹, Baolin Wang¹, Siobhan A. Wilson¹, Konstantin von Gunten¹, Daniel S. Alessi¹, Carlos Paulo², Amanda R. Stubbs² and Ian M. Power²

¹Department of Earth and Atmospheric Sciences, University of Alberta, T6G 2E3, Canada

²Trent School of the Environment, Trent University, K9L 0G2, Canada

Summary

Mineral carbonation is a form of carbon capture, utilisation and storage (CCUS) that aims to transform excess atmospheric CO₂ into environmentally benign carbonate minerals which are stable over geological time. This method is part of a strategy for mining companies to offset their greenhouse gas emissions [1]. In this study, we investigated the reactivity of processed kimberlite (tailings) and kimberlite ore from the Venetia diamond mine, South Africa. Highly reactive phases, such as brucite [Mg(OH)₂], are uncommon in the samples collected from Venetia necessitating the development of new strategies for mineral carbonation. Kimberlite ore and tailings from this mine consist of a clay-rich mineral assemblage that is dominated by lizardite (a serpentine mineral) and smectites. Smectites are swelling clays that can act as a source of Mg and Ca for carbonation reactions via cation exchange, dissolution and/or direct replacement of smectites to form carbonate phases. Although carbonation of serpentine and brucite has long been a focus of CCUS in mine wastes [2], smectite carbonation has not been explored in this setting; however, the reactivity of smectites has been well studied for other industrial applications.

Quantitative X-ray diffraction using Rietveld refinements coupled with Fourier-transform infrared spectroscopy indicate that smectites of stevensite–saponite composition are abundant in the studied samples (ranging from 1.3 to 15.4 wt.%). Synchrotron-based X-ray fluorescence mapping correlated with scanning electron microscopy show that smectites are distributed as altered, smooth regions measuring from 1 to 20 µm in breadth. These phases are rich in Mg and Ca and are Al-poor. To better understand the behaviour/reactivity of smectites during the cation exchange process, we have used batch experiments with pure endmembers of Ca-, Mg- and Na-montmorillonite under different treatment conditions [NH₄-citrate (1M), NH₄-O-acetate (1M), NH₄-Cl (1M) and Na₃-citrate (0.5M)]. In addition, since calcite dissolution is an undesirable source of cations, and may represent a loss of the carbon stored as primary mineralization, we have performed batch experiments with pure calcite under the same treatment conditions. After 24 hours of reaction, ICP-MS analyses reveal that the four treatments have the same efficiency for Ca and Mg exchange, while NH₄-Cl and NH₄-O-acetate treatments minimize calcite dissolution. Our end goals are to optimize settling time and to maximize extraction of Ca and Mg for carbonation reactions during ore processing.

[1] Power et al., 2014, *Minerals*, 4, 399–436

[2] Wilson et al., 2009, *Economic Geology* 104, 95–112