Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.38041

The leaching behaviour of ultramafic minerals and major cations and implications on carbon mineralisation

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Silicates and alkaline-earth oxides are abundant in (ultra)mafic materials, and their dissolution can release Mg, Ca, and Fe for carbon mineralisation. Several geochemical tests were conducted to evaluate the CO_2 removal capacity (RCO_2) and leaching behaviour of four ultramafic samples: RRP1, RRP2, and Site X from Canada and WGN4 from Australia. Major phases (wt. %) are serpentine in RRP1 (42%) and Site X (24%), feldspar in RRP2 (30%), and amphibole in WGN4 (64%). All the samples contain Mg, Fe, and Ca in major quantities (1.2 – 23 %) and sequential chemical extractions partitioned Mg as the most leachable (36 – 95 %), with WGN4 leaching the least. This was corroborated by the modified Sobek acid neutralising capacity (ANC) test, where only 0 – 9 % of WGN4 minerals reacted with 0.5 M HCl at 90 ºC. The high dissolution (> 50%) of minerals in the other samples resulted in high ANC values (223 – 550 kg $CaCO_3$/t). A subsequent kinetic leach test using 0.2 M H_2SO_4 at room temperature showed dissolution rates of Mg (2.1 – 39 mg/L.min), Ca (0.24 – 2.2 mg/L.min), and Fe (0.2 – 1.9 mg/L.min) to be strongly correlated with pH (R^2 = 0.87 – 0.96). The gradual mineralogical change as pH decreased from 10 to 1.2 indicated the relative reactivity order as brucite > calcite > dolomite > magnesite > forsterite > lizardite > mica > antigorite > chlorite > talc > amphibole > feldspars.

The maximum possible RCO_2 (t rock/t CO_2) based on the concentration of cations are 2.5 (RRP1), 5.3 (RRP2), 2.9 (Site X) and 11(WGN4). Thus, some (ultra)mafic samples have high RCO_2 but require high acid quantities and/or aggressive leach conditions for dissolution, but other minerals, such as chlorites and amphiboles, have limited dissolution regardless. Therefore, RCO_2 evaluations and optimisation of site-specific leaching conditions for (ultra)mafic materials should prioritise cation leach rates over theoretical maxima.