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The Effects of Iron on Olivine Utilization for Simultaneous CO_2 Storage and Nickel Extraction

YING WANG AND YOUNG-SHIN JUN

Washington University in St. Louis

Presenting Author: w.ying@wustl.edu

CO_2 emissions pose a significant global challenge with adverse environmental, human health, and economic impacts. Simultaneously, a shortage of critical elements intensifies concerns over resource depletion of high-quality ores amid escalating demands. Combining CO_2 mineralization with the recovery of critical elements (e.g., Ni) from low-grade ores, such as mafic and ultramafic rocks, presents a promising solution to both problems. Olivine, a magnesium-rich silicate with small amounts of critical elements, is widely used to capture and store CO_2 through carbonation, forming magnesium carbonate ($MgCO_3$). However, in its natural state, olivine often contains impurities such as iron (Fe), whose percent content is much higher than that of Ni. This preponderance of Fe can lead to the formation of iron (hydr)oxides on the surface of unreacted olivine, decreasing the dissolution of Ni and Mg and further reducing carbonation and critical element recovery. This research examined Ni dissolution from San Carlos olivine at high temperature (T) and high CO_2 pressure (P). The findings indicated that iron oxide (hematite) layers impeded the olivine's dissolution during high T and high P processes. To address this issue, we introduced sodium dithionite ($Na_2S_2O_4$) as an effective reducing agent, significantly improving the dissolution rate of Ni from olivine by preventing iron(III) oxide secondary mineral formation. In a system with $Na_2S_2O_4$, no iron oxide formed on the olivine surface, increasing Mg dissolution by 2.85 times and increasing Ni dissolution by 2.66 times within 24 hours compared to a system without $Na_2S_2O_4$. Furthermore, our findings indicated that after seven cycles of reaction (one cycle consisting of replacing the solution with fresh sodium dithionite solution every 24 hours), we recovered 85.8% of the total Mg and 78.2% of the total Ni. Our results demonstrated an efficiency comparable to the 40–50% recovery efficiencies reported for both Mg and Ni in processes at 50°C with the addition of 1 M HCl, for 120 minutes. This approach enhances olivine's CO_2 mineralization potential, and it holds promise for other mafic and ultramafic minerals, such as pyroxene. It also contributes to developing more sustainable carbon capture methods and new strategies for recovering critical elements from low-grade ores.