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Assessment of Transcritical CO_2 Cycling as a Coupled Comminution-Carbonation Strategy for Ore Processing

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Achieving global net-zero emissions requires both effective carbon dioxide removal methods and sustainable efficient approaches to critical mineral extraction. Although mineral deposits hosted in ultramafic rocks supply critical metals essential for renewable energy technologies, their processing relies on energy-intensive mechanical comminution that may offset anticipated decarbonization gains. A novel approach using transcritical carbon dioxide ($tscCO_2$) cycling, developed by Rockburst Technologies' CoreBurst™, offers an alternative pathway for simultaneous rock fragmentation and carbon mineralization. However, the mechanisms by which $tscCO_2$ initiate fracture propagation, mineral liberation, and reaction pathways remain incompletely understood.

To address this gap, we conducted a series of comminution experiments on samples of nickel-bearing ores hosted in ultramafic rocks in the presence of a CO_2-rich working fluid under varying conditions (40-80°C, 90-190 bar). Mineral liberation efficiency and selective breakage were compared with conventional mechanical comminution using rod-milling. Pre- and post-treatment samples were characterized using electron microscopy and X-ray diffraction to quantify changes in mineralogy, grain boundary exposure, and reaction products. Our results demonstrate enhanced preferential breakage along mineralogical boundaries, leading to significantly improved liberation of critical mineral phases, up to 30% higher than mechanical methods. We also observed carbonation reactions in tailing minerals during comminution, indicating simultaneous mineral trapping of CO_2. Microstructural observations suggest that penetration of the transcritically-cycled fluid promotes fracture propagation along reactive grain boundaries, thereby coupling comminution and mineralization.

These findings present a pathway for reducing energy consumption in processing of critical minerals ore, while enabling selective critical mineral recovery alongside permanent carbon sequestration, linking resource extraction with climate mitigation objectives.