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Accelerated CO_2 Mineralization: Unlocking Mineral Harvesting for Scalable Ex-Situ Carbon Sequestration

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The applicability of ex-situ CO_2 mineralization as a carbon disposal process is currently hindered by slow reaction rates. To overcome this limitation, we have developed a scalable acid treatment process to enhance the carbonation rate of basalt and other silicate materials, providing a more efficient and scalable pathway for permanent carbon sequestration. This approach takes advantage of the dramatic increasing dissolution rates of silicate minerals with decreasing pH. By controlling fluid chemistry and reaction parameters, basalt dissolution can be accelerated by orders of magnitude. This allows for separation of the original basalt into distinct metal rich solids and aqueous fluids. Notably, this increases the availability of calcium and magnesium for CO_2 mineralization, while simultaneously enabling harvesting of distinct metal oxides from the original rock, including silicon, aluminum and iron oxy-hydroxide minerals, that can be used in other industrial processes for additional value. The released calcium and magnesium can then be carbonated to efficiently precipitates stable carbonate minerals such as calcite and hydromagnesite. Consequently, this approach not only provides for more efficient ex-situ mineralization but also provides additional income streams by unlocking valuable mineral byproducts. Figure 1 presents images of the basalt used in this study, sourced from Harrat Rahat in Saudi Arabia, alongside the mineralized carbonate products, the Al-rich byproduct, and the reacted basalt residue. The reacted basalt, having undergone partial dissolution, retains structural integrity and can be repurposed as a concrete filler, further expanding the industrial applications of this process.

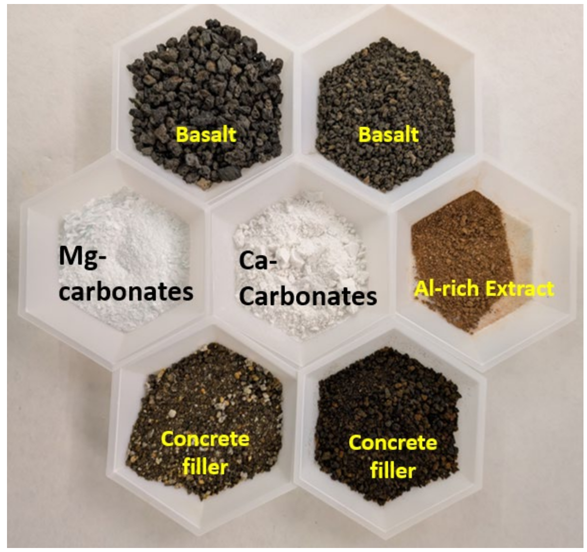

Figure 1: Basalt from Harrat Rahat, Saudi Arabia, before and after accelerated ex-situ mineralization. The initial basalt sample (top) undergoes acid-enhanced dissolution, yielding distinct solid byproducts: stable carbonate minerals, an Al-rich precipitate, and partially reacted basalt residue. The mineralized carbonates (center-left) represent permanent CO_2 sequestration, while the Al-rich byproduct (center-right) can be repurposed for industrial applications. The reacted basalt (bottom) retains its structural integrity and can be used as a concrete filler, further enhancing process sustainability.