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Grain scale investigation of olivine dissolution: Uncertainty in dissolution rate calculation

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Olivine ($(Mg, Fe)_2SiO_4$) is one of Earth's most abundant minerals and has received significant attention as a potential feedstock for enhanced silicate weathering (ESW), a technique for reducing atmospheric carbon dioxide (CO_2). The dissolution rate of olivine is typically estimated by analyzing water chemistry or tracking changes in grain size distribution over time. However, these methods may have limitations due to: (1) the natural abundance of Mg^{2+} and silica in seawater, which might hinder the measurement of those cations released from olivine dissolution; (2) the estimation of dissolution rates from grain size distribution changes between time steps ignores mineral characteristics such as geometry and reactive surface area. To address this, we present multi-grain olivine (grain pack) investigations during dissolution using laboratory X-ray micro-computed tomography. The dissolution was conducted by subjecting the olivine grain pack to acidic 1M HCl solutions for 66 hours while imaging at four-time steps (0 hours, 20 hours, 42 hours and 66 hours). Using image processing of the 3D reconstructed olivine grain pack, each grain was tracked over the dissolution experiments and the dissolution rates were calculated using four different approaches: (1) global dissolution rates (r_{glob}), which calculate the entire grain volume difference over time and normalize to the surface area of those grains; (2) individual dissolution rates (r_{indv}), which is similar to the bulk dissolution rates, yet calculated for each grain; (3) equivalent diameter dissolution rates (r_{eq}), which mimic the dissolution rates calculation from the changes of grain size distribution; and (4) the local dissolution rates (r_{loc}), which tracked the surface retreat of each grain over the dissolution experiment. Results showed that all calculated rates were within the same order of magnitude but with varying uncertainties, with the equivalent diameter dissolution rates (r_{eq}) having the highest uncertainty. Additionally, the result will be applied to a dissolution model and compared with an ongoing CESW experiment. This investigation highlights the importance of uncertainty considerations in dissolution rate measurements and contributes to the monitoring, reporting and verification (MRV) of CESW applications.