Quantifying micron-scale grain detachment during weathering experiments on limestone

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Weathering in carbonate rocks is often assumed to be governed by chemical dissolution. However, mechanical processes can also contribute to carbonate weathering by fracturing the rock into smaller fragments. Such processes can even extend down to the micron-scale, with small grains undergoing partial dissolution, followed by detachment from the rock surface, thereby accelerating overall weathering rates. Although this process could be crucial for the understanding of carbonate weathering at the global scale, the role played by grain detachment is poorly understood. To quantify the contribution of grain detachment to surface retreat rates, and to determine the impact of the flow regime, we carried out a series of simulated weathering experiments on micritic limestone. Using atomic force microscopy, we obtained high resolution in situ data of surface topography for reacting rock surfaces. In all the experiments, both grain detachment and chemical dissolution were observed. However, in the laminar conditions we explored in this study we found no clear correlation between the flow rate and detached grain size, or between the flow rate and the frequency of grain detachment events. Importantly, our results establish that grain detachment contributes significantly to the overall surface retreat, on average accelerating mass loss by 38 ±16% (1σ). In addition to speeding up weathering, this micron-scale mechanism could also influence the evolution of porosity in aquifers and hydrocarbon reservoirs, and provide a natural flux of colloids that could transport heavy metals or radionuclides in groundwater.