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Stochastic characterization of calcite dissolution rate from in-situ and real-time AFM imaging

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Carbonate dissolution processes are key in many environmental areas as well as in the industrial sector. In subsurface environments, a detailed knowledge of mineral dissolution/precipitation kinetic rate laws is a critical component in the context of, e.g., aquifer contamination assessment, geologic carbon sequestration, toxic waste disposal, or hydraulic fracturing of hydrocarbon reservoirs. The recent employment of advanced measurement instruments such as Atomic Force Microscopy (AFM) and Vertical Scanning Interferometry (VSI) enables direct observations of the mechanisms occurring on the mineral surface during the reaction, providing evidence that the dissolution process is strongly affected by several sources of variability at the local (i.e., micro-scale) mineral-fluid interface. In this context result, marked spatial heterogeneities in the dissolution rate are documented. Therefore, a change of perspective towards a quantification based on a stochastic approach is of primary importance. We propose to employ geostatistical tools to characterize the spatial heterogeneity of dissolution rate maps obtained from in-situ and real-time AFM imaging. We collect datasets of the surface topography of a millimeter-scale calcite sample subject to dissolution, from which we evaluate reaction rate maps. Our work is aimed at (1) characterizing the statistical behavior of topography and dissolution rate data and their spatial increments; (2) identifying an appropriate interpretive model for such statistics; and (3) evaluating quantitatively, through observed trends of model parameters, the temporal evolution of the spatial heterogeneity of reaction kinetics.