Progress towards a universal chemical alteration mechanism: coupled interfacial dissolution-reprecipitation (CIDR)

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The chemical alteration and weathering of minerals and glasses play a key role in System Earth with respect to CO_2 and the global terrestrial carbon cycle, the chemistry of aqueous fluids ranging from the pore scale to oceans, water-rock interactions in the lithosphere, and element fluxes in the critical zone. It is also important in terms of environmental and industrial processes, such as the production of soils, acid mine drainage, contaminant cycling, geological storage of nuclear waste, and CO_2 sequestration and trapping. Modeling and quantitative prediction of these processes at the macroscale require precise knowledge of the molecular-scale mechanisms that control alteration. Over the past two decades there has been a lively debate within the earth and material sciences communities about whether traditional theories still hold, or alternatively, if it is time to consider new ideas. In a nutshell, the crucial point revolves around the question whether it is chemical reactions or diffusion that ultimately control alteration.

In this talk I will review studies from the recent literature which highlight the role that advanced state-of-the-art methods and analytical techniques have played in the development of a new theory that decribes the alteration process of both minerals and glasses: coupled interfacial dissolution-reprecipitation (CIDR). This theory is based on a tight spatial and temporal coupling between a chemical dissolution front, where all elements are stoichiometrically released, and the reprecipitation of a secondary phase within a thin fluid film at the interface. CIDR is distinctly different from a classical precipitation process that is controlled by the degree of chemical oversaturation of a bulk fluid. The key to the analytical measurements that underpin CIDR are techniques that provide either exceptionally high spatial and/or mass resolution. New data that supports CIDR have been obtained by a variety to techniques, such as advanced TEM techniques (HRTEM-STEM-EFTEM-EELS, liquid cell TEM), atom probe tomography, atomic force microscopy and fluid cell Raman spectroscopy. Data based on these techniques are not compatible with the tradtional idea of diffusion-controlled chemical alteration.