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Effect of bacteria and dissolved organics on mineral dissolution kinetics:

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Quantification of the effect of microorganisms and associated organic ligands on mineral dissolution rate is one among the last remaining challenges in modeling of water-rock interactions under earth surface and subsurface environments. This is especially true for deep underground settings within the context of CO2 capture, sequestration and storage. First, elevated CO2 pressures create numerous experimental difficulties for performing robust flow-through experiments at a given saturation state. Second, reactivity of main rock-forming minerals in abiotic systems at pCO2 » 1 atm and circumneutral pH is still poorly constrained. And third, most of microbial habitats of the subsurface biosphere are not suitable for routine culturing in the laboratory, many of them are anaerobic and even strictly anaerobic, and many bacteria and archae cultures can live only in the consortium of microorganisms which is very hard to maintain at a controlled and stable biomass concentration.

For experimental modeling of bio-mineral interactions in the laboratory, two other main conceptual challenges exist. Typical concentration of dissolved organic carbon that serves as a main nutrient for heterotrophic bacteria in underground waters rarely exceeds 3-5 mg/L. Typical concentration of DOC in nutrient media used for bacteria culturing is between 100 and 10,000 mg/L. Therefore, performing mineral-bacteria interactions in the laboratory under environmentally-sound conditions requires significant dilution of the nutrient media or the use of flow-through reactors. Concerning the effect of organic ligands and bacterial excudates on rock-forming mineral dissolution, at the present time, mostly empirical (phenomenological) approach can be used. Indeed, the pioneering studies of Stumm and co-workers have established a firm basis for modeling the catalyzing and inhibiting effects of ligands on metal oxide dissolution rate. This approach, very efficient for studying the interaction of organic and inorganic ligands with trivalent metal oxides, is based on applying multiple spectroscopic techniques allowing to reveal the chemical structure of adsorbed complexes. However, due to i) low surface area of most rock-forming minerals (carbonates, non-clay silicates), ii) difficulties of applying surface spectroscopic techniques at elevated pressures, and iii) very complex nature of bacterial exometabolites, it is not possible at the present time, to use rigorous surface complexation approach for rationalizing ligand- and bacteria-affected mineral dissolution under sub-surface CO2 storage environment. In this work, we present examples of overcoming these difficulties via concerted study of olivine, wollastonite and calcite interaction with heterotrophic bacteria and methanogenic archaes.