

Probing stabilization mechanisms at the soil organic-mineral interface at the molecular length scale.

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Soils store more carbon than the atmospheric and vegetative pools combined. Understanding the dynamics of this carbon pool in the carbon cycle is crucial to both predicting climate and sustaining ecosystem services, however to date a detailed description of the stabilization mechanisms of soil organic carbon (SOC) in soils is lacking. Recent studies have demonstrated that soil geochemistry has a significant impact on SOC storage, suggesting that organic-mineral interactions control carbon lifetimes. In this study, we probe the organic-mineral interface using model interactions that will allow us to build complexity systematically. Using dynamic force spectroscopy, we make and break bonds between model organic molecules and mineral surfaces, which allows us to mechanistically probe the energy landscape of organic-mineral interactions. We demonstrate the ability to measure the binding free energy of interactions between organic functional groups and model mineral surfaces as a function of solution chemistry. In particular, at ambient pH, we discovered that acidic functional groups exhibit the highest binding free energy when interacting with a mica surface. The strength of binding increases at lower ionic strength and low pH, suggesting that hydrogen bonding may play a significant role in acid-SOM sorption to negatively charged clay surfaces. In contrast, amine functional groups bind more strongly to goethite. Both mineral surfaces, despite their different chemistries, demonstrate differences in binding with changes in ionic strength, providing implications for SOM stability in drier conditions due to climate change.