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A Friend or a Foe: Role of Minerals in the Organic Carbon Dynamics and the C-Cycle

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Organic carbon (OC) dynamics in soils and sediments is strongly influenced by their mineral composition and abundance. Through adsorption, minerals are considered to retain and protect OC from the microbial attack and thus influence the C-cycle in these systems. The magnitude of OC adsorption by minerals varies with its composition, surface area and chemistry. Laboratory and field studies showed that certain minerals are considered to play a more important role than the others. Yet little is known about the role of minerals in the OC breakdown.

We tested mineral-dissolved OC reactions for ~180 days and characterized the reactions in this time span using FTIR, luminescence and XANES spectroscopies, and mass-spectrometry (FT-ICR ESI-MS/Orbitrap). Minerals considered are quartz, calcite, 1:1 clay (kaolinite), 2:1 clay (smectite), Fe-oxide (goethite), Al-oxide (boehmite), and a disordered Al-silicate (allophane), which represent diverse soil and sedimentary environments.

The results suggest that the magnitude and kinetics of sorption vary significantly among these different minerals. Quartz and calcite retained relatively less OC, while Fe-/Al-oxides retained the highest, with clays and disordered Al-silicates in between. OC adsorption was also faster for Fe-/Al-oxides, where the majority of adsorption was complete within 24 h with a slow adsorption continued into 6 months. Clay minerals began with a slow adsorption in the first 150 h, but their adsorption kinetics were faster after.

Molecular studies reveal a strong fractionation of OC during mineral adsorption, and it is influenced by the mineral surface chemistry and reaction time. Major differences for mineral sorption were observed for the condensed aromatics, less-conjugated aromatics, and unsaturated aliphatic compounds at short-time scales. However, adsorption of aromatics continued over longer time scales for all minerals. Interestingly, we also observed mineral induced catalytic breakdown of selected OC, where ring-opening and oxygenation was common.

A summary of these results suggests that sorption in the initial stages is supported by the pristine mineral surface characteristics, and subsequent reactions are influenced by the initial (in)organic-coatings on mineral surfaces. A discussion on how these findings influence the OC cycle in different terrestrial environments will be presented.