The soil matrix: visualizing and quantifying microscale associations of organic and mineral components

Soil structure is resulting from soil forming processes involving organic and mineral materials at the molecular scale, and determines major soil functions. In this context soil organic matter is not only of importance as a carbon sink, but also as agluing agent for soil structure. The spatial distribution of elements characteristic of organic matter (e.g., C or N) and minerals (e.g., Fe, Al, O, or Si) in soils and sediments at the submicrometer scale is of special interest for the identification of key biogeochemical processes, such as C sequestration. Nanoscale secondary ion mass spectrometry (NanoSIMS) delivers high lateral resolution and the simultaneous measurement of seven ionic species and provides insights into the microstructure of soils and organo-mineral associations. Specific image processing approaches are presented that allow to map different soil components and to elucidate their association within the soil microstructure: Visualization of element distributions in rhizosphere transects from the surface of root channels into the soil matrix allows distinguishing different zones of organo-mineral interactions in a paddy soil. Two types of micrometer-sized domains, each characterized by a specific micro-architecture with a definite organo-mineral assemblage are identified within an aggregate originating from an arable loamy topsoil. A chronosequence study reveals increased coverage and a simultaneous development from patchy-distributed organic coatings to more connected coatings with increasing time of soil development.