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Elucidation of 3D Chemical and Physical Architecture of Soil Microstructures by Correlating Spectro-Microscopic Techniques and Developing Novel Computational Methods

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Soils represent a heterogenous dynamic system consisting of a variety of mineral and organic components of different sizes and composition. Soil microaggregates of sizes < 250 μm are the most important entity of association between organic matter (OM) and mineral constituents as they are involved in organic carbon (OC) sequestration processes, i.e. the incorporation and storage of OC, in soils [1]. Detailed representations of these soil microstructures and their chemical distribution are needed to find preferable sites for OM deposition which is essential to study biogeochemical processes at relevant spatial scales. Correlating microscopy and spectroscopy techniques allows thus to provide the required complementary information, at both high resolution and high sensitivity.

Soil samples were enriched here with isotopic carbon (^{13}C) in an incubation experiment to trace the fate of the freshly introduced OC with respect to the inherited OM (^{12}C, ^{14}N) [2]. A correlative 3 + 1 dimensional method was used to link 3D structural surface with 1D chemical information (Figure 1) [3,4]. Hence, first a 3D surface reconstruction of a soil microaggregate was created with a photogrammetry approach from partially overlapping Secondary Electron (SE) images. Chemical maps were obtained by Secondary Ion Mass Spectrometry (SIMS) analyses on the same microaggregate and projected onto the 3D SE surface model. The final 4D model was then processed numerically to find preferable topography sites for OM deposition on the microaggregate's mineral phase.

In this contribution, traditional 2D and novel 4D correlative workflows will be presented, specifically for soil biogeochemical applications. Furthermore, we will show a processing method to statistically evaluate the topography by local curvature variations at fresh and inherited OM hotspots to learn more about the microscale OC sequestration process [5].

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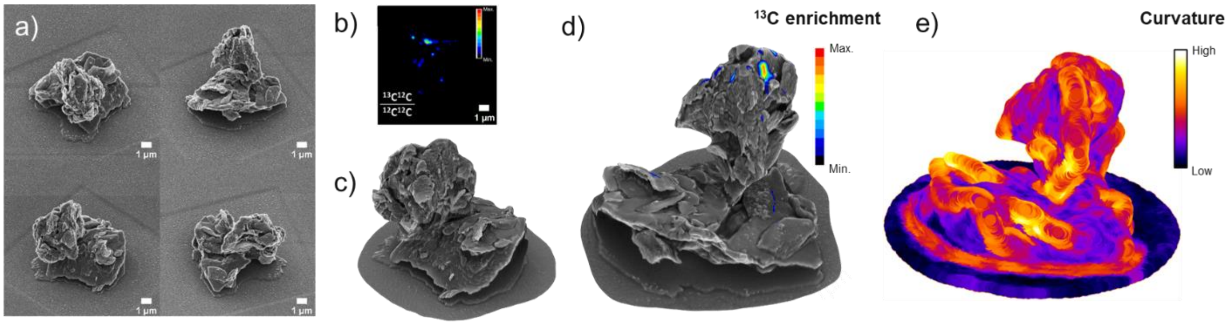

Figure 1. 3D + 1D surface reconstruction workflow of a soil microaggregate enriched with ^{13}C. a) Sequential SE image acquisition around the soil microaggregate (35 images in total). b) SIMS ratio image ($^{13}C/^{12}C$) showing the enrichment in ^{13}C. c) 3D SE surface reconstruction using the images in a). d) 3D + 1D surface reconstruction obtained by overlaying the SIMS image in b) with the 3D surface model in c). e) Illustration of local curvature information obtained from the 3D SE model in c) used to find preferable topographical sites for OM deposition.

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