Potential of visualisation methods to further our understanding of soil organic matter dynamics

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In the light of the expected future climate change, soil organic matter decomposition and its possible feedback to CO_2 concentrations into the atmosphere has recently received considerable interest. The magnitude of this effect and differences among soils are uncertain due to the inherent complexity of soils that are structurally heterogeneous across a wide range of spatio-temporal scales. In terms of understanding of CO_2 feedback mechanisms, fundamental approaches which explicitly recognise the complexity of soils and the spatial organisation of their constituents are necessary in order to further our understanding of soil organic matter dynamics. A major obstacle to progress is the lack of techniques of adequate sensitivity and resolution for data collection needed to further our understanding of soil organic matter dynamics at relevant scales.

Contemporary visualisation methods are providing new insights into the spatial organisation of pore networks and location of micro-organisms within the fabric of the soil [1]. Recently, secondary ion mass spectrometry (SIMS) has received much interest from soil scientists to explore the biophysical interface in soils. This innovative approach [2] provides a hitherto unavailable means to evaluate links between the heterogeneous architecture of the soil matrix and the location of microbial activity at scales at which soil processes are mediated (nano- and micro-scale, i.e. molecular and microbial) [3]. We will present our recent findings illustrating the capacity of the latest technology available in microscopy and isotope detection, including optical fluorescent microscopy and SIMS, to improve our fundamental understanding of soil organic matter turnover. Particularly, practical considerations in the use of these techniques with respect to experimental design and sample preparation will be emphasized.

[1] Nunan et al. (2003) FEMS Microbiol. Ecol. 44, 203-215. [2] Herrmann et al. (2007) Rapid Comm. Mass Spec. 21, 29-34. [3] Herrmann et al. (2007) Soil Biol. & Biochem. 39, 1835-1850.

Natural organic matter and the event horizon of mass spectrometry

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Soils, sediments, freshwaters and marine waters contain natural organic matter (NOM) - an exceedingly complex mixture of organic compounds that collectively exhibit a nearly continuous range of properties (size-reactivity continuum). Ultrahigh resolution Fourier transform ion cyclotron (FTICR) mass spectra of NOM reveal several thousand molecular formulae, corresponding in turn to several hundred thousand distinct chemical environments of carbon even without accountancy of isomers.

The degree of complexity of NOM can be brought into sharp focus through comparison with the theoretical limits of chemical complexity, as constrained and quantized by the fundamentals of chemical binding [1]. Throughout a sizable range of mass, H/C and O/C elemental ratios, the molecular formulae within NOM attain one-hundred percent of the theoretical C,H,O-compositional space which denotes the isomer-filtered complement of the entire, very vast space of molecular structures composed solely of carbon, hydrogen and oxygen. The method-dependent selectivity of the ionization process suggests that the observed mass spectra represent simplified projections of still more complex mixtures.

[1] Hertkorn et al. (2008) Anal. Chem., 80, 8908-8919.