**Pore- to Core-Scale Research to Inform Ecosystem-Scale Soil C Biogeochemistry**

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The spatial separation of substrate, microbes, and extracellular activity is an important mechanism of soil organic carbon (SOC) protection in soils, and one that is difficult to represent in predictive models at any scale. Macropore networks and their connectivity control microbial access to physically protected C in soils*.* Under conditions of partial to full water saturation, potentially labile compounds can desorb and diffuse from micropore domains to macropore networks to locations accessible to microorganisms. Therefore, the quality of the SOC in pore waters held with different tensions is a key characteristic needed to differentiate physical and chemical SOC protection mechanisms. The decomposability of this C is needed to determine the potential contribution of this protected C pool to net GHG fluxes as the protection mechanism breaks down through changing local environmental conditions.

We have studied intact soil cores collected from the Disney Wilderness Preserve, FL (DWP). Water dynamics in this system, particularly water table rise and fall, appear to be a strong control on the emissions of C-gases and the persistence of soil organic matter in these soils. Soils at DWP are dominated by sandy textures, and depending local topographic position, show moderate to high levels of SOM accumulation at the surface. Samples of soil pore water held at two different water tensions (15, 500 mb) were collected from three continuous-depth DWP soil cores (0-30, 30-60, and 60-90 cm), from three transect locations (dry, intermittently wet, and wet). The more tightly held pore waters (500 mb) had significantly more condensed hydrocarbons and tannins compared to the more loosely held water (15 mb), which had significantly more lipids (Fig 1). These differences were consistent for all three transect positions, and all three soil depths. These pore waters were then used as growth substrates for cultivation of selected bacteria (*Streptomyces cellulosae, Cellvibrio japonicus*) and fungi (*Trichoderma reesei*). For all organisms, significantly more CO2 was respired from the higher-tension pore waters characterized by the more complex C compounds. If mobilized, SOC that is protected in isolated soil pores is biologically available and would contribute to the net greenhouse gas fluxes we currently seek to minimize.

**Intro/Background**

The spatial separation of substrate, microbes, and extracellular activity is an important mechanism of soil organic carbon (SOC) protection in soils, and one that is difficult to represent in predictive models at any scale. Macropore networks and their connectivity control microbial access to physically protected C in soils.Under conditions of partial to full water saturation, potentially labile compounds can desorb and diffuse from micropore domains to macropore networks to locations accessible to microorganisms. Therefore, the quality of the SOC in pore waters held with different tensions is a key characteristic needed to differentiate physical and chemical SOC protection mechanisms. The decomposability of this C is needed to determine the potential contribution of this protected C pool to net GHG fluxes as the protection mechanism breaks down through changing local environmental conditions.

**Objective: Identify distribution, quality and bioavailability of SOC located in soil pores.**

**Approach**

Intact soil cores from three continuous depths (0-30, 30-60 and 60-90 cm) at three transect locations (dry, intermittently wet, and wet) were collected from the Disney Wilderness Preserve, FL (DWP). Soil pore water was extracted at different water tensions (15, 150 and 500 mb) representing water held in pores of different sizes (approximately 150-, 10- and 3 μm pore diameters). Fourier transform ion cyclotron resonance (FTICR) mass spectrometry was used to characterize C chemistry from the pore water following extraction.

Filter-sterilized pore water (15, 150 mb) was used as growth substrates for select cellulolytic bacteria and fungi in order to determine its degradation potential (or substrate bioavailability) in a short-term incubation. CO2 was measured at hours 2, 4, 8, 16, 24, 36, 48, and then every 24 hours for a total of 8 days on a PP systems EGM-4. Dissolved carbon and nitrogen and C structure via FTICR was measured pre- and post-incubation to determine microbially-mediated transformations in the quantity and quality of carbon compounds.

Select Microorganisms:

Cellvibrio japonicus (DSMZ 16018) gram-negative

Streptomyces cellulosae (ATCC® 25439™) is a cellulolytic (gram-positive) actinobacteria from soil

Wild-type Trichoderma reseei (QM6a) - asexual spores (not yet germinated or no conidia development)

**Results**

1. “Greater C complexity in soil water from fine pore domains”
   1. Quality of C differs between pore water from different domains: FT-ICR profiles of pore water separate along axes 1 and 2 by pore water domain (p < 0.05). **Figure 1**.
   2. Condensed hydrocarbons, lignin and unsaturated hydrocarbons explain the majority of the variation along axes 1, 2, and 3 respectively (**Table 1**).
   3. Pore water sampled from the finest domain (-500 mb pressure) was relatively enriched in tannins and condensed hydrocarbons. Pore water sampled from the largest domain (-15 mb pressure) were dominated by lipids. (**Figure 2**).
2. Soil water from finer domains has a greater degradative potential
3. Respiration of C differs between pore water from different domains
   1. For all inoculants (bacterial and fungal) after an initial lag more C was respired from the pore water pulled from finer domains (150 mb) than larger domains (15 mb). (**Figure 3**).
   2. Trichoderma (fungal inoculant) respired a greater amount of C relative to both bacterial inoculants.

**Ecosystem-Scale Soil C** (implications)

* This research will develop a mechanistic understanding of the chemical and biological processes associated with the balance between C protection and metabolism in structured environments.
* New knowledge could include the role of water saturation*,* or key classes of C compounds, or new model parameters in describing for C transfer from protected to labile pools under definable conditions
* We will test whether this new knowledge improves ecosystem-scale models under changing conditions.
* Develop a reaction network to represent pore- to core-scale biogeochemical processes that control the degradation of SOC, CO2 and CH4 production and CH4 transformation to CO2 in soils by incorporating experimental results and mechanistic insights from Task 2. ***Comparison of core-scale and ecosystem-scale models***
* The mechanism-based biogeochemical kinetic models of SOC degradation that explicitly consider metabolic reactions and pathways and organic carbon speciation will be compared with the empirical first-order kinetic models typically used for ecosystem simulations (Subtask 1.2). This comparison is to provide mechanistic insights into the parameters and model structures used in the ecosystem models, and to establish functional relationships linking the empirical parameters in the first-order models with the parameters and variables in the mechanism-based biogeochemical models. Sensitivity analyses, for example, by varying concentrations of different organic carbon speciation in the mechanism-based models, will identify the relative importance of the mechanistic variables to the parameters in the ecosystem models. The insights gained and the functional relationships established from this comparison will be used to improve the ecological models either by explicitly incorporating the functional relationships or establish new variables to account for them in the reaction-based CLM (Subtask 1.3).
* New knowledge could include the role of water saturation*,* or key classes of C compounds, or new model parameters in describing for C transfer from protected to labile pools under definable conditions

**Future Work**

* Enzyme activity of pore waters
* Broad- and high-resolution descriptions of SOC chemistry in particulate, mineral-associated C fractions
* Measuring and modeling how changes in hydrologic cycling alter C availability and GHG emissions at the pore and core scale. principal
* **The overarching science objective of the proposed work is to develop the mechanistic understanding of how soil carbon in protected locations is metabolized as a result of pore-scale changes in SOC bioavailability, and to test that understanding for improving the predictive power of ecosystem models.**

*“Tri*[choderma reesei](http://en.wikipedia.org/wiki/Trichoderma_reesei) *is a haploid filamentous fungus from the phylum* Ascomycota*. It is of industrial significance due to its production of cellulytic enzymes that can be used for conversion of plant biomass into glucose” “T. reesei has the capacity to secrete large amounts of* [*cellulolytic*](http://en.wikipedia.org/wiki/Cellulolytic)[*enzymes*](http://en.wikipedia.org/wiki/Enzyme) *([cellulases](http://en.wikipedia.org/wiki/Cellulase" \o "Cellulase) and* [*hemicellulases*](http://en.wikipedia.org/wiki/Hemicellulase)*).*

<http://genome.jgi-psf.org/Trire2/Trire2.home.html> picture credit

<http://www.genome.jp/kegg-bin/show_organism?org=cja> (Cellvibrio KEGG)

<http://www.genome.jp/kegg-bin/show_organism?org=tre> (Trichoderma KEGG)

Carbon is transported

Terrestrial and aquatic systems are connected by the transportation/pathway of dissolved organic matter (DOM).

Sorbed and desorbed

Soils are a main source of DOM, an important component of the global carbon cycle and main C and energy source for microbial life in aquatic systems…

DOM, an important component of the global coarbon cycle and main C and energy source for microbial life in aquatic systems often begins in path to rivers and oceans in soils. DOC be sorbed, desorbed, transformed or mineralized in soils

DOC plays a principal role in the global carbon cycle

Water-soluble carbon is often considered an accessible

Soluble carbon located in protected pore domains (pore size diameters under –

Microbial uptake

DOM is often considered labile, but can be protected in small pore spaces and thus, be unavailable for uptake by soil microorganisms.

DOM biodegradability

Water-soluble organic matter

**Biodegradation properties of soluble organic matter in soil pore water from different pore size domains..or from macro- and micropores.**

**Increased biodegradation of soluble organic matter from protected locations in soils..or from micropores**

**Authors:** Smith, Bailey, need other TES PIs?, Malak,

**Abstract** (300 words)

Dissolve organic matter (DOM), or water-soluble carbon (C), is often considered the most bioavailable form of soil C and is an important component in the global carbon cycle. Mineralization of DOM is determined in part by its molecular composition and its location in the soil matrix. DOM protected in fine pore domains may be potentially labile compounds, but may not be accessible to microorganisms. Identifying the composition and biodegradability of DOM located in physically protected and unprotected pore spaces is important to our overall understanding of its contribution to soil CO2 emissions and C stabilization. The objective of this study was to determine the biodegradation potential of soluble DOM located in large, unprotected pore domains and in fine, and thus occluded, pore domains. Intact soil cores from three continuous depths (0-30, 30-60 and 60-90 cm) at three transect locations (dry, intermittently wet, and wet) were collected from the Disney Wilderness Preserve, FL (DWP). Soil pore water was extracted at different water tensions (-15, and -150 mb) representing water held in pores of different sizes (approximately 150- and 10 μm pore diameters). In order to determine the biodegradability of the extracted DOM, we used it as growth substrates for select cellulolytic bacteria and fungi (*Streptomyces cellulosae, Cellvibrio japonicus*, and wildtype *Trichoderma reesei)* in a short-term incubation. We measured changes in dissolved organic carbon and nitrogen (DOC/N), and the composition of DOM using Fourier transform ion cyclotron resonance (FT-ICR) mass spectrometry coupled with Electrospray ionization (ESI) pre and post incubation to determine microbially-mediated transformations in the quantity and quality of carbon compounds. We also recorded evolved CO2 regularly over the incubation (8 total days).

Preliminary analyses show that DOM located in micropores was relatively enriched in tannins and condensed hydrocarbons, whereas macropore-associated DOM was composed of relatively more proteins and lipids. Shifts in composition of DOM following the incubation was characterized by an enrichment in lignin, tannins and condensed hydrocarbons in the macropore-associated DOM compared to the macropore-associated DOM, which became relatively depleted in tannins. Following an initial lag, total evolved CO2 was greater in pore water extracted from fine pore domains compared to the large pore domain extracted soil water for all inoculants. Overall, results show that the DOM located in protected pore domains, while considered more complex ( or more recalcitrant or slower to degrade), was more readily decomposed than the macropore-associated DOM. This suggests that if mobilized, DOM originally located in physically protected pore domains, it may have a greater contribution to greenhouse gas production that previously perceived.

..or I could see ending with (copied from the poster):

Identifying the composition and degradation potential will inform reaction-based models that link decomposition processes and hydrodynamics to the breakdown of protected soil C

Water soluble carbon, or DOM, is an important component in global C cycle (considered labile, but if protected – it is not degraded/accessible, microbes depend on water for basic metabolic uptake reactions, Water, Dom is how sC moves through both terrestrial and aquatic systems- therefore it is important for understanding the pathway of C in soils and how it contributes to GHG production and the stabilization of C in soils. DOM is also a significant substrate for microbes – water necessary for diffusion of substrates through cell walls.

-composition of DOM can control its biodegradability and its location in the soil matrix controls its bioavailability.

Soil cores were collected

Results show that the DOM located in protected pore domains while considered more complex, and thus more recalcitrant (or slower to degrade), was more biodegradable than the macropore-associated DOM.

To understand the contribution of DOM

Bioavailability – “potential of microorganisms to interact with substances” Marschner and Kalbitz, 2003

Biodegradability – “actual utilization” - mineralization (CO2 production) and transformation of DOM composition.

Water-soluble organic matter, simplified as DOM.

Changes in the quality of DOM from the

Understanding ability/capability of soil microorganisms to mineralize

Extract soil water from both physically occluded pore domains (fine pores approx. 10 μm diameter) and from larger, physically unprotected pore-size domains (pores approx. 150 μm diameter).

Physically unprotected/available/

Occlude/protected/

Turnover of DOM in the form of water-soluble C is an important component of the global carbon cycle, and is determined in part by its molecular composition and location in the soil matrix. DOM protected in fine pore domains may be potentially labile compounds, but may not be accessible to microorganisms. The objective of this study was to determine the biodegradation potential of soluble DOM located in large, unprotected pore domains and in fine, and thus occluded, pore domains.

Mineralization of DOM is determined in part by its molecular composition and its location in the soil matrix (or accessibility for microorganism). Therefore,

Preliminary results

Intact soil cores from three continuous depths (0-30, 30-60 and 60-90 cm) at three transect locations (dry, intermittently wet, and wet) were collected from the Disney Wilderness Preserve, FL (DWP). Soil pore water was extracted at different water tensions (-15, and -150 mb) representing water held in pores of different sizes (approximately 150- and 10 μm pore diameters). Fourier transform ion cyclotron resonance (FTICR) mass spectrometry was used to characterize C chemistry from the pore water following extraction. In order to determine the biodegradability of the DOM, we filter-sterilized the extracted pore water and used it as growth substrates for select cellulolytic bacteria and fungi in a short-term incubation. We measured changes in dissolved organic carbon and nitrogen (DOC/N), and the composition of DOM using Fourier transform ion cyclotron resonance (FT-ICR) mass spectrometry coupled with Electrospray ionization (ESI) pre and post incubation to determine microbially-mediated transformations in the quantity and quality of carbon compounds.. We also recorded evolved CO2 regularly over the incubation (8 total days).

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Change in DOC, Composition and evolved CO2: important to measure all three.

We measured changes in DOC, quality of C (via FT-ICR profiles of pore water) and evolved CO2 to identify biodegradability (including mineralized C, assimilated C and transformation of original compounds into other components of DOM).

We need to measure biomass?!! What if increased\]=[

While DOM may be less-degradable (low molecular weight – Amon and Benner 1996) but bacterial growth efficiency was higher (possible less-degradable Dom had more “compounds needed for biomass production”)

“aromatic DOM compounds are generally more stable than

molecules with aliphatic structures. In addition to this, soluble polyphenols, phenolic

acids and plant-derived tannins have been shown to inhibit the activity of various enzymes

(Benoit et al., 1968; Williams and Gray, 1974; Gianfreda et al., 1995; Wetzel, 2000).” From Marschner and Kalbitz 2003

“Since this fraction is enriched with carbohydrates from cellulose and hemicellulose

breakdown and from microbial origin (Guggenberger et al., 1994), its high biodegradability

is probably due to these easily utilisable substances. As a consequence, this fraction

generally amounts to less than 20% of total DOC in soil solutions (Vance and David, 1991;

Qualls and Haines, 1992; Guggenberger and Zech, 1993; Guggenberger et al., 1994;

Andersson and Nilsson, 2001; Kaiser et al., 2001b). In consequence, the hydrophilic and

hydrophobic acid fractions generally dominate, which is attributed to their content of

recalcitrant compounds and their higher degree of biodegradation (Guggenberger et al.,

1994). Kalbitz et al. (2003) found a close negative correlation between DOM degradability

and hydrophobic DOM portions.”

“using the assumption that more condensed aromatic structures with a red-shifted

fluorescence are less biodegradable than structures with a low degree of condensation and

conjugation.”

“Carbohydrates and amino acids are highly decomposable in soils (Haider, 1992) and are

utilized preferentially by microorganisms during degradation of different compounds in

DOM solutions (Volk et al., 1997; Amon et al., 2001; Kalbitz et al., 2003). However, Volk

et al. (1997) stated that the often used classification of carbohydrates as labile DOM

components should be seen with caution, as carbohydrates can also be bound to stable

DOM compounds.

Compounds with alkyl or aromatic structural units generally accumulate during the

decomposition of soil organic matter (Baldock et al., 1992; Ko¨gel-Knabner et al., 1992;

Baldock and Preston, 1995; Huang et al., 1999) and have thus been associated with a low

biodegradability. Boissier and Fontvieille (1993) found that phenols and polyphenols were

closely related to the amount of nondegradable DOM in incubation experiments. Similarly,

Wershaw and Kennedy (1998) observed a relative increase in aromatic structures during

litter decomposition. Kalbitz et al. (2003) showed that the biodegradability of DOM

extracted from forest litter layers was negatively correlated to its content in aromatic

structures determined with 1H-NMR.”

“wo recent studies

showed that CO2 evolution from soil samples can be largely

explained by the decrease in water-extractable organic

carbon (Marschner and Noble, 2000; Marschner and

Bredow, 2002). The finding that biodegradability of DOM

is similar to that of other fractions of soil organic matter

(Kalbitz et al., 2003) suggests that biodegradation of soil

organic matter is mediated by the aqueous phase.” Kalbitz et al 2003

All abstracts must be received on or before the **deadline** of **Friday April 24** 2015

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Authors: aPeyton, et al.   
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Abstract (300 words)