# Task 3a: Transport and sequestration of dissolved organic C in contrasting soils amended with C-14 enriched leaf litter


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# Objectives

- **Use $^{14}C$ enriched litter as a well defined source to quantify dissolved organic C flux through soil profiles as a function of storm events.**

- **Quantify the impact of coupled hydrological and geochemical processes on the fate and transport of dissolved organic C through contrasting soil profiles being used in the Enriched Background Isotope Study at ORNL.**

- **Quantify the mechanisms that control enhanced carbon accumulation within deep subsoils of forested Ultisols and Inceptisols.**

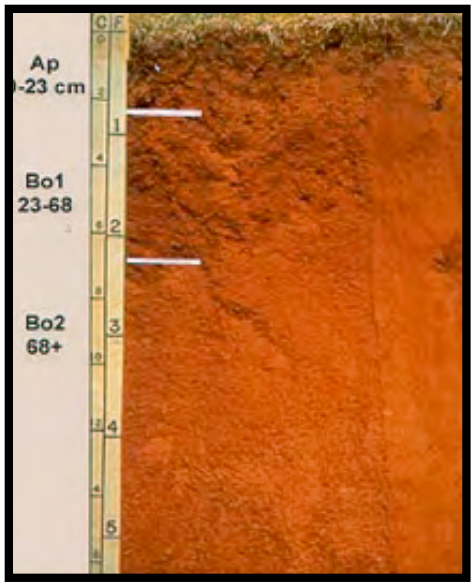
# Background

**Widespread, highly developed mature soils such as Ultisols, Oxisols, Alfisols, and some Inceptisols have deep soil profiles that have a tremendous capacity to sequester organic C that has been made soluble from surface horizons.**

**Mineral stabilized organic C within the subsoil decreases the rate of carbon turnover by orders of magnitude relative to upper A/B and E/B horizons. The potential storage capacity of these lower horizons globally is estimated in the hundreds of gigatons.**

**Competing geochemical and hydrologic processes (e.g. sorption and micropore protection vs. preferential flow and biodegradation) control organic C accumulation or loss through soil profiles.**

**Ultisol devoid of organic C due to agricultural abuse**




**Ultisol enriched with organic C through improved management technologies**

## Example of deep profile organic C sequestration

**Anthropogenically enriched soil of the Amazon**

**Adjacent unenriched soil**

These soils are from the same physiographic position and have the same clay content and clay mineralogy. The soil on the left was enriched by ancient human occupation centuries ago; the right is unenriched. This illustrates that such soil enrichments can be maintained for several centuries.

# Approach

- Two background and two enriched plots from each of the four EBIS sites (16 plots) were each instrumented with four tension lysimeters and four tension-free lysimeters. Two of each type were placed within the A- and B-horizons of the soil profiles (8 samplers per plot).

- Besides the addition of enriched and background litter, a nonreactive Br tracer was evenly applied over each of the instrumented areas using a backpack sprayer (i.e. distributed initially to the soil matrix porosity).

- Solution samplers were monitored during all storm events and analyzed for Br, TOC, inorganic anions, and pH. Numerous select samples were analyzed for $^{14}C$.

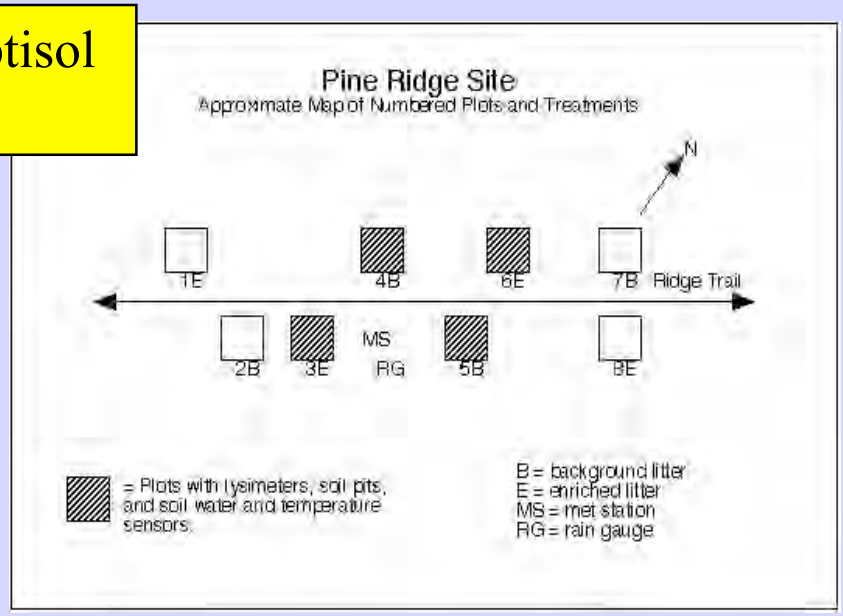
- Bulk soil samples from each plot were characterized for select physical and chemical properties and organic C sorption isotherms were quantified for each subsoil.

# Monitoring scheme

Inceptisols on PR and HR

Inceptisols

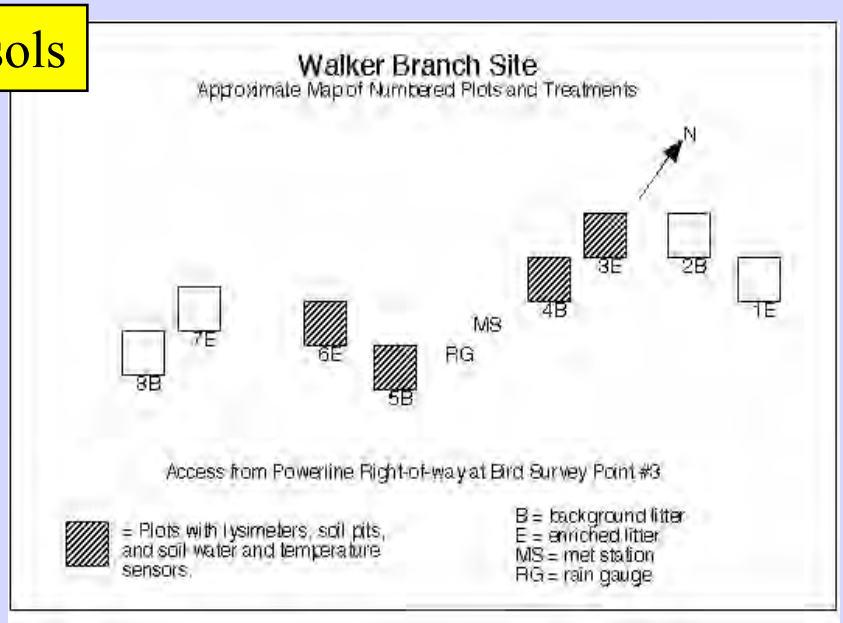



Ultisols on WB and TVA

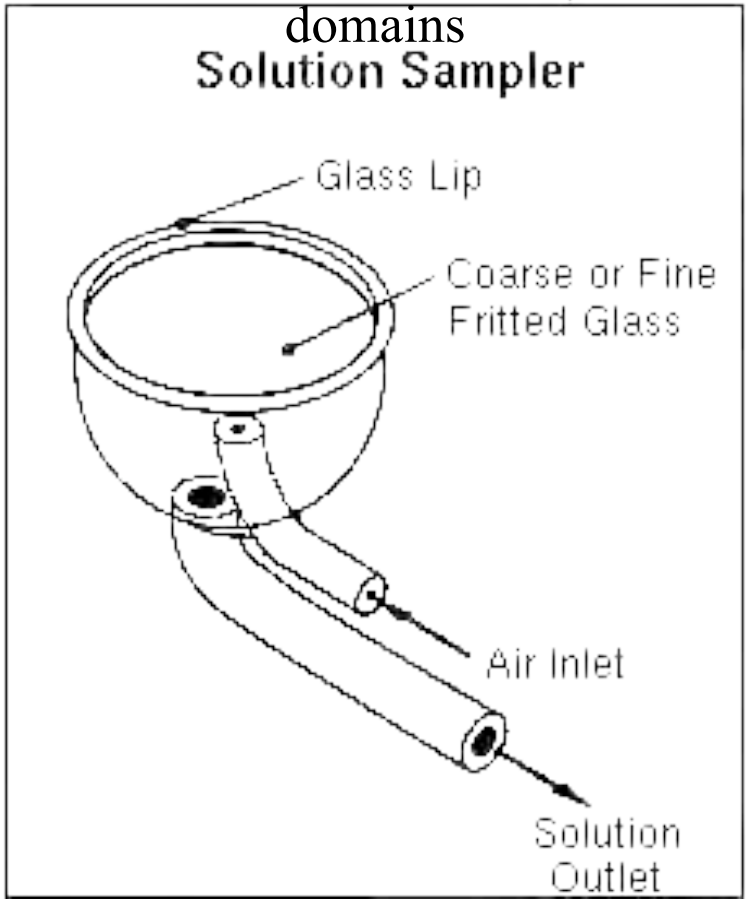
Ultisols



# Multi-porosity sampling capabilities

Zero/low tension solution sampler for monitoring macropore and mesopore domains

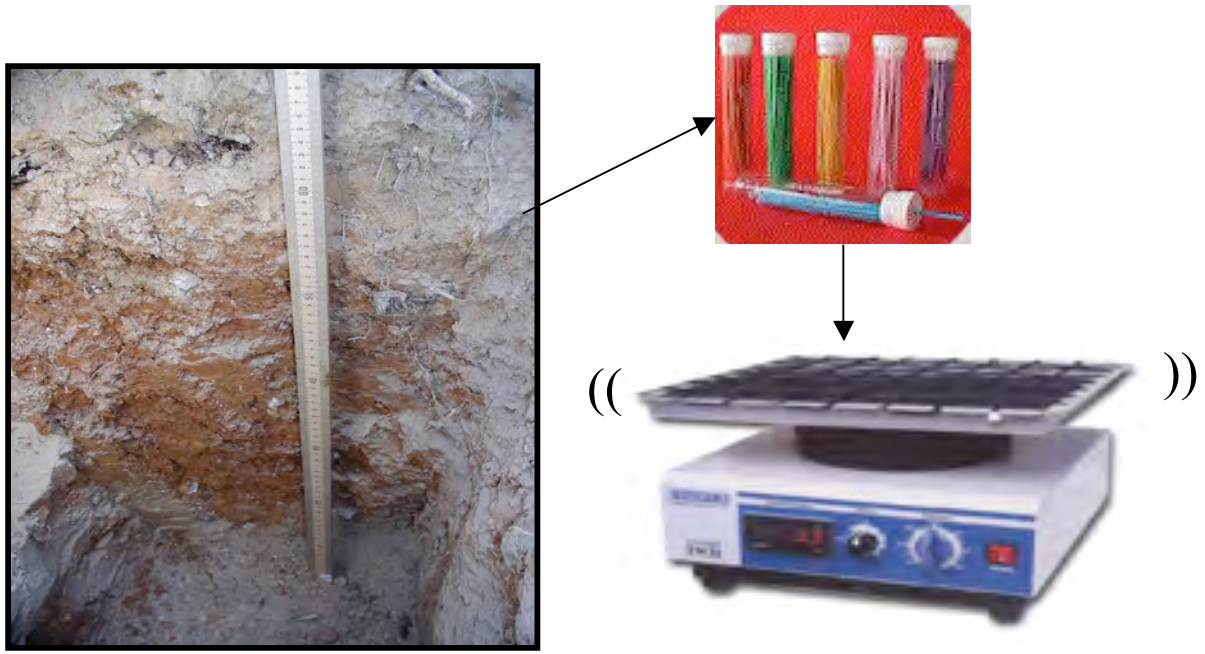



Funds lacking to do an adequate investigation of large pore organic C fluxes

High tension solution sampler for monitoring primarily micropore domains

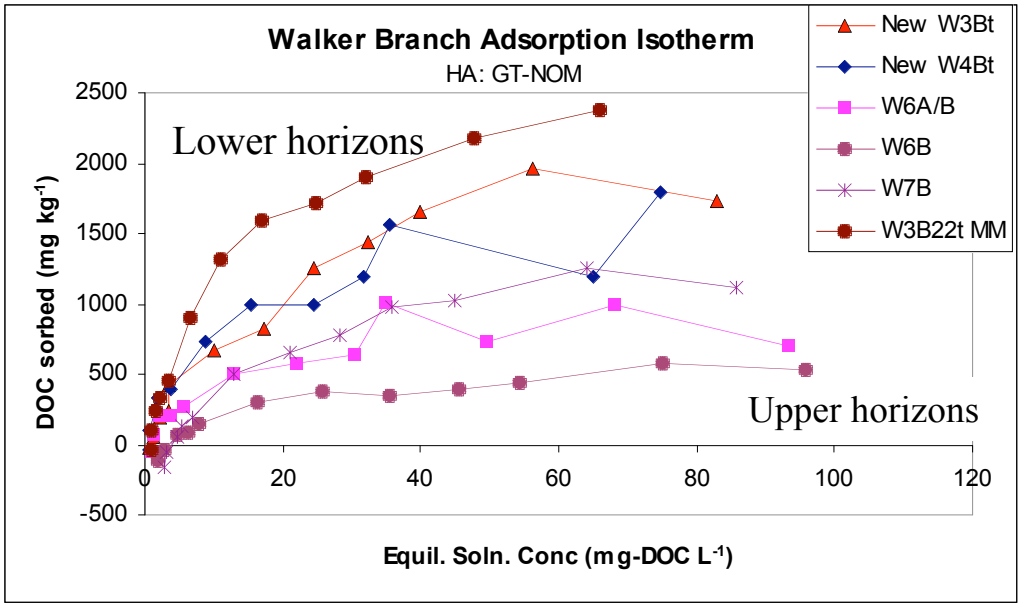
# Results: Organic C sorption isotherms

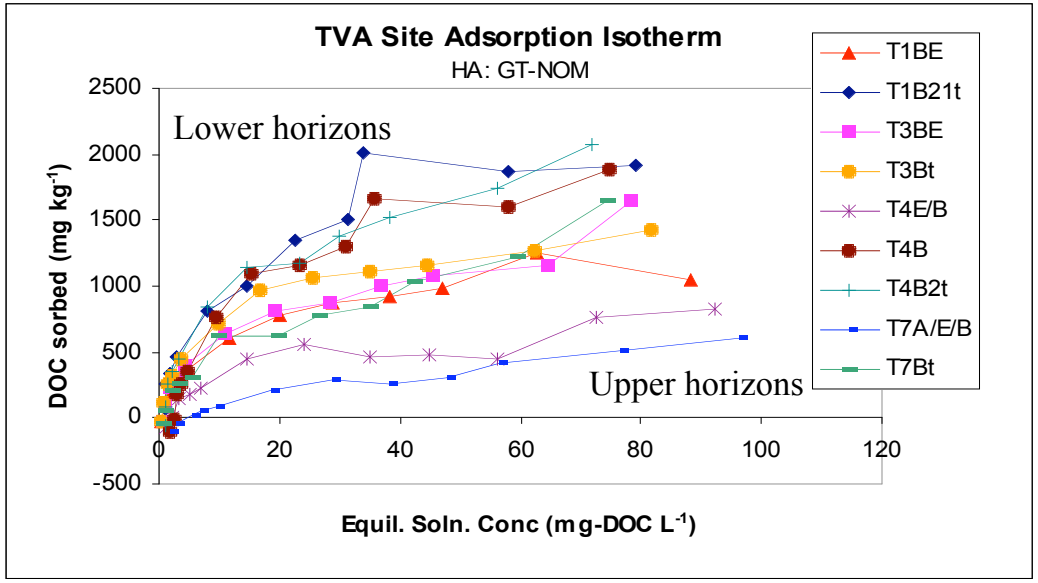
- A shake-batch method was utilized to construct dissolved organic carbon isotherms on the Ultisol and Inceptisol subsoils from the various EBIS plots.



- Select physical and chemical properties of the subsoil samples were determined in an effort to cross-correlate soil properties with differences in DOC solid-phase adsorption.

# Carbon sorption isotherms on Ultisol soil profiles

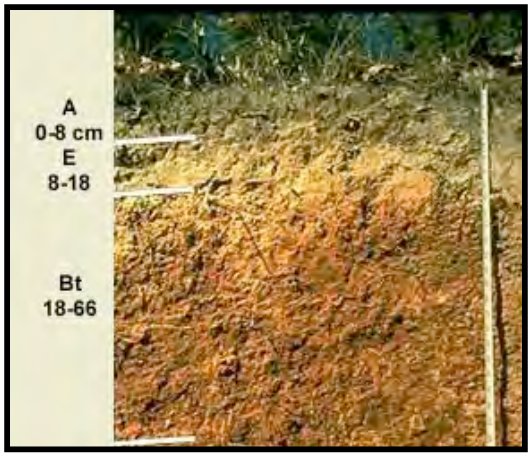


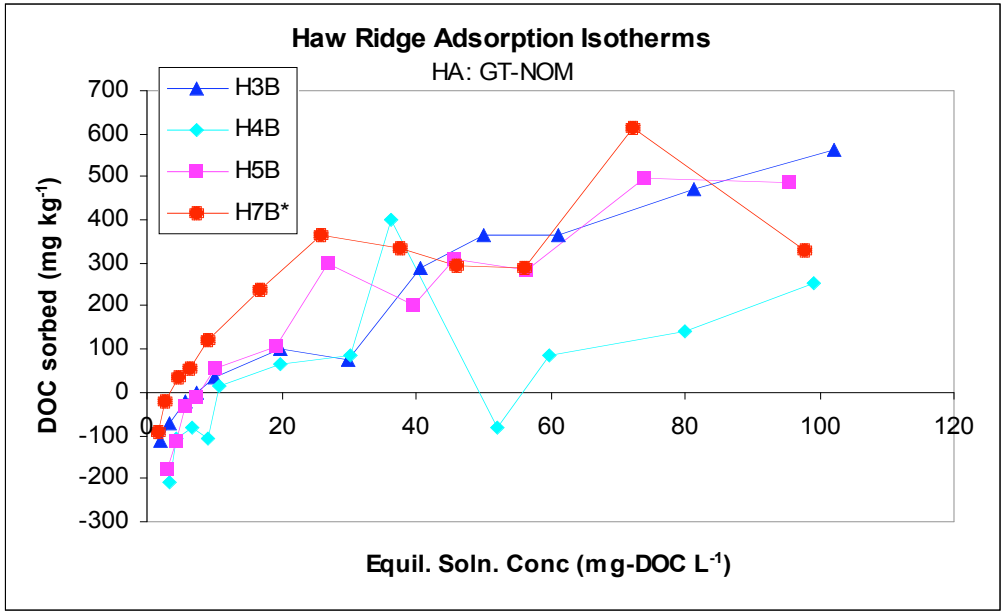

Soil samples from lower B-horizons have significantly larger carbon sorption capacities relative to upper A, E, A/E, and B/E horizons.

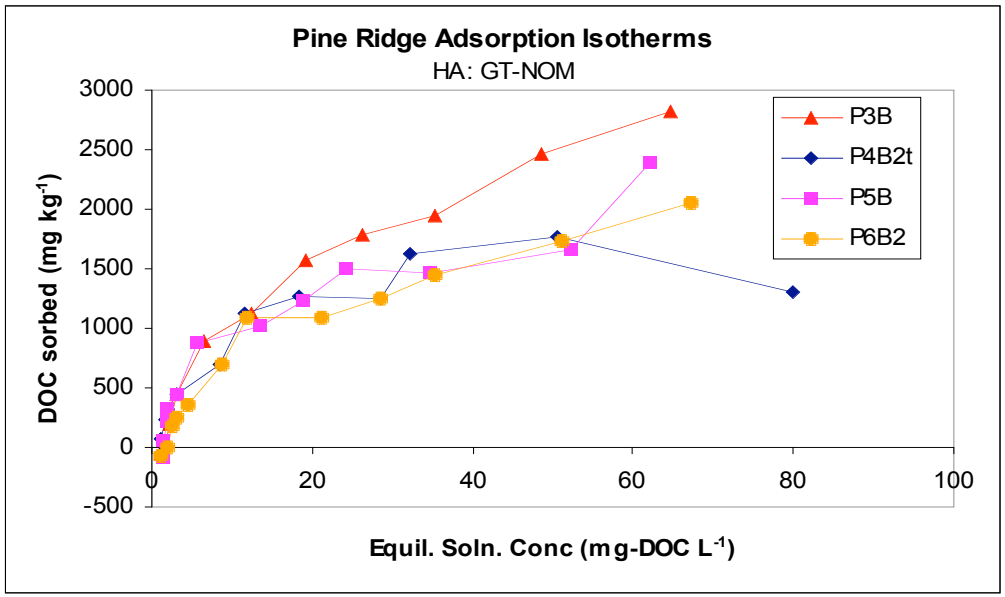
B-horizons are more acidic, Fe-oxide rich, and have lower indigenous surface bound C, all of which promotes enhanced sorption of added organic C.

Typical soil profile



# Carbon sorption isotherms on Inceptisol soil profiles

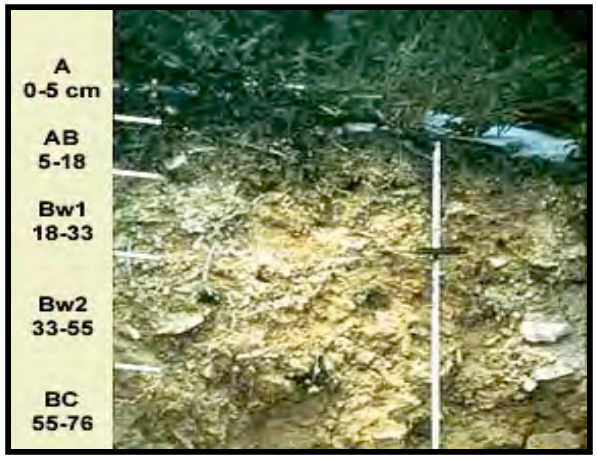



Lower organic C sorption on sandy inceptisols with low Fe-oxide content and significant indigenous solid phase O.M. (i.e. Haw Ridge).

Higher organic C sorption on clayey inceptisols with high Fe-oxide content (i.e. Pine Ridge).

Typical soil profile

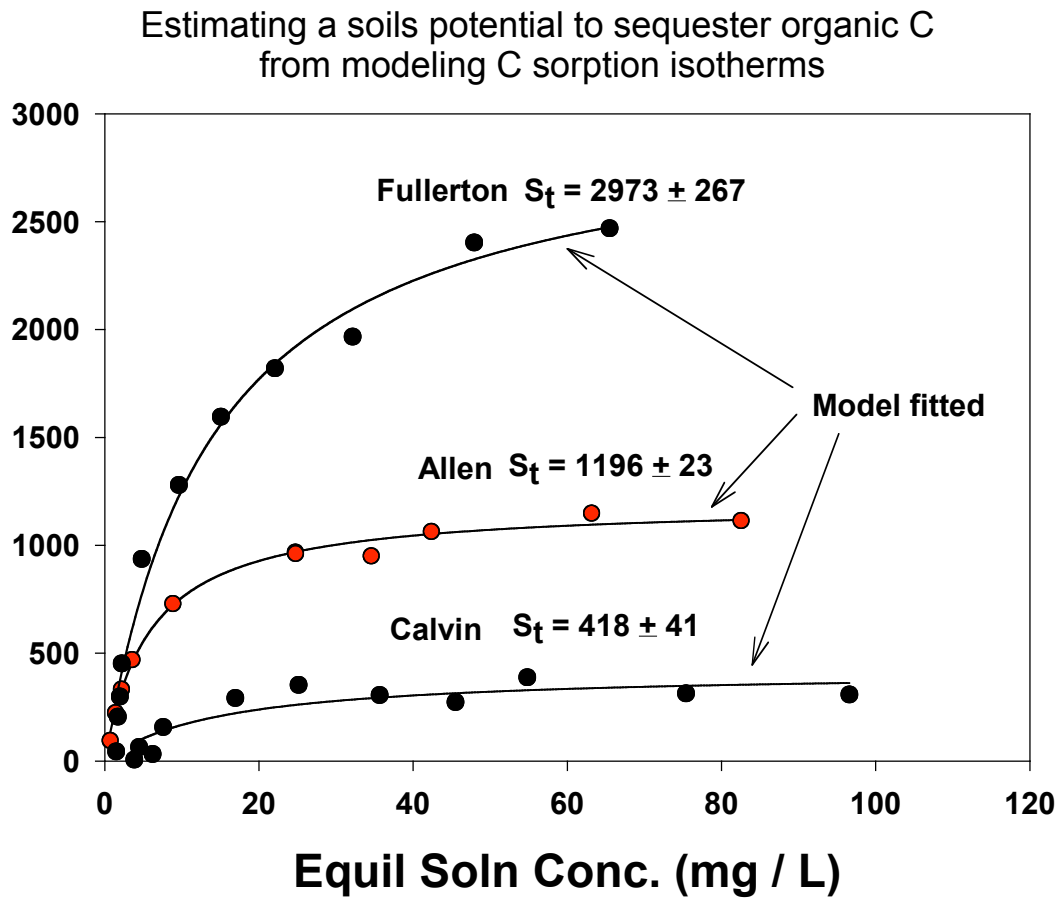


# Obtaining an estimate of maximum organic C sorption for each soil

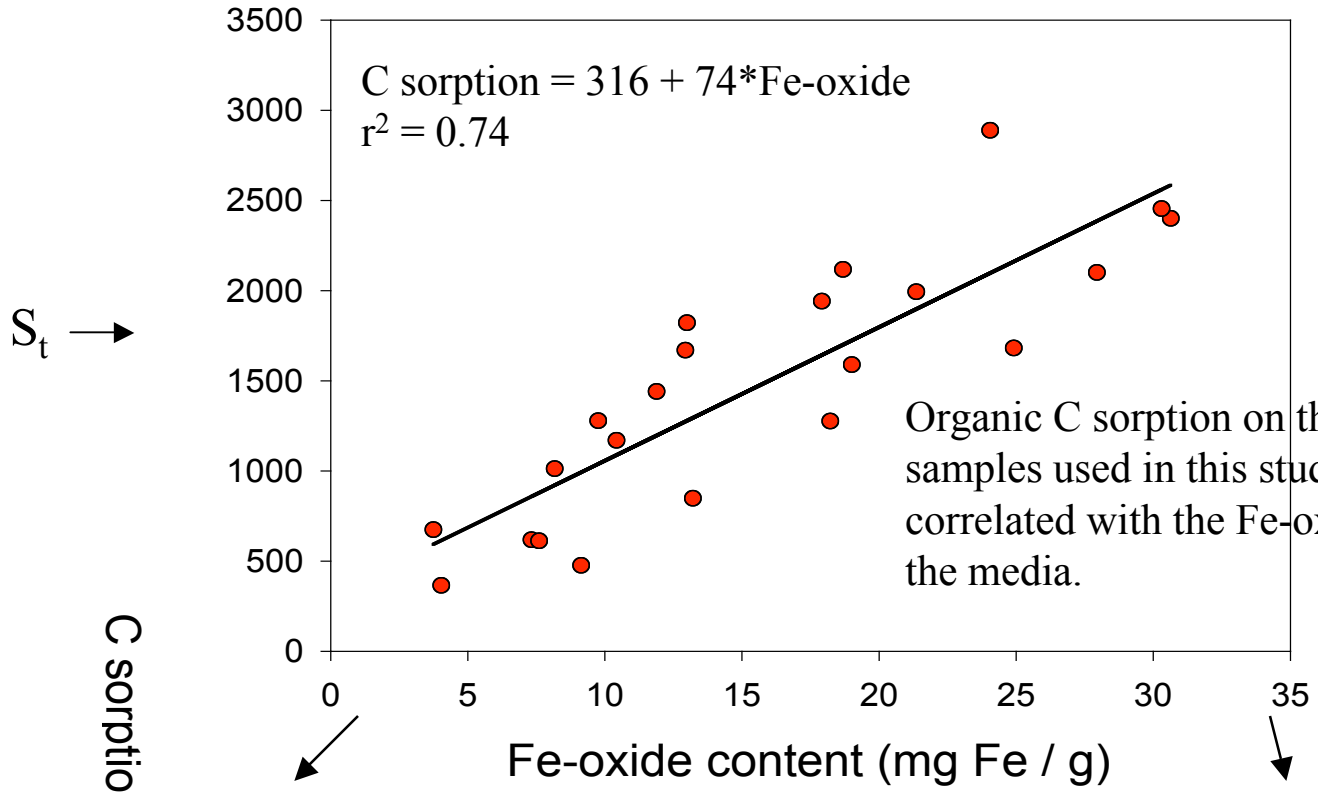
The langmuir equation is optimized to the observed data from the previous two slides where estimates of the maximum organic C sorption ($S_t$) to a particular soil are obtained.

Data fits are generally good with adequate 95% confidence limits for the estimated $S_t$ parameter.

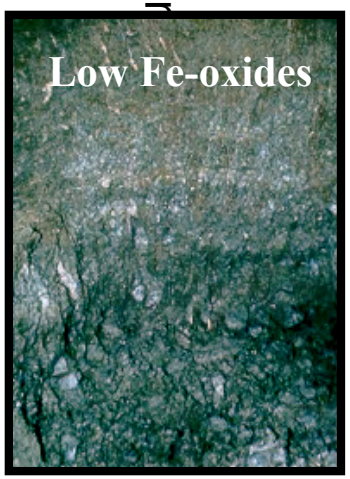
The $S_t$ parameter is used in a multiple regression or neural net modeling strategy where soil physical and geochemical properties serve as the independent variables.



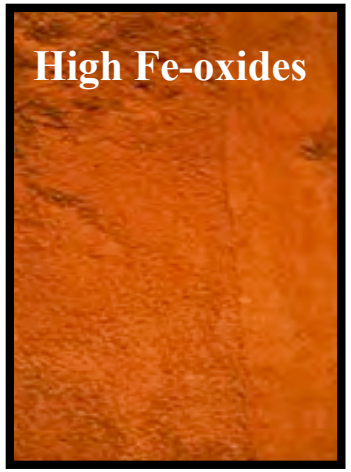
## Influence of soil Fe-oxides on organic C sorption

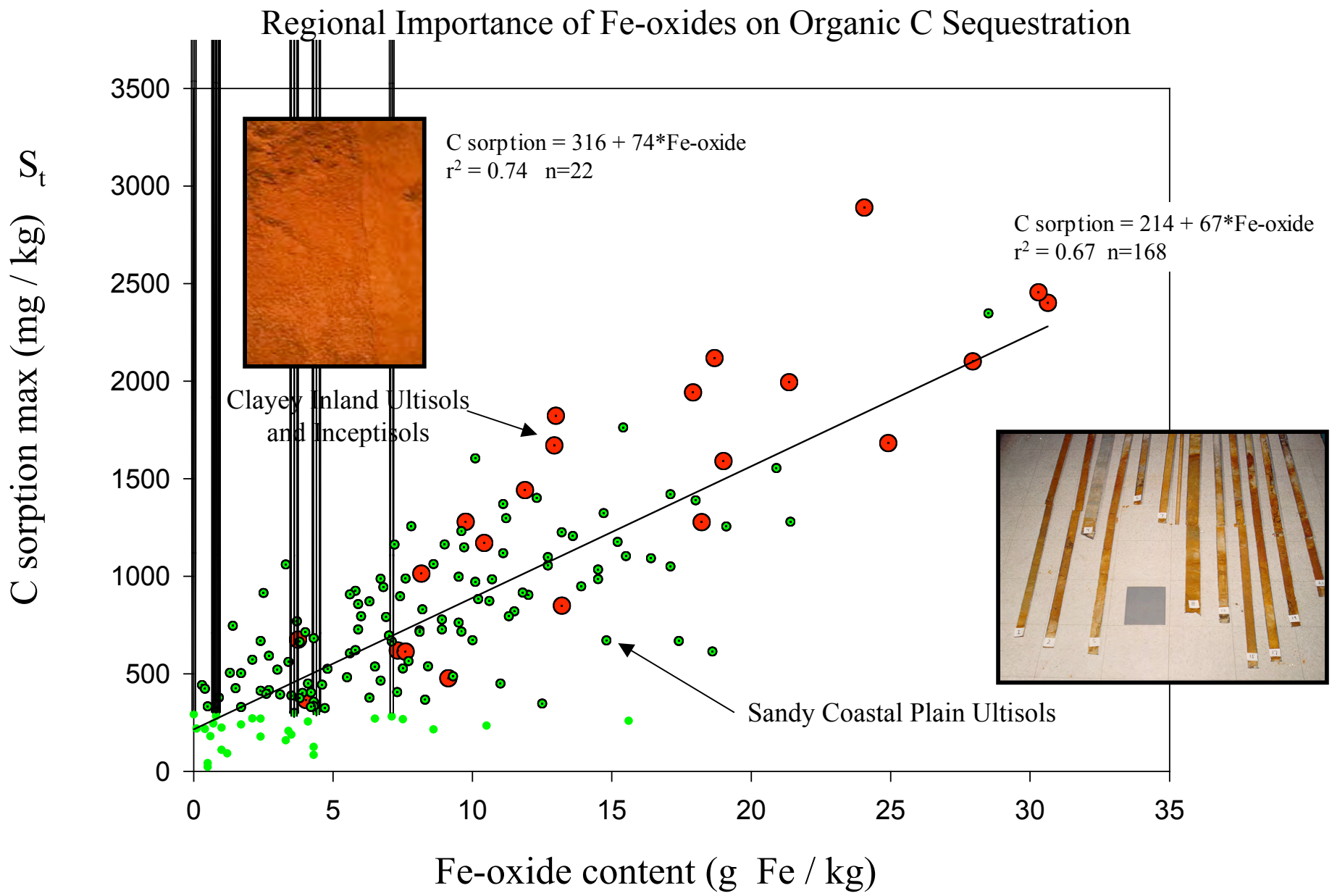



Organic C sorption on the EBIS soil samples used in this study was strongly correlated with the Fe-oxide content of the media.




Fe-oxide coatings on mineral surfaces strongly sequester pore water organic C which can potentially limit bioavailability and transport to groundwater.






**This slide simply shows additional evidence of the importance of Fe-oxides in sequestering organic C**

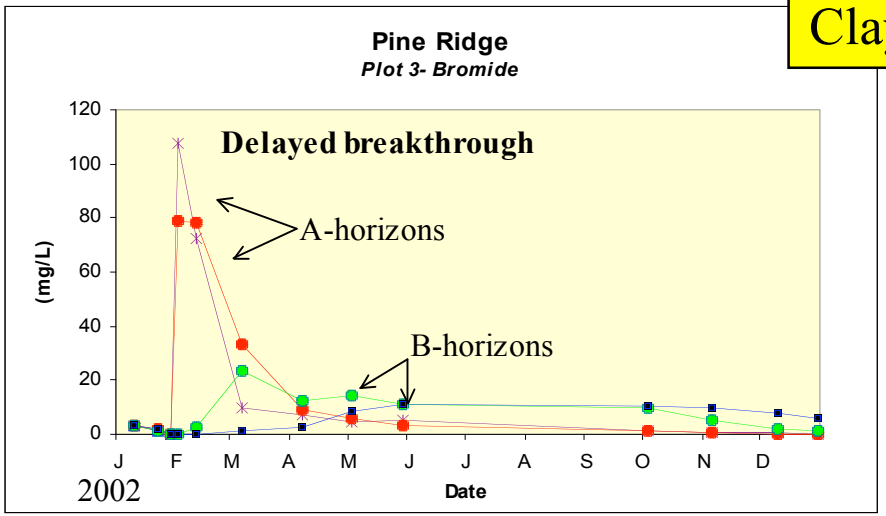
# Storm driven transport of organic C

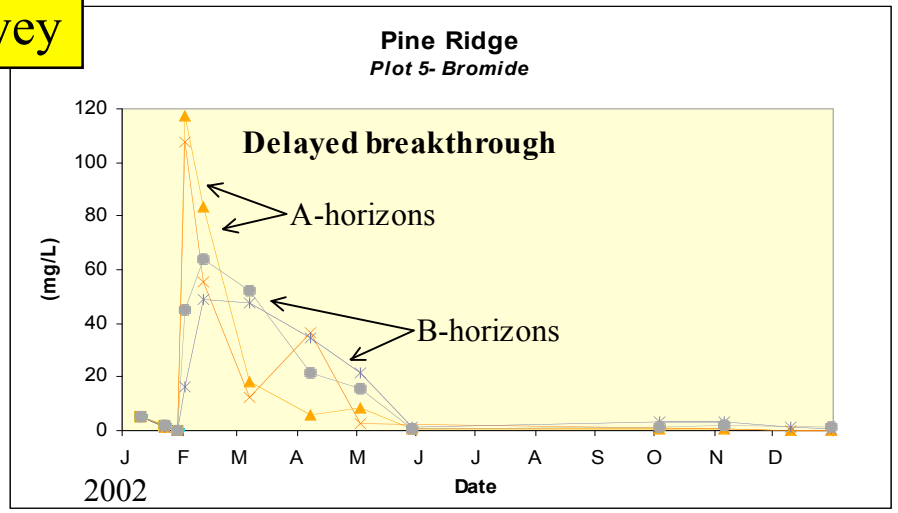
# Example storm driven Br breakthrough in Inceptisol soil profiles

**Non-reactive Br tracer provides useful data for quantifying flow and transport processes at the various sites.**

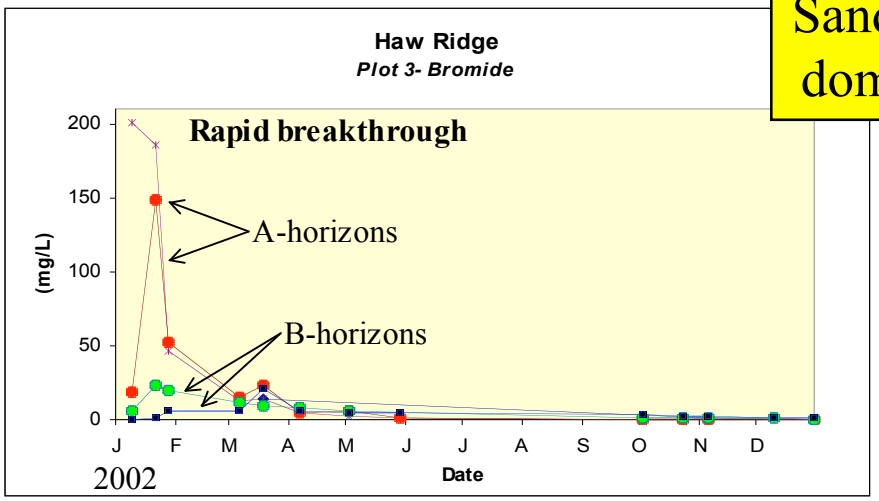
**Haw Ridge exhibits the most rapid infiltration characteristics which is consistent with its more highly structured media and lower microporosity relative to the more clayey Pine Ridge and Ultisol soils.**

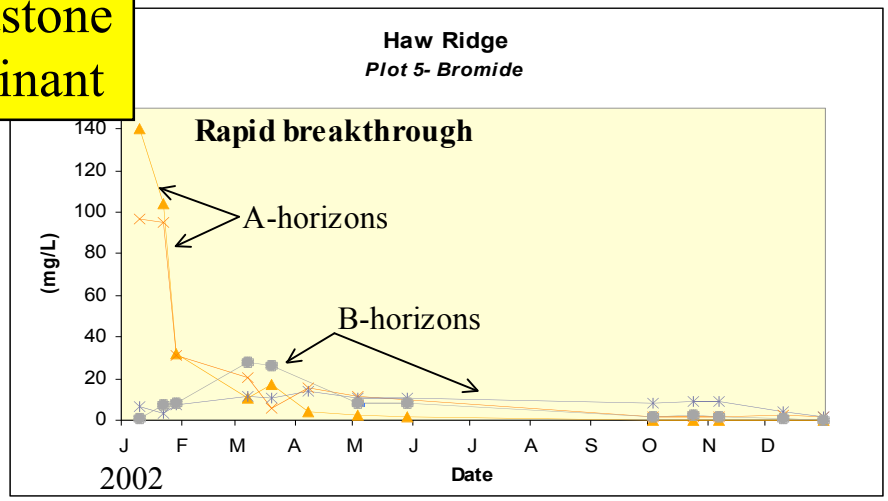
Clayey




Sandstone dominant



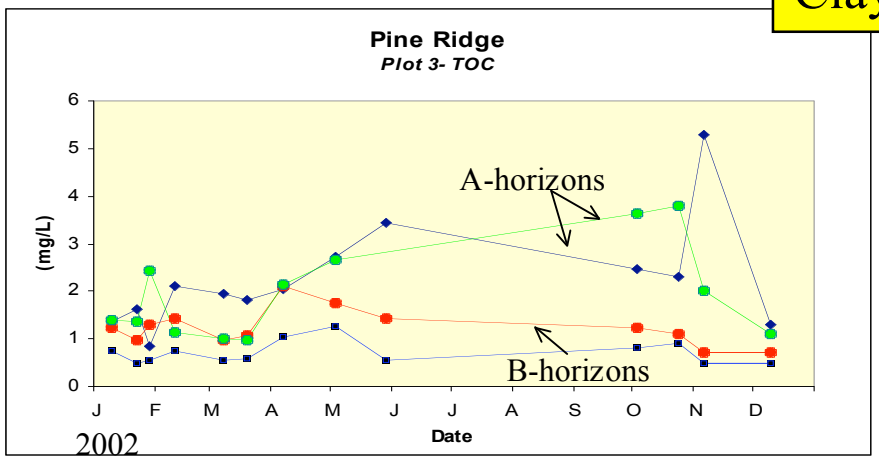



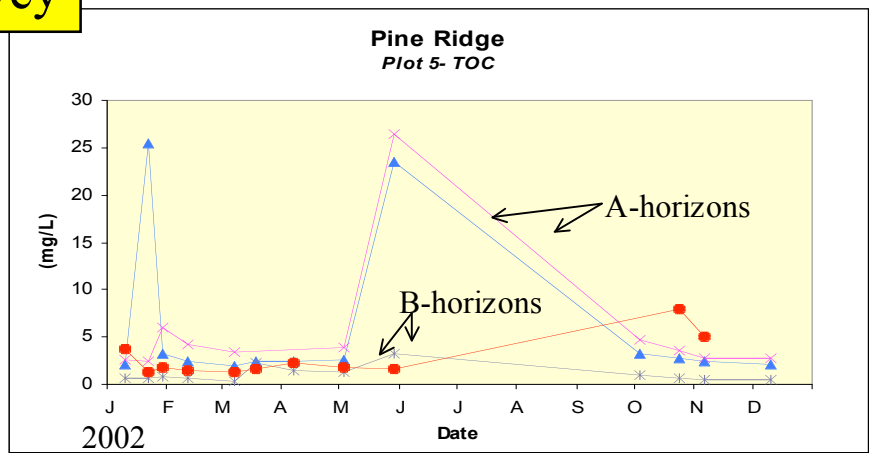
# Example storm driven DOC concentrations in Inceptisol soil profiles

**DOC concentrations higher for A-horizons relative to B-horizons.**

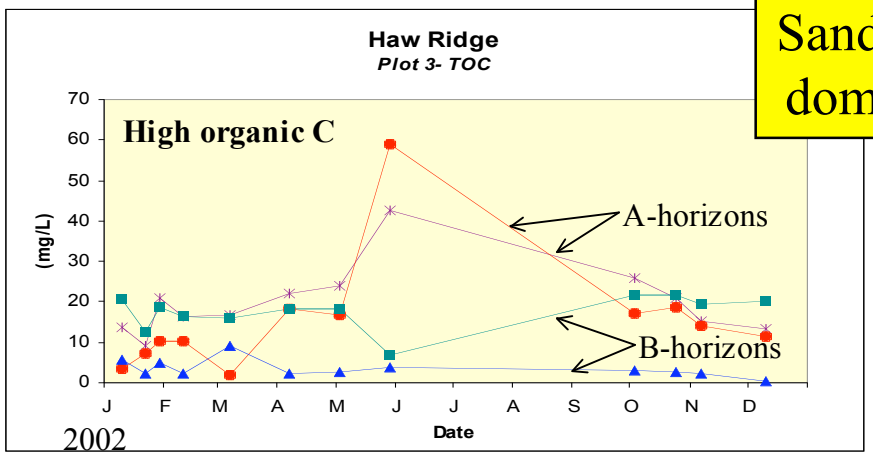
**Haw Ridge (sandy inceptisol) consistently has highest pore water organic C concentrations that continue into the B-horizon. Since infiltration is more rapid in these soils coupled with their lower organic C retention capacity, greater losses of dissolved organic C may be expected in these systems.**

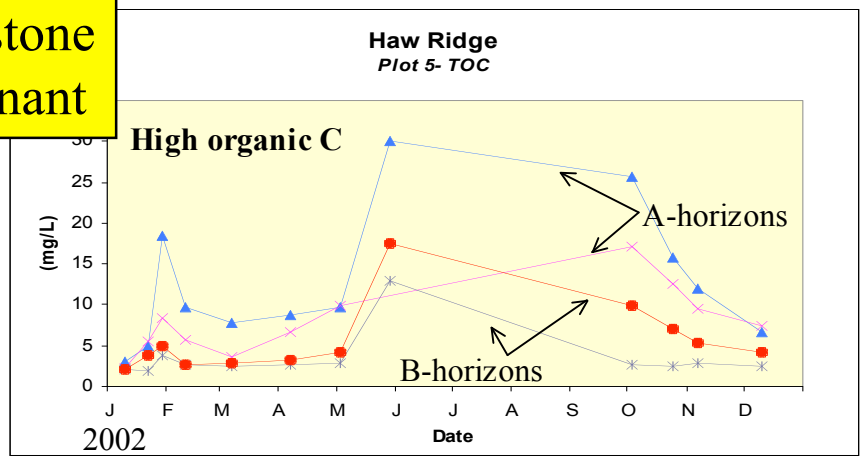
Clayey




Sandstone dominant

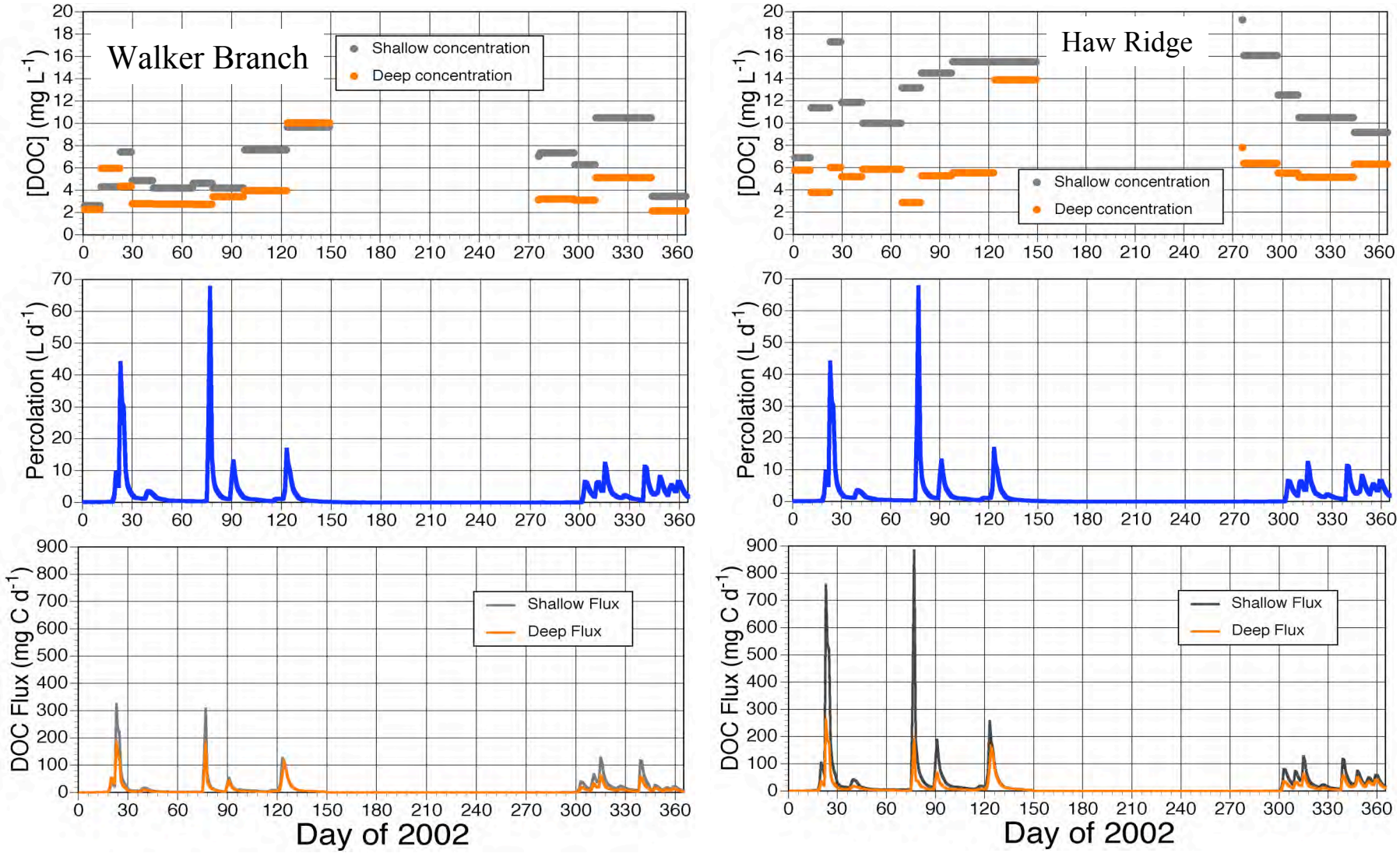


# 2002 Organic C flux through soil profiles

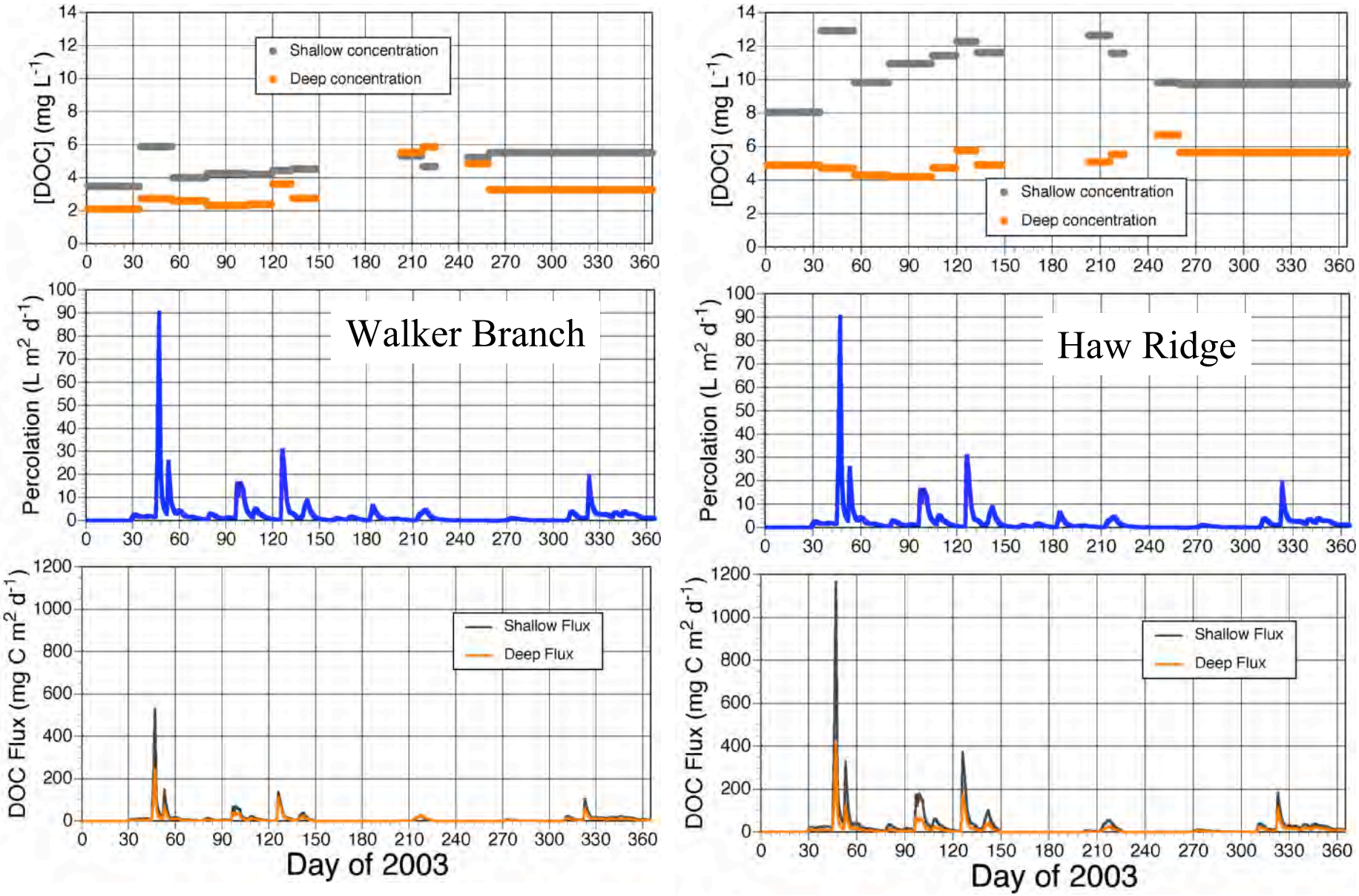
**DOC flux higher for A-horizons relative to B-horizons.**

**Haw Ridge (sandy inceptisol) has highest C flux relative to Pine Ridge and Ultisol soils which is consistent with its more labile C source and rapid flow and transport characteristics.**



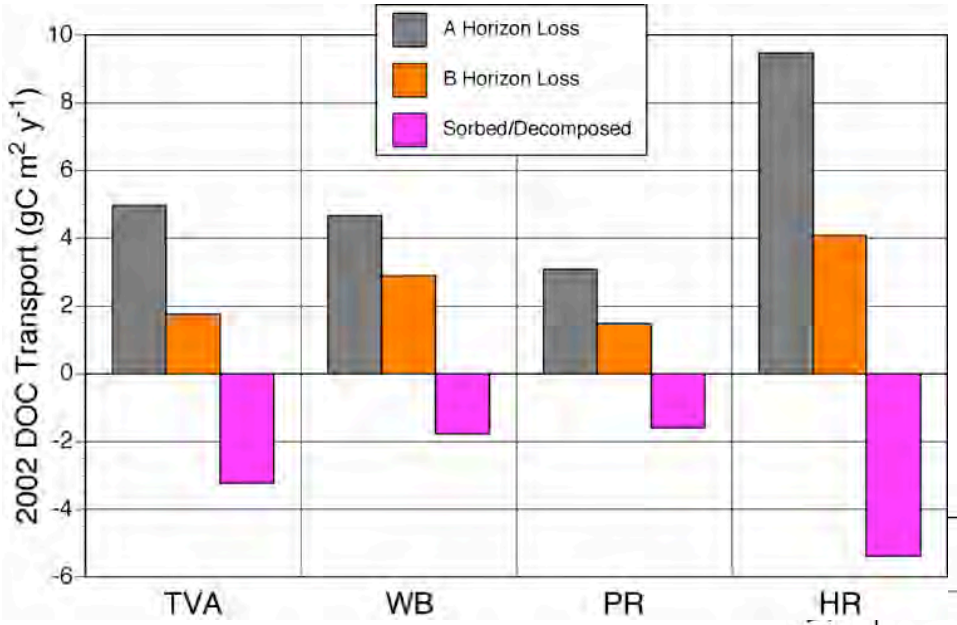
# 2003 Organic C flux through soil profiles

**Similar trends as 2002**



# 2002 and 2003 Organic C transport the through soil profiles

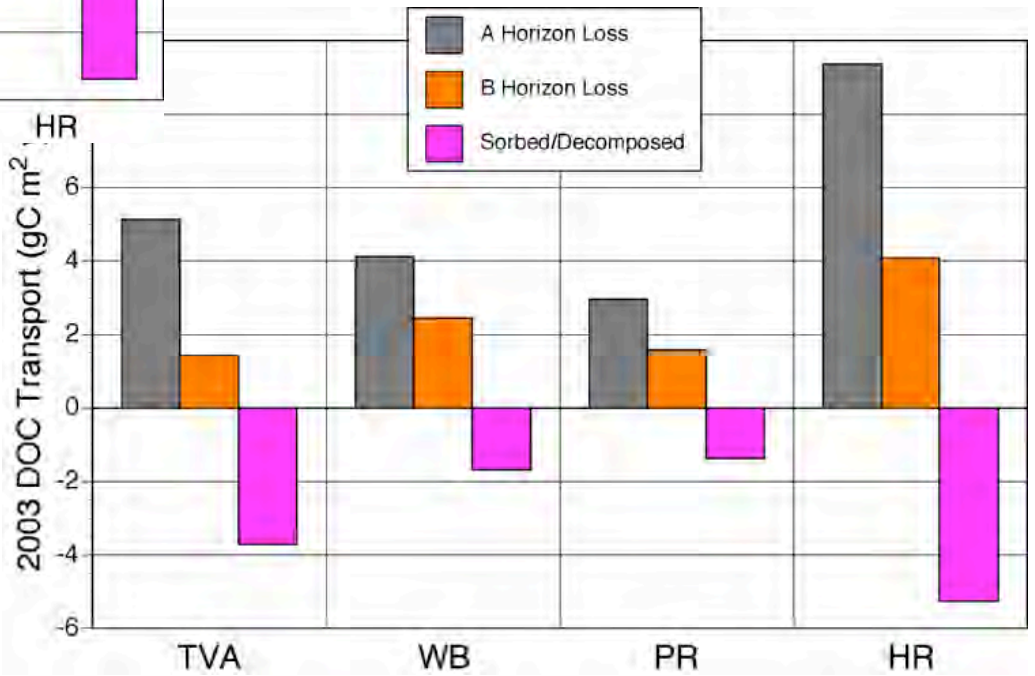
**Estimated organic C inputs into the B-horizons showing that these lower horizons typically receive more C than they lose.**




**Oddly enough, the field flux data suggest the inceptisols have a greater retention capacity for organic C in the B-horizons which is inconsistent with laboratory data and flow characteristics of the soils.**

**Not sure if this is an artifact of our failure to monitor preferential flow or our generic use of WBW percolation data for other soils.**

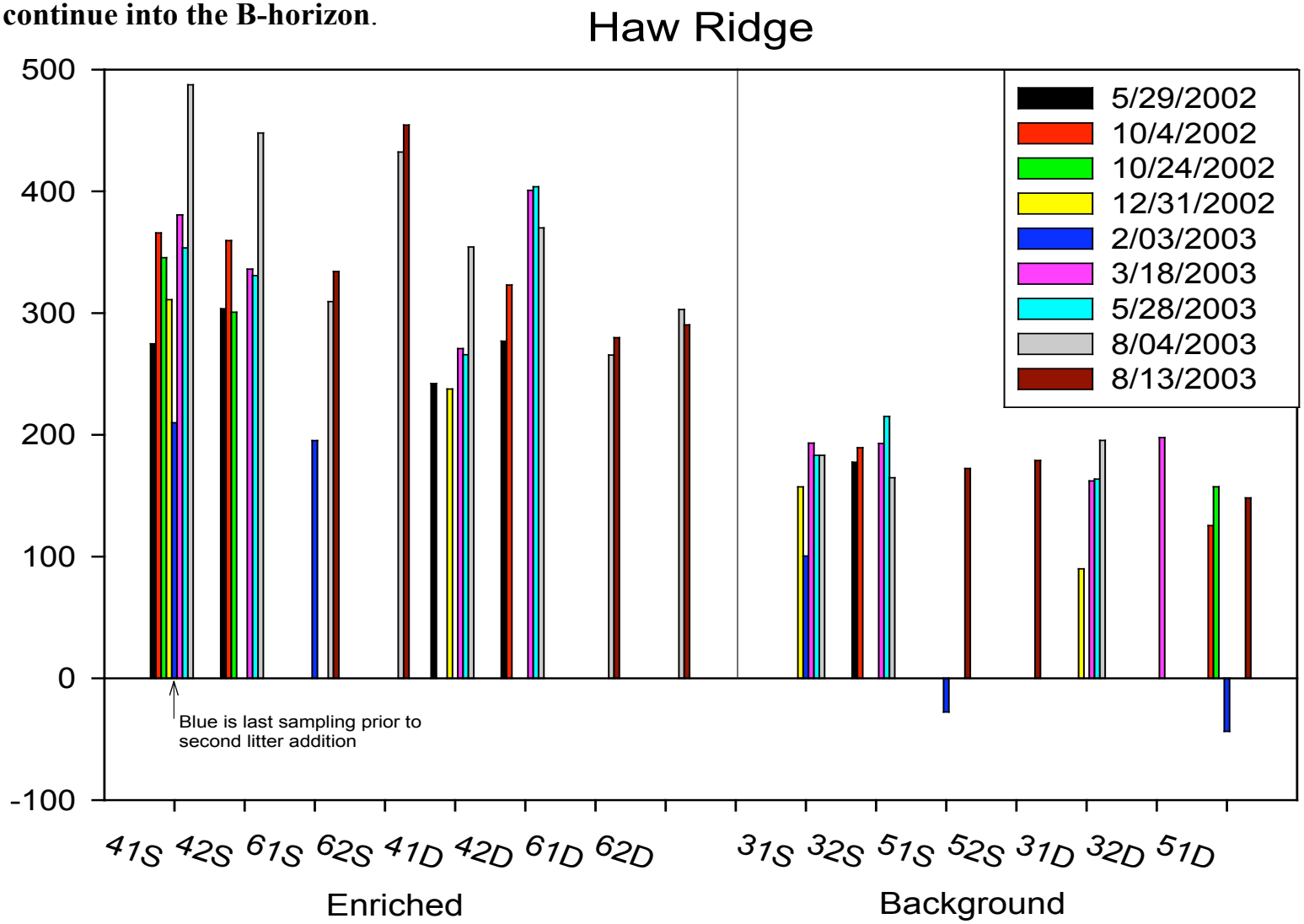
**Will work with Hanson to modify infiltration model for different soils (e.g. soil specific water retention functions).**



# $\Delta^{14}C$ signatures in select pore water from Haw Ridge Inceptisol soil profile

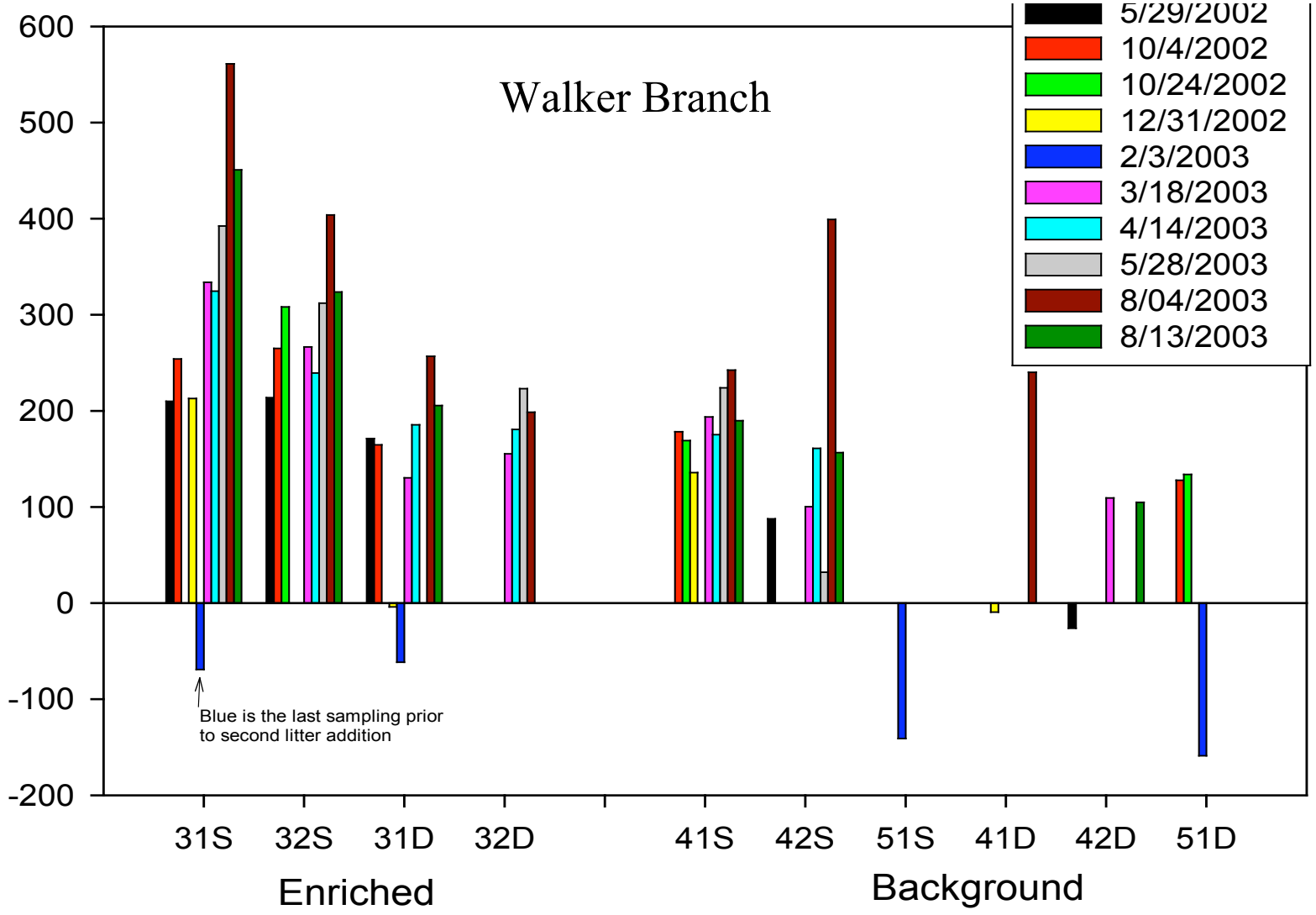
**Enriched plots have higher $\Delta^{14}C$ signatures in pore water than background plots.**

**Pore water from Haw Ridge has a higher $\Delta^{14}C$ signatures relative to Walker Branch which is consistent with the more rapid flow and transport characteristics and lower organic C retention capacity of HR. Elevated $\Delta^{14}C$ values continue into the B-horizon.**



# $\Delta^{14}C$ signatures in select pore water from Walker Branch Ultisol soil profile

**Pore water from WB has a lower $\Delta^{14}C$ signature relative to HR with B-horizon samples showing no evidence of enrichment. This may be related to the higher organic C retention capacity of WB. Trends for WB similar to the other clayey soils Pine Ridge and TVA.**

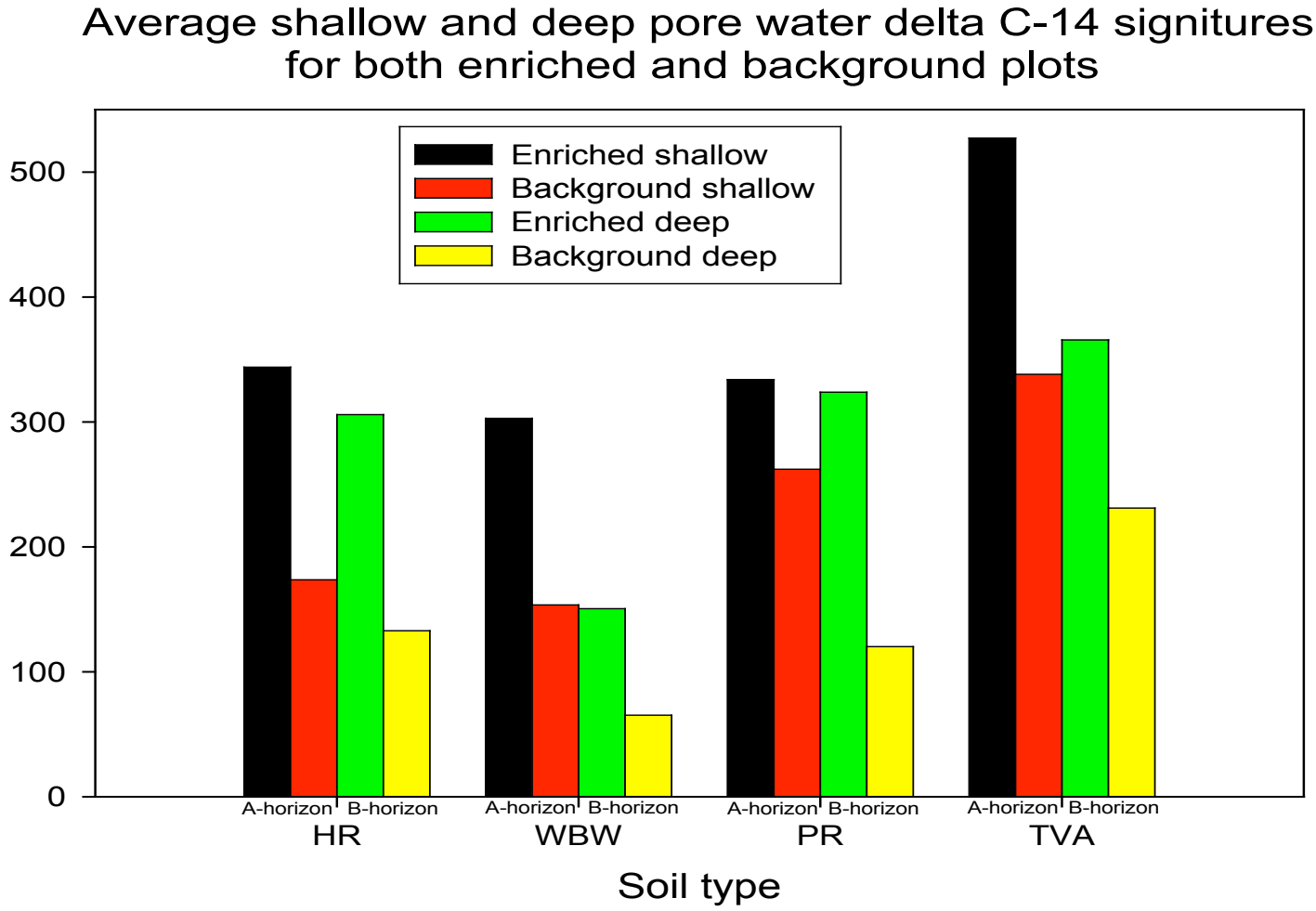


# Average $\Delta^{14}C$ signatures of all pore water from each site

**Possible pre-enrichment of Pine Ridge and TVA prior to EBIS experiment.**

**Enriched A- and B-horizons have consistently higher $\Delta^{14}C$ pore water than background A- and B-horizons for all sites.**

**Enriched pore water moves deeper in the Inceptisols relative to the Ultisols.**



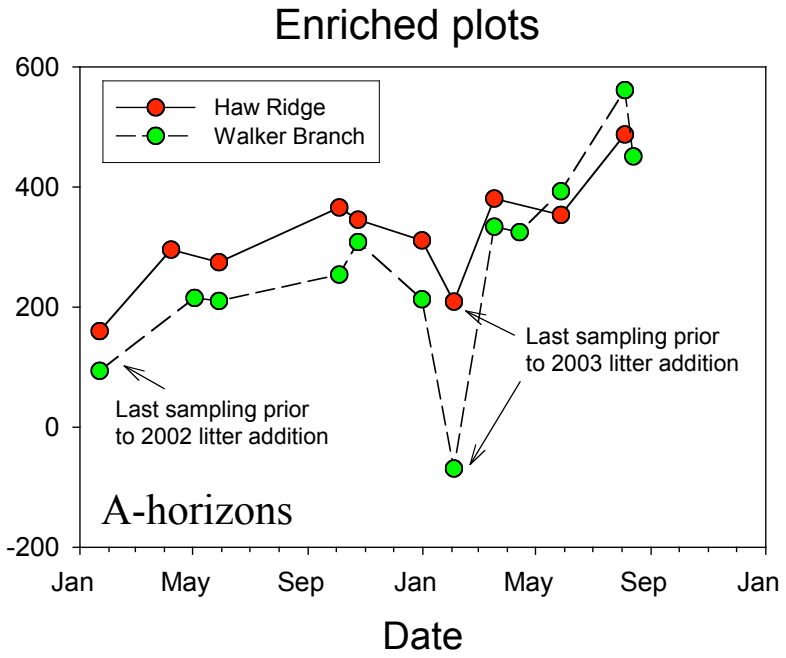
## Movement of the pore water $\Delta^{14}C$ signature through the A-horizon

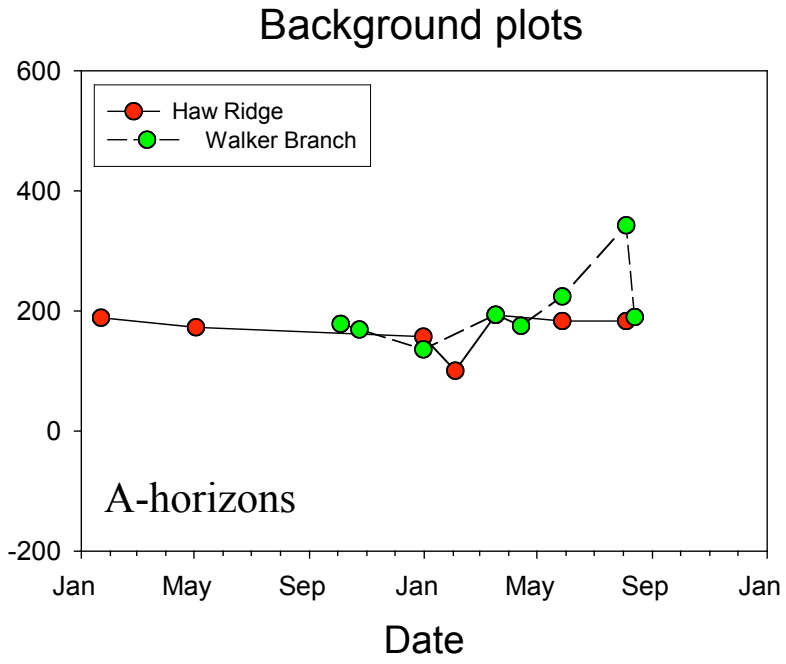
**Pore water $\Delta^{14}C$ signature increases with time and is quite responsive to the yearly addition of enriched litter.**

**Background $\Delta^{14}C$ pore water are essentially flat -200.**

**These data combined with DOC concentration data should enable some nice model testing. Everyone is welcome to any and all data.**

**The one negative $^{14}C$ value is either a bad data point or it suggests potential transition from predominantly litter sources of $^{14}C$ to some older sources of $^{14}C$ from time-to-time.**



# Summary

- **Non-reactive Br tracer provides useful data for quantifying flow and transport processes at the various sites.**
- **Dissolved organic C fluxes at each site are consistent with the soil hydrodynamics and labile nature of the A-horizon organic matter.**
- **Net organic C accumulations observed in the B-horizon where organic C sorption was strongly correlated with the soil Fe-oxide content.**
- **Pore water $\Delta^{14}C$ signatures show enriched plots have higher values than background plots, and the data is consistent with site hydrological and geochemical characteristics.**
- **These data combined with the Br and DOC concentration data should enable model testing of litter decomposition rates and organic C transport through soil horizons.**