

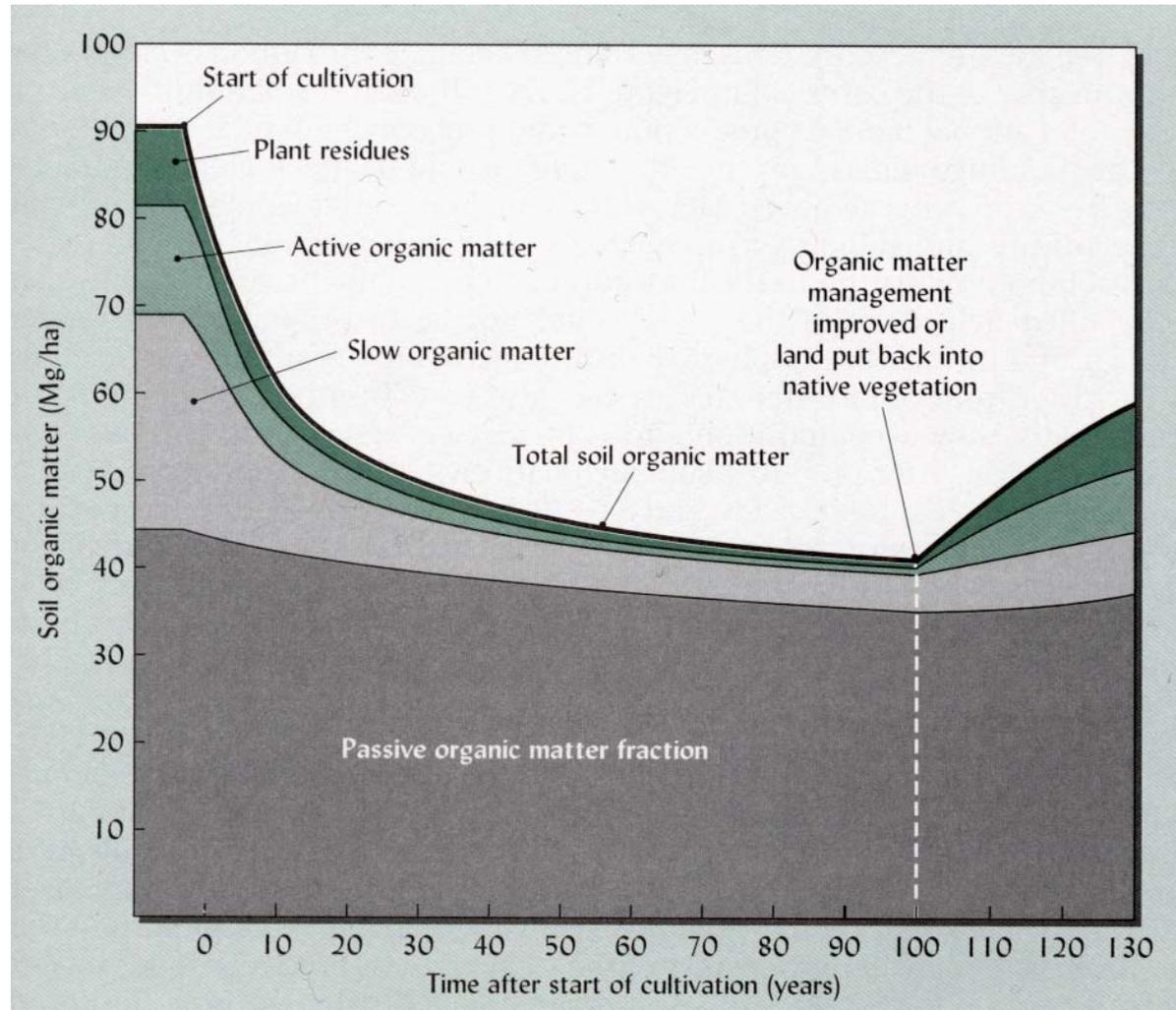
# Identifying New Mechanisms for Enhancing C Sequestration by Soils

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**Abstract: Carbon sequestration by soils occurs primarily within adjacent soil aggregates separated by porous planes of weakness. Repeated rehydration of intra-aggregate regions by C-enriched soil solutions permeating intra-aggregate micropores, deposit C on the mineral walls of pore networks. A novel and new soil aggregate exploration chamber identified significantly lower intra-aggregate soil porosities than are present at aggregate surfaces. Saturated hydraulic conductivities (Ks) through more porous aggregates from forest soils were 7-10 times greater than agricultural soils. Spatial distributions of clay minerals within aggregates resulted in more rapid weathering of clays on aggregate surfaces. Greater solution flux rates through the more porous external regions of aggregates appear to account for the higher soil C contents on surfaces of soil aggregates. Soil aggregates with low C and clay contents exhibit greater surface erosion rates. Greater knowledge of these unexplored process-level mechanisms are leading to managements that enhance the sequestration of C by soils. Organo-mineral models are being used to project optimal C sequestration rates of specific C ligands.**

**Introduction:** Soils have been losing soil organic matter for the past 100 years, Fig. 1. Most of these losses have been the result of excessive tillage. recent incorporations of no tillage farming have begun to reverse these losses, with net increases in C sequestration.

Process-level mechanisms associated with these increases in soil C are being investigated by numerous disciplines, with little success in the identification of functional mechanisms that assist managers with methods for continuing these increases in greater sequestration of C by soils.



**Fig. 1. Changes in the various fractions of soil organic matter in the 0-25 cm soil depths. ( In: N.C. Grady and R. R. Weil. 2002. The Nature and Properties of Soils, 13<sup>th</sup> edition, Prentice Hall, New Jersey. Fig. 12-17, p.523)**

# SAE chamber system for separating soil aggregates into concentric layers

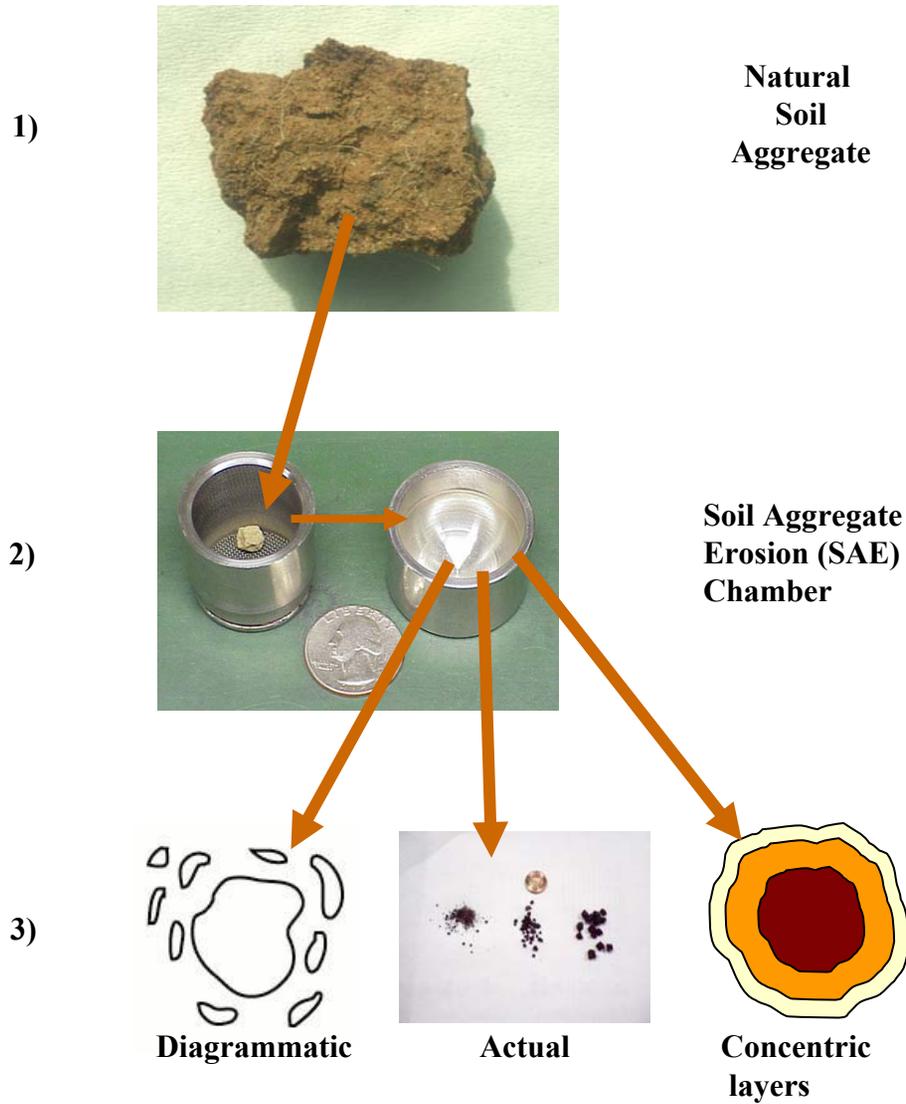


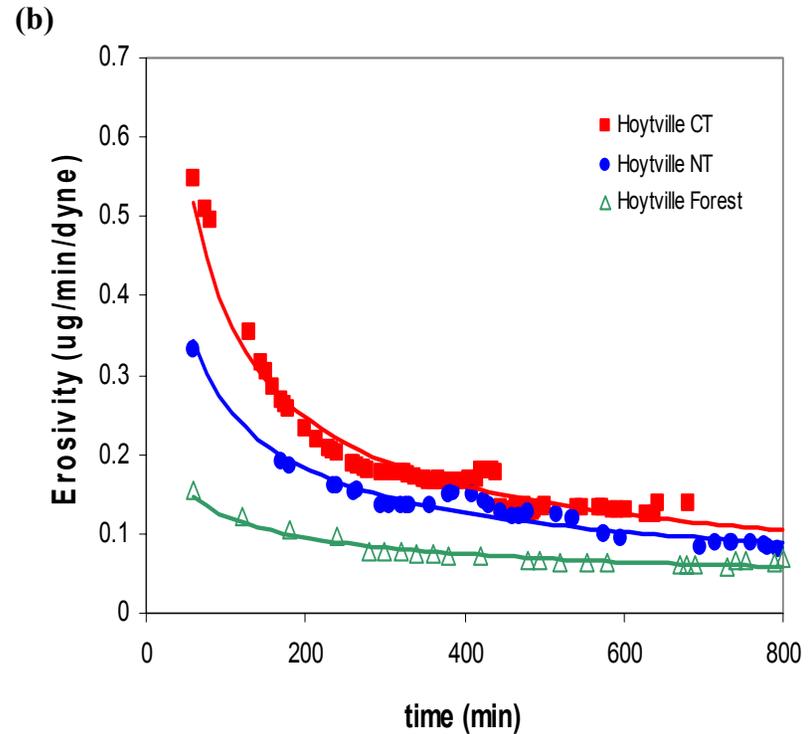
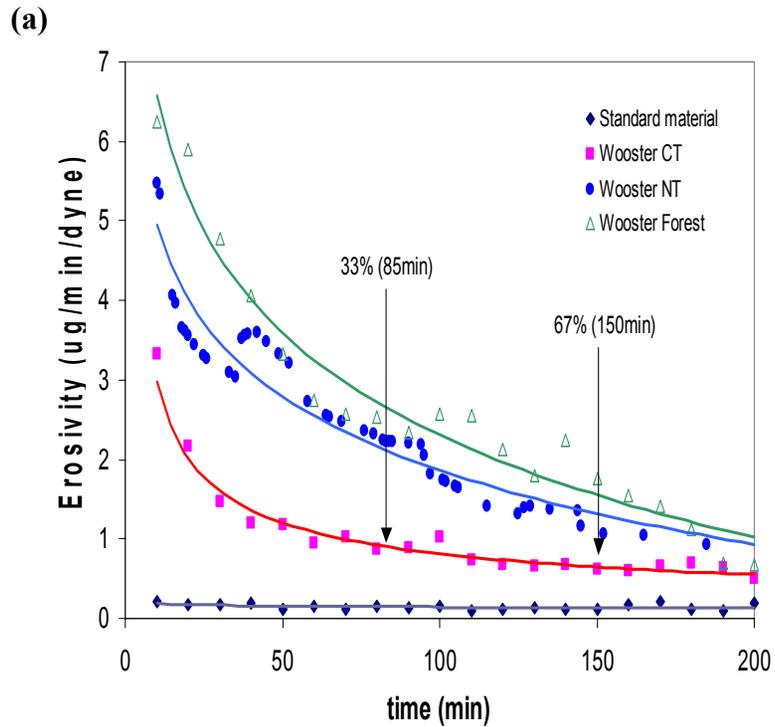
Fig. 2. Three step process for removing individual concentric layers from aggregates for analyses.

**Abrasive resistance of soil aggregates can be determined by the SAE chamber system, Fig. 2, for eroding soil aggregates from NT and CT experiments. The SAE method identifies erosivity rates for each layer or region of individual aggregates. Erosivity is defined as the rate of soil removal from aggregate surfaces when specific centrifugal forces are applied to an aggregate enclosed in the SAE chamber. Soil materials at the aggregate-SAE wall interface, resist external centrifugal forces ( $C_f$ ), Eq. 1, until  $C_f$  exceeds internal shear strengths of the aggregate.**

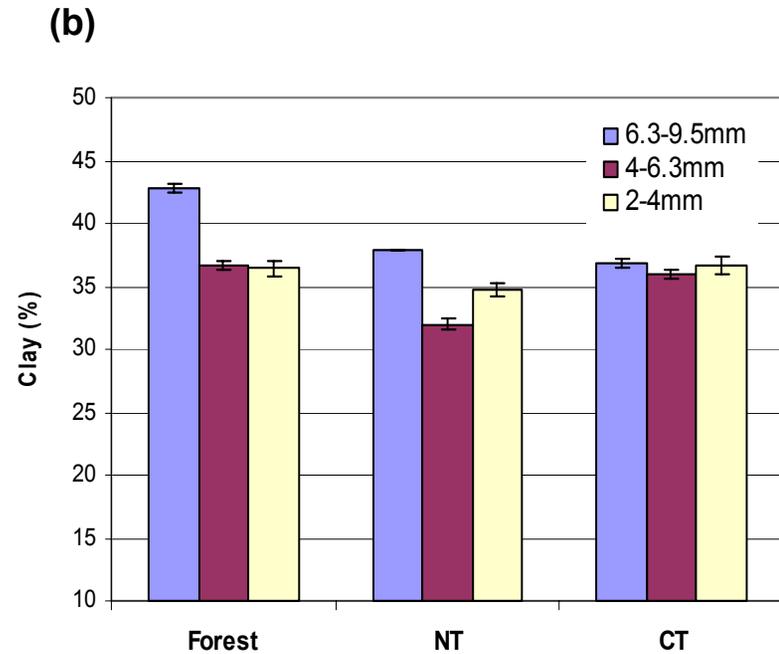
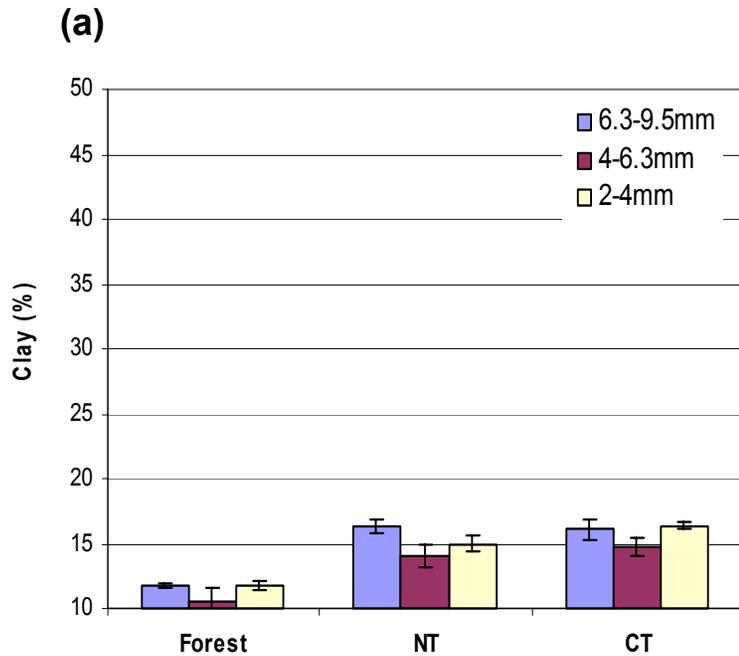
$$C_f = m(t) \omega_1^2 [1.25 + R_1 - R_2(t) + 2/5 R_1^2 / R_2(t)] \text{ (g cm sec}^{-2}\text{)} \quad (1)$$

**Where: m = mass, t = time,  $\omega$  = mechanical force, R = radius**

**Erosivity rates, Fig. 3, for Wooster soils (a) low in C and low in clay, Fig. 4, were an order of magnitude greater than Hoytville soils, containing higher C, caption in Fig. 3, and higher clay, Fig. 4. When soil C is low, then erosivity is inversely related to porosity. When soil C is high, then porosity has minimal effects on aggregate erosivity.**

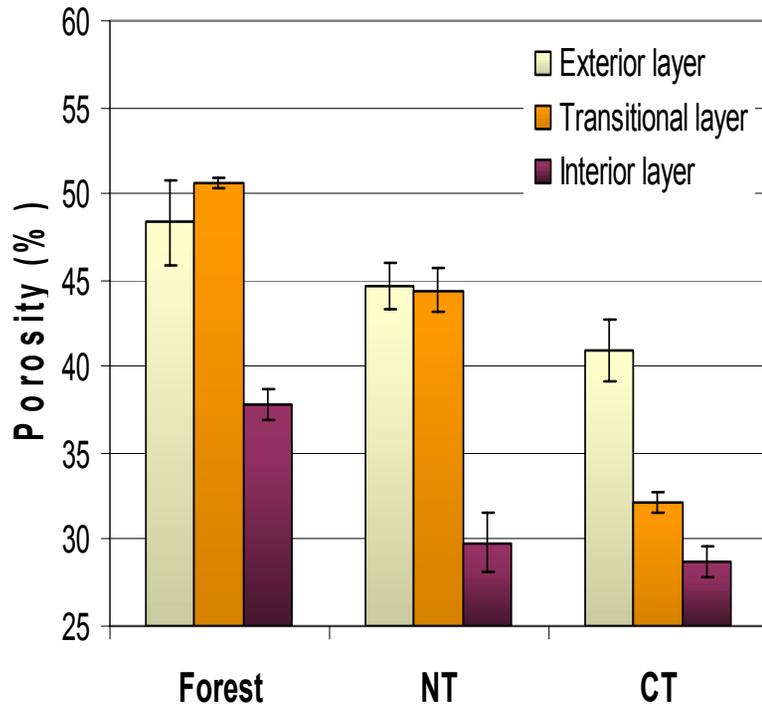


**Fig. 3. Lower C (10.8 g/kg) in Wooster soils (a) resulted in greater erosivity. Greater C (17.8 g/kg) in Hoytville soils (b) resulted in lower erosivity for aggregate sizes: 4.0 - 6.3 mm across.**

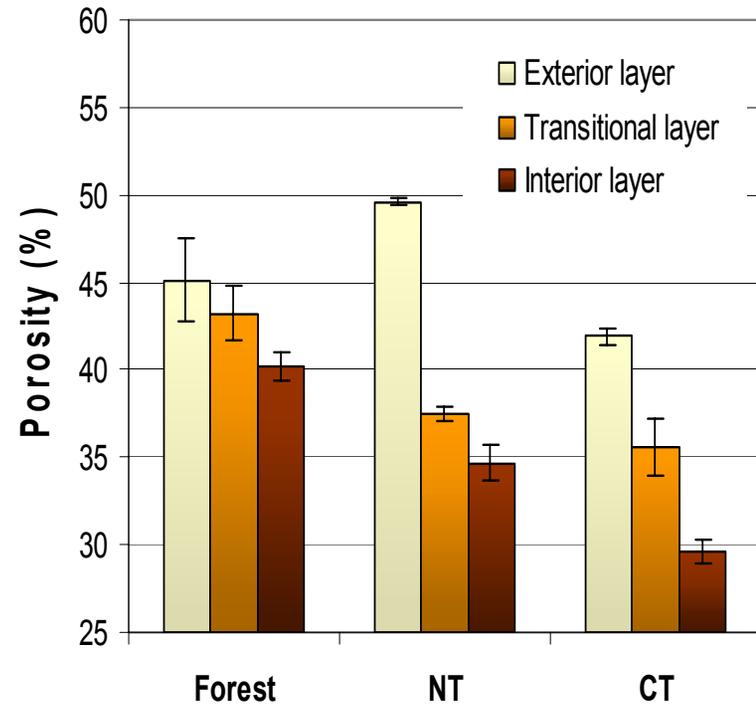


**Fig. 4. Clay contents of aggregates at 0-5 cm depths from Wooster (a) and Hoytville (b) soil series. Bars are standard errors of 3 field replicates (n=10).**

(a)



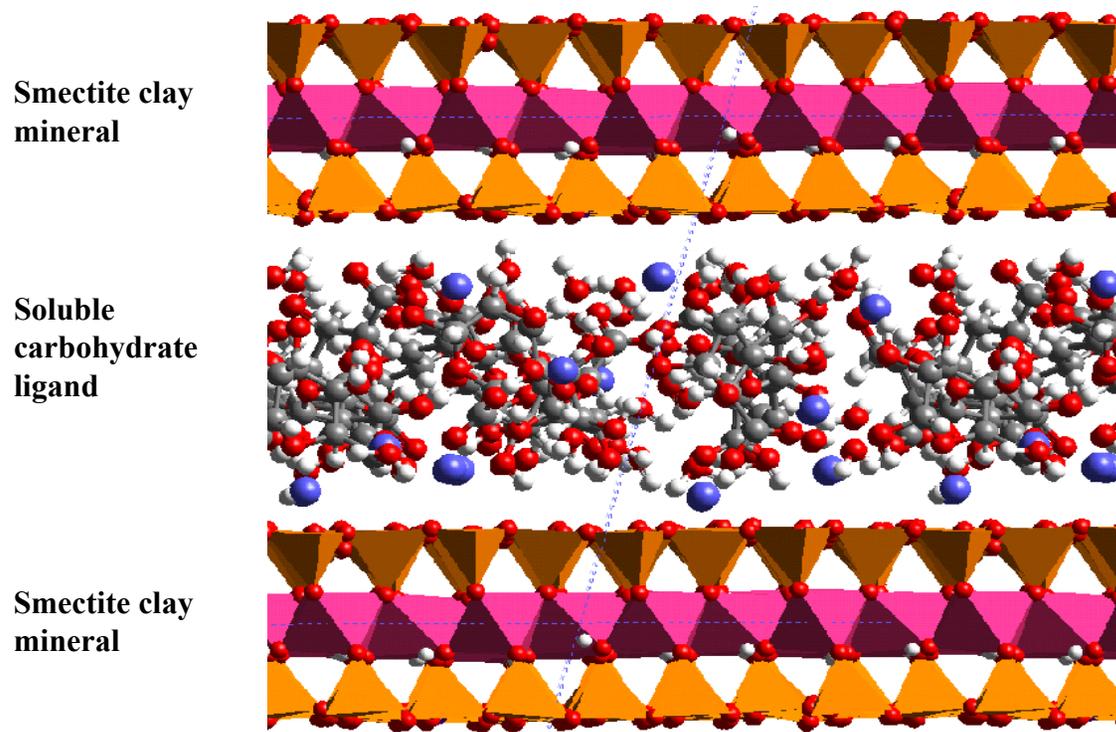
(b)



**Fig. 5. Internal porosity of soil aggregates, 6.3-9.5mm across (a) and 4-6.3 mm across (a) from Wooster, and 6.3-9.5 mm across, from Hoytville (b). Bars are the standard errors of three field replicates (n=10).**

***Biogeochemistries at organo-mineral sites, within micropores of aggregates are strategic mechanisms for increasing soil C sequestration.*** Polymerized galacturonate is a plausible natural organic compound for C sequestration within clay minerals. The polymers bind strongly to divalent cations through chelation with their carboxylate functional groups, Ca-polygalacturonates are known to be significant components of plant and microbial pectins, and clay minerals are known to be strongly selective for chelated divalent cations over unchelated inorganic cations. Joint modeling (Fig. 6) and experimental studies are underway to examine the adsorption of such carbohydrates by clay minerals and relate it to soil structure formation and C sequestration.

**Continuous supplies of soluble organic C (SOC) to the soil solutions which bathe surfaces of soil aggregates, via macropore flow, provide multiple opportunities for the continuous, yet intermittent flow of SOC solutions into soil aggregates having greater internal porosities. NT aggregates containing 6-7% greater porosities appear to sequester greater quantities of C via frequent hydration/dehydration cycles.**



**Fig. 6. Snapshot of a molecular dynamic simulation of a hydrated Ca-smectite intercalating polygalacturonate. Gray atoms are C, red are O, white are H, and blue are Ca.**

**Discussion:** Separate laboratory studies have demonstrated that additions of simulated maize root exudates during nine wetting and drying cycles increased the aggregate stability (MWDs) of NT aggregates 4-fold with concurrent 15 to 70% increases in the soil microbial biomass. Therefore, it is suggested that one mechanism for sequestering greater quantities of C by NT soils is the greater impounding of SOC by interior regions of aggregates which have greater longevity in the absence of tillage. Additionally, decomposing surface plant residues associated with NT management practices, combined with accompanying belowground root biomass supply continuous additions of SOC to soil aggregates in the upper regions of NT soils. Although C respiration rates of NT soils are greater than CT, it appears that more C is being sequestered by NT aggregates than is being lost through respiration. Therefore, we conclude

**Conclusions:** The continuous flow of SOC from above and belowground plant residues penetrates more deeply into soil aggregates, at the rate of approximately 120 microns per week, sequestering more C more deeply within aggregates that are not disturbed by mechanical tillage. This mechanism could also be one explanation for greater C sequestration by soils managed by continuous cover cropping.