Modelling Bulk Density According to Structure Development: Toward an Indicator of Microstructure Development in Ferralsols.

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Ferralsols have a ferralic horizon at some depth between 30 and 200 cm that results from long and intense weathering. Their clay fraction is usually mainly low-activity clay consisting of kaolinite with hematite, goethite and gibbsite in different proportions. Ferralsols show little or no horizonation, and their macrostructure is absent to moderate. On the other hand, they have typically a strong microstructure consisting of microaggregates < 1 mm in size. Because of the lack or small development of macrostructure, porosity of Ferralsols is closely related to the development of microstructure and the assemblage of elementary particles within the microaggregates with a small contribution of large pores resulting from root development and macrofaunal activity. Their physical properties are then closely related to the development of this microstructure. However, there is still no model in the literature that predicts changes of microstructure of these soils using easily accessible soil properties when land-use is modified. The objective of this work was to relate microstructure development to the bulk density (D_b) in Ferralsols and then to make possible the use of D_b as an indicator of microstructure development.

Ferralsols under native vegetation and cultivated pasture were sampled in the Brazilian Cerrado region. Bulk density, sand, silt, and clay content and aggregate size distribution were measured from the surface to 1.6 m depth with increments of 0.1 m. Thin sections were prepared from undisturbed samples collected at different depths and backscattered electron scanning images (BESI) were generated.

Results showed that clay content ranged from 18.6 to 79.8 % and bulk density between 0.80 and 1.25 g cm^{-3} among the 108 samples studied. Visual assessment of BESI showed that soil material corresponded to either microaggregates (0.1 to 0.5 mm in size) in loose arrangement or to microaggregates in close arrangement forming much larger aggregates (> 5 mm). From calculations with D_b we demonstrated that the pore volume of the microaggregates (V_p in cm^3 g^{-1}) can be described by a single linear relationship with the clay content whatever the type of microaggregate arrangement and land use (V_p = 0.003 %clay + 0.0029, R^2 = 0.99). Accurate analysis of the microaggregate size showed that 96.2 and 95.7 % of microaggregates were < 0.8 mm with 73.2 and 95.7 % between 0.1 and 0.5 mm under native vegetation and pasture, respectively. The mass proportion of microaggregates in loose arrangement was estimated for a subset of clayey Ferralsols using the < 0.8 mm soil material that was obtained by dry sieving ($\Phi_{<0.8}$). Linear regression coefficients were calculated for the relationship between $\Phi_{<0.8}$ and the reciprocal of bulk density (1 / D_b) ($\Phi_{<0.8}$ = 1.97 (1 / D_b) – 1.52, R^2 = 0.82), assuming no interaction between microaggregates in loose arrangement and those in close arrangement forming the aggregates > 5 mm in size. The porosity of these two arrangements was estimated as 0.71 and 0.51, respectively.

Thus, D_b can then be used as single indicator of microstructure development in clayey Ferralsols with 70 < clay content < 80 %. For Ferralsols with a smaller clay content, D_b corrected by the clay content can also be used as an indicator of microstructure development. Thus, whatever the clay content, D_b might be discussed in term of consequences of agriculture practices on microstructure development, making easier to infer consequences for other physical properties such as resistance to penetration, water retention and hydraulic conductivity.

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Abstracts

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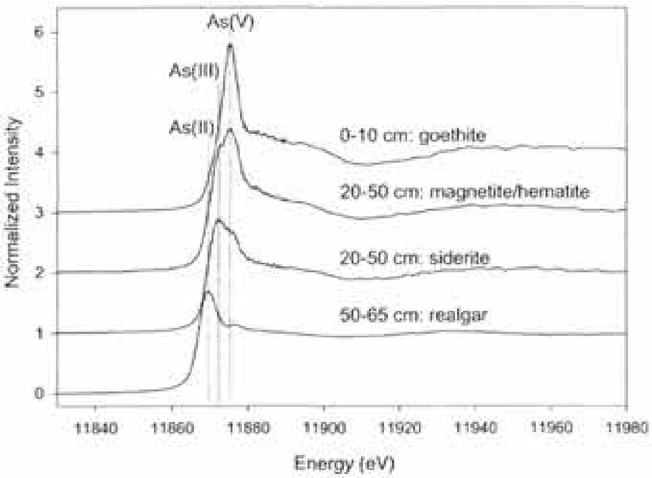

63-11 652a A. Dathe

Direct Observation and Quantification of Colloid Retention in Unsaturated Porous Media.

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Colloid transport through the vadose zone is of growing concern in recent years. Non-water-soluble contaminants can enter an aquifer very quickly (colloidal facilitated transport) or colloids can be pathogens itself (for example Cryptosporidium parvum), thus yielding the risk of polluting drinking water. Little is known about the complex mechanisms of transport and retention of colloids at the pore scale in soils. Measurements of colloid and microbial transport have been limited to the evaluation of breakthrough curves from column experiments in which only an integrated signal of all retention processes in the column is obtained or to the visualization in micromodels with limited applicability to realistic conditions. The objective in this presentation is to observe and model colloid transport and retention on the pore scale. Flow experiments were run in a horizontal flow chamber using clean quartz sand as porous medium and synthetic fluorescent microspheres or bacteria (Escherichia coli, containing a green florescent protein) as colloids. The water phase was stained with Rhodamine B. In order to establish unsaturated conditions, porous plates were mounted at the inlet and outlet of the chamber. The chamber was mounted under a Laser Scanning Confocal Microscope (Leica TCS SP2) which allows the acquisition of time series and 3D reconstruction of pore-scale images. Three spectral channels were used: a 488 nm (argon) line excites the colloid fluorescence, a 543 nm green (HeNe) line excites Rhodamine B fluorescence, and a transmitted light channel detects the reflectance of laser light at the grain surfaces. Thus, three 8 bit images were detected simultaneously for every time step. The system is also capable of obtaining image stacks in the z-direction, which allows the determination of the position of attached colloids relative to the interface between air, water menisci, and solid grains. The 3D z-stacks reveal that the colloids are attaching at the air/water meniscus/solid (AWmS) interface, where the water menisci diminish into a thin film covering the grains. Methods of digital image analysis are presented for quantification of the number and area of moving and retained colloids. After thresholding, binary images are obtained. Colloids that appear at the exact same position in two consecutive images are counted as attached. The results show that once the first colloid is attached at the AWmS interface, the attachment rate increases until the number of locations where the colloids can be attached near other colloids becomes limiting. The attachment continues until there is no space for the colloids to attach anymore. A theoretical model is presented that is capable of predicting the observed colloid attachment processes. Forces acting on the colloids are discussed.

63-12 652b W. Bleam

Iron L-edge and K-edge X-ray Absorption Studies of Nontronite Reduction.

O. Li, Univ of Wisconsin; K. Lee, Univ of Illinois at Urbana-Champaign; J. Kostka, Florida State Univ; J. W. Stucki, Univ of Illinois at Urbana-Champaign; W. Bleam, Univ. of Wisconsin.

The reduction and re-oxidation of the iron-rich smectite mineral nontronite causes changes in short-range structure discernible by polarized extended x-ray absorption fine structure (EXAFS) spectroscopy. Reduction causes shifts that indicate internuclear distance changes and a broadening in the overall EXAFS spectrum caused by increased structural disorder. Re-oxidation in air restores the nontronite EXAFS spectrum but not to its original state. Non-reversible structural changes occur mainly during the first reduction cycle; peak width and intensity after a second redox cycle resemble values observed after the first reduction cycle. No differences appear in the polarized EXAFS spectra of nontronite samples reduced by Shewanella oneidensis when compared to samples reduced by sodium dithionite. We also evaluate the iron-migration hypothesis that predicts a significant redistribution of octahedral iron during nontronite reduction. Our polarized EXAFS data and analysis fails to support this hypothesis and proposes a different structural model for ferrous nontronite. Previous studies show iron L-edge XANES is very sensitive to spin state, crystal field strength and symmetry. Our results demonstrate iron reduction changes the intensity but not the position of two peaks dominating x-ray absorption at the L3-edge. The intensity ratio of these two peaks is linearly correlated with the iron oxidation state in the clay, permitting us quantify the Fe(II)/Fe(III) ratio using Fe L3-edge XANES spectroscopy.

Session Number 64

Thursday, 13 July 2006

2.1A Soil Structuring as a Dynamic Process and Particles Transfer—Oral

Room 108AB, First Floor (Convention Center)

64-1 10:15 AM R. Horn

Stress Strain Effects on Coupled Mechanical and Hydraulic Processes.

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The stress strain processes in structured unsaturated arable and forest soils depend very much on the internal soil strength and on the existing hydraulic and mechanical boundary conditions. These variables affect soil deformation by compaction and shearing to a great extent. As soon as the internal soil strength, defined as the precompression stress value, is exceeded by external forces, an intense virgin compression process occurs in combination with shearing forces at high pore water pressure values. These processes result in a complete homogenisation of the soil profile down to a certain depth. Consequently both the hydraulic and the gas fluxes are affected which results in an intense alteration of ecological and mechanical properties of the site due to enhanced swelling and shrinkage. The consequences of such compaction and shearing on soil hydraulic functions and on the rigidity of pore systems must be analysed and considered also with respect to model water fluxes. **Keywords:** mechanical strength, shear stress, precompression stress, swelling and shrinkage, structured soils, pore size distribution, hydraulic conductivity, modelling.

64-2 10:45 AM A. Bruand

Modelling Bulk Density According to Structure Development: Toward an Indicator of Microstructure Development in Ferralsols.

A. Bruand, Université d'Orléans; L. C. Balbino, EMBRAPA Arroz e Feijão; N. Volland-Tuduri, Université d'Orléans; I. Cousin, INRA; A. Reatto-Braga, EMBRAPA Cerrados; M. I. Lopes de Oliviera, EMBRAPA Cerrados; E. De Souza Martins, EMBRAPA Cerrados; M. Brossard, IRD; J. R. DISNAR, CNRS.

Ferralsols have a ferralic horizon at some depth between 30 and 200 cm that results from long and intense weathering. Their clay fraction is usually mainly low-activity clay consisting of kaolinite with hematite, goethite and gibbsite in different proportions. Ferralsols show little or no horizonation, and their macrostructure is absent to moderate. On the other hand, they have typically a strong microstructure consisting of microaggregates < 1 mm in size. Because of the lack or small development of macrostructure, porosity of Ferralsols is closely related to the development of microstructure and the assemblage of elementary particles within the microaggregates with a small contribution of large pores resulting from root development and macrofaunal activity. Their physical properties are then closely related to the development of this microstructure. However, there is still no model in the literature that predicts changes of microstructure of these soils using easily accessible soil properties when land-use is modified. The objective of this work was to relate microstructure development to the bulk density (D_b) in Ferralsols and then to make possible the use of D_b as an indicator of microstructure development. Ferralsols under native vegetation and cultivated pasture were sampled in the Brazilian Cerrado region. Bulk density, sand, silt, and clay content and aggregate size distribution were measured from the surface to 1.6 m depth with increments of 0.1 m. Thin sections were prepared from undisturbed samples collected at different depths and backscattered electron scanning images (BESI) were generated. Results showed that clay content ranged from 18.6 to 79.8 % and bulk density between 0.80 and 1.25 g cm^{-3} among the 108 samples studied. Visual assessment of BESI showed that soil material corresponded to either microaggregates (0.1 to 0.5 mm in size) in loose arrangement or to microaggregates in close arrangement forming much larger aggregates (> 5 mm). From calculations with D_b we demonstrated that the pore volume of the microaggregates (V_p in cm^3 g^{-1}) can be described by a single linear relationship with the clay content whatever the type of microaggregate arrangement and land use (V_p = 0.003 %clay + 0.0029, R^2 = 0.99). Accurate analysis of the microaggregate size showed that 96.2 and 95.7 % of microaggregates were < 0.8 mm with 73.2 and 95.7 % between 0.1 and 0.5 mm under native vegetation and pasture, respectively. The mass proportion of microaggregates in loose arrangement was estimated for a subset of clayey Ferralsols using the < 0.8 mm soil material that was obtained by dry sieving ($\Phi_{<0.8}$). Linear regression coefficients were calculated for the relationship between $\Phi_{<0.8}$ and the reciprocal of bulk density ($1 / D_b$) ($\Phi_{<0.8} = 1.97 (1 / D_b) - 1.52$, $R^2 = 0.82$), assuming no interaction between microaggregates in loose arrangement and those in close arrangement forming the aggregates > 5 mm in size. The porosity of these two arrangements was estimated as 0.71 and 0.51, respectively. Thus, D_b can then be used as single indicator of microstructure development in clayey Ferralsols with 70 < clay content < 80 %. For Ferralsols with a smaller clay content, D_b corrected by the clay content can also be used as an indicator of microstructure development. Thus, whatever the clay content, D_b might be discussed in term of consequences of agriculture practices on microstructure development, making easier to infer consequences for other physical properties such as resistance to penetration, water retention and hydraulic conductivity.

64-3 11:05 AM A. Eynard

Soil Wettability Relationships with Soil Organic Carbon and Aggregate Stability.

A. Eynard, T. E. Schumacher, R. A. Kohl, D. D. Malo, South Dakota State Univ.

Soil wettability is a dynamic soil property, which results from complex interactions between many other physical and chemical properties. As opposed to water repellency, soil wettability defines the ability of the soil to intake water. The term hydrophilicity (antonym of hydrophobicity) strictly refers to the molecular origin of soil surface-water interactions determined by the physiochemical nature of the structure of soil surfaces. Wettability can be measured as a wetting rate, which is affected by the organic and mineral composition of the soil surfaces (hydrophilic and/or hydrophobic) and by the structural arrangement of soil components (solids, water solution, and air) at larger scale. At a molecular scale the composition of solid surface-exposed chemical groups (hydrophilic and/or hydrophobic) and their packing density determine wettability. At a scale ranging from soil aggregates to pedons to fields and larger soil units the spatial distribution and composition of soil particles and pores determine wettability. The pattern of wettability at different depths in the profile and at different landscape positions on the land surface determines the differences in wettability of fields, landscapes and regions. Soil porosity and soil pore characteristics determine wettability both by contributing to the water potential gradient and by determining the hydraulic conductivity. Water tension determines the hydraulic gradient, which controls the forces acting on the pore walls during wetting and may drastically change the porosity and dismantle the aggregate structure. Soil management practices affect soil pores directly through traffic and tillage, and indirectly through addition and removal of soil organic C. A clear relationship between organic C and wettability becomes evident when organic C is the dominant difference between soils while other properties such as clay content are similar. Soil organic C is one of the most effective tools for managing wettability. Soil organic C amount, quality and location within the soil structure are key factors of aggregate stability and aggregate wettability. Wettability is a desirable property for agricultural soils when it is related to stable porosity, as may be found in high organic matter soils (e.g., grasslands). Wettability is excessive when fast aggregate wetting results in aggregate destruction as observed in low organic matter cultivated soils. Wettability is too low when organic matter coatings on soil minerals make soil surfaces hydrophobic precluding soil water entry. Deposition of volatilized compounds after fire, patches of oil spills, thick layers of partially decomposed litter deposits and areas where dominant fungal growth produces high concentration of hydrophobic organic compounds are cases where increasing organic C decreases soil wettability. However in most agricultural soils, increased amounts of organic C tends to increase soil wettability, except when the location of the organic soil constituents prevents structural failure and soil dispersion during rapid wetting at low water tension. Different wettabilities result from differences in structural stability (pore stability) during wetting, while structural stability changes with wettability (rate of wetting). Therefore measurements of structural stability such as wet aggregate stability tests are a partial characterization of soil wetting behavior. Wet aggregate stability determined by directly wet-sieving air dry soil without any prewetting treatment subjects aggregates to sudden wetting at 0 water tension. Additional stress on aggregates are created by the scouring action of turbulent water and by the abrasion of aggregates during shaking. Other methods for measuring may add stress on the aggregate by the beating action of simulated raindrops but a major part of the measurement is a wettability measurement. A complex of soil properties contributes to wettability so that there is a lack of a unique simple relationship. Therefore, wettability measurements by simple tests (such as the water drop penetration time (WDPT) or the wetting rate under tension by the Büchner funnel apparatus) can integrate information on soil quality and support land management choices.

64-4 11:25 AM D. J. Cosentino

Predicting Short-term Aggregate Stability Dynamics After the Addition of Maize Straw. The Role of Hydrophobicity.

D. J. Cosentino, INRA; C. Chenu, UMR Biogeochimie des Milieux Continentaux; P. Hallett, Scottish Crop Research Institute; D. Tessier, INRA; J. C. Michel, INRA.

Northern Europe has wide distribution of silty agricultural soils with a fragile and unstable aggregated structure. Water is the main agent of aggregate breakdown through the mechanisms of slaking, differential swelling and mechanical rupture. Of the factors influencing aggregate stability, organic matter has a predominant role, particularly by the stimulation of microbial activity. Microbial exudates are know to stabilize soil by bonding soil particles, but another mechanism that has received less attention is an increase to hydrophobicity. Stabilization by organic matter additions is highly temporal and difficult to predict. This is primarily due to the complexity of the processes and large number of variables involved (quantity and quality of OM, internal soil characteristics, climate and management). Straw incorporation, for instance, will help stabilize fragile soils, but the long-term impacts are not understood. The objective of this work was to establish, in controlled conditions, quantitative relationships between rate of straw additions to soil and the temporal evolution of aggregate stability and the main microbial agents. Here, we focused on the evolution of hydrophobicity. Different doses of maize straw (from 0 to 20 gC kg^{-1} soil) were added to 3-5 mm silty soil aggregates. Soil was incubated in jars at 20°C during 8 months at -10 kPa. At different incubation times we measured total respiration, microbial biomass carbon, ergosterol content (as a biomarker of fungi), soil water repellency, and aggregate stability. We used the slaking test from the aggregate stability method of Le Bissonnais (1996). We determined the water repellency of aggregates using two methods: water drop penetration time (WDPT) (Chenu et al., 2000) and microinfiltration with two liquids, water and ethanol (Repellency Index – R) (Hallett and Young, 1999). Over the very wide range of doses of C input used in this study, aggregate stability towards slaking, microbiological variables and water repellency responded positively and proportionally to the C added after one week of incubation. After adding 20 gC kg-1 soil the aggregates developed a truly hydrophobic character with WDPT of ~70s and R of ~13, whereas the reference sample (no straw addition) exhibited wettable behavior with WDPT< 2s and R of ~2. The repellency index correlated well with ergosterol content, which suggests that fungi play a major role in hydrophobicity. After one month, aggregate stability and ergosterol content were still proportional to the doses of C added, but hydrophobicity decreased suggesting that its contribution to aggregate stability at this stage is less important. Both repellency methods were very well correlated ($R^2 = 0.953$). We conclude that the decomposition of plant residue in soil induced aggregate stabilization at least partly due to fungal induced repellency. Furthermore, fungal mediated hydrophobicity and fungal mediated physical entanglement of aggregates do not have the same temporal dynamics after organic matter additions.

64-5 11:45 AM A. Papadopoulos

Quantifying Physical Aspects of Soil Quality Associated with Organic Agricultural Practices.

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Soil structure determines the operating environment for all physical, chemical and biological processes within the soil. In particular, it determines the accessibility of air, water and nutrients for plant roots, as well as seedling emergence and root penetration. The aim of this research was to investigate the effects of organic farming practices on developing and maintaining soil structure and compare them with conventional practices. The study involved implementing quantified image analysis of soil structure at a number of scales of observations (macro to micro) in both two and three dimensions. Soil images were acquired from X-ray Computed Tomography (CT), undisturbed polished soil blocks and soil thin sections (Fig. 1). Key soil physical and chemical properties such as soil organic matter, aggregate stability, hydraulic conductivity, bulk density, soil penetration resistance and water release characteristics were also measured. Soil porosity, pore size distribution and pore perimeter data were collected and fractal geometry was used to characterise pore roughness. Soil samples were obtained from experimental organic sites across the UK, from contrasting soil textures. In conventionally cultivated soils, the pore size distribution was dominated by small number of large pores (>800 µm), while organically cultivated soils exhibited a broader range of pore sizes. Organically managed soils had higher aggregate stability than conventionally managed soils ($P<0.05$). Where clover (Trifolium pratense) was involved in the organic crop rotation, a significant increase in soil macroporosity occurred consisting of increased roughness of macropores (fractal dimension = 1.45) in the top 5 cm of soil. An understanding of how soil structure is affected by the different farming practices and the impact of structural developments on soil function is vital for sustainable land management.