# 2015 GSA Annual Meeting Planner for Susquehanna Shale Hills Critical Zone Observatory

## *Baltimore, Maryland, USA*

**(1-4 November 2015)**

***Monday, 2 November 2015***

Paper No. 172-4
Presentation Time: 2:25 PM

# IMPORTANCE OF VEGETATION FOR MANGANESE CYCLING IN FORESTED WATERSHEDS

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Ecosystems throughout the world are experiencing significant biogeochemical perturbation from anthropogenic activities. As one example, manganese (Mn) is enriched in surface soils at the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO) in Pennsylvania due to past atmospheric inputs from industrial sources. At the SSHCZO, large quantities of Mn that are leached from soil components into solution are taken up by vegetation each year; as a result, only relatively small quantities of Mn are transferred from hillslopes into the stream. Here, we combined mass balance models at the containerized seedling (mesocosm) and pedon-scales with synchrotron-source spectroscopies (X-ray fluorescence and X-ray absorption near edge structure) to examine Mn geochemistry in the soil-plant system and the impact of vegetation on Mn transport in forested catchments.

Manganese uptake into vegetation exceeded Mn losses in soil leachate, and net Mn loss from soils decreased in the presence of vegetation due to uptake into plant tissues. Since Mn is a micronutrient for plants, it is not expected to be taken up in large quantities; yet the ratio of uptake to leaching was higher for Mn (~20-200X) than for major plant nutrients (Ca, Mg, and K) and other metal cations (Fe and Al) (<5X). Given these observations, we conclude that vegetation exerts a stronger influence on the cycling of Mn than other major cations in this ecosystem. In contrast, Na did not accumulate in plant tissue and was preferentially lost in soil leachate. Tree roots and leaves were dominated by soluble Mn(II) that was rapidly oxidized and immobilized as Mn(III/IV)-oxides during decomposition of roots and leaves. Therefore, biological cycling slows the loss of Mn from watersheds because trees take up dissolved Mn from the soil and store it in biomass for years to decades. Mn that is stored in biomass is oxidized and immobilized as Mn-oxides in the soil during decomposition. This study demonstrates that vegetation plays an important role in controlling the Mn retention in watersheds, and that certain types of vegetation, such as the temperate forest studied here, have the ability to slow the rate that Mn is transferred from soils into water systems.

Session No. 172

T204. The Reactive Soil: Processes at the Bio-Geo Interface in the Rhizosphere
Monday, 2 November 2015: 1:30 PM-5:30 PM
Room 343 (Baltimore Convention Center)
Geological Society of America *Abstracts with Programs.* Vol. 47, No. 7, p.442

## ***Tuesday, 3 November 2015***

Paper No. 201-5
Presentation Time: 9:00 AM

# SOIL ARCHITECTURE AND PREFERENTIAL FLOW ACROSS SCALES

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In the spectrum of things in nature that range from nonliving to living, soils fall right in the middle – functioning as the bridge between the biotic and the abiotic worlds and possessing enormous internal power as the nurturing ground for life. The co-evolution of fast and slow processes in soils is the nature's way of sustainable development, where hidden forces drive natural succession and non-closed fluxes lead to structural and informational accumulation in soil profiles. A new kind of physics is needed to enhance the understanding of complex soil systems, including the internal organization of soils in response to perturbations and the medium number syndrome (i.e., systems too complex for classical analytics and too organized for statistical treatment). This presentation will illustrate the new kind of physics needed for enhanced understanding and modeling of soil architecture and preferential flow across scales.

Session No. 201

T200. Landscape Dynamics: Integrating Soils, Hydrology, and Climatic Processes to Understand Weathering, Sediment Transport and Biospheric Processes
Tuesday, 3 November 2015: 8:00 AM-12:00 PM
Room 336 (Baltimore Convention Center)
Geological Society of America *Abstracts with Programs.* Vol. 47, No. 7, p.508

***Tuesday, 3 November 2015***

Paper No. 214-2
Presentation Time: 9:00 AM-6:30 PM

# INVESTIGATION OF A RELICT PERIGLACIAL FEATURE: HICKORY RUN BOULDER FIELD, HICKORY RUN STATE PARK, PENNSYLVANIA

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The centerpiece of Hickory Run State Park is a prominent, 1 km-long expanse of boulders located just south of the Last Glacial Maximum boundary in the Appalachian Plateau province, northern Carbon County, Pennsylvania. Designated as a National Natural Landmark, this gently sloping (<1°) deposit of angular to sub-rounded sandstone and conglomerate clasts, many of which are up to several meters long, is revered for its enigmatic beauty. Although periglacial processes have been invoked to explain the formation and transport of the boulders, it has yet to be shown whether the field developed solely during the LGM, or whether it originated considerably earlier and has evolved over multiple glacial/interglacial cycles. Here we report on the remote sensing techniques we used to develop a sampling strategy for cosmogenic nuclide analysis with the goal of understanding the age and history of the boulder field.

Using eCognition, an automated classification program, along with aerial imagery taken by a UAV, we analyzed trends in size, roundness, and orientation of boulders. Results show a decrease in size and an increase in boulder alignment and roundness down the primary axis of the field. While collecting samples, we observed large blocks on top of small, polished cobbles, and groundwater flowing beneath much of the field and adjacent wooded areas. We hypothesize that block roundness is an indicator of increased age, and that boulder alignment is indicative of downslope transport, perhaps facilitated by subsurface water. The nearby forest is encroaching on the boulder field, with duff forming soils between blocks; we hypothesize that these forest blocks may have been the first to cease movement, and blocks in the main body of the field may have different, perhaps shorter, and likely more dynamic exposure histories.

To test these hypotheses, we sampled boulders (n=53) in transects across the boulder field, in the surrounding forest, and on nearby tors (which some believe are the source of the field) for cosmogenic 10-Be and 26-Al analysis; extractions are in progress. Results will be used to test for patterns of boulder age downslope, differences in age between the forest and field, complex burial history (i.e. shielding by ice, toppling of blocks), and will also suggest whether blocks originated on nearby hillslopes or formed in-situ.

Session No. 214--Booth# 216

T57. Soil to Sediment and Channels—From Geologic to Modern Time Scales: A Session to Honor the Work of Milan Pavich (Posters)
Tuesday, 3 November 2015: 9:00 AM-6:30 PM
Exhibit Hall (Baltimore Convention Center)
Geological Society of America *Abstracts with Programs.* Vol. 47, No. 7, p.550

## ***Wednesday, 4 November 2015***

Paper No. 333-1
Presentation Time: 1:35 PM

# PREDICTIVE UNDERSTANDING OF BIOGEOCHEMICAL REACTIONS IN HETEROGENEOUS POROUS MEDIA

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Water-rock-microbe interactions play a pivotal role in applications relevant to energy, water, and environment. It is important to understand, quantify, and predict biogeochemical processes in shallow critical zones as well as in deep oil and gas reservoirs. The extent and rates of these interactions are dictated by an array of factors including reactive mineral abundance, water flow, and spatial patterns that regulate water distribution. In this talk I will share some thoughts learned from our recent work on the role of spatial heterogeneities in determining biogeochemical reactions integrating column experiments (tens of centimeters), field studies (tens of meters), and reactive transport modeling. At the column scale, flow-through experiments and modeling have shed lights on how spatial patterns of magnesite dictate its dissolution rates under a variety of flow velocity and permeability contrast conditions. At the field scale, the spatial distribution of water-conducting properties and mineral reactivity synergize to govern where, when, and how much microbe-mediated bioreduction (sulfate-reducing and iron-reducing) reactions occur in engineered uranium bioremediation experiments at Rifle, CO. At both scales, a relatively small proportion of the reactive minerals effectively participate in reactions; reaction rates are highest when the characteristics of spatial heterogeneities maximize the water conducted through the biogeochemically-active zones. Insights gained here have interesting implications for applications relative to water, energy, and environment.

Session No. 333

T100. Advances in Groundwater Modeling
Wednesday, 4 November 2015: 1:30 PM-5:30 PM
Room 341 (Baltimore Convention Center)
Geological Society of America *Abstracts with Programs.* Vol. 47, No. 7, p.838

***Wednesday, 4 November 2015***

Paper No. 329-3
Presentation Time: 2:30 PM

# TOPOGRAPHIC FINGERPRINTS OF MICRO-CLIMATE AND LITHOLOGY IN THE CENTRAL APPALACHIANS

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To elucidate the roles of climate, tectonics, and lithology in controlling topographic evolution in the central Appalachians, we combine high resolution, LiDAR-derived digital topography and the cosmogenic radionuclide $^{10}$Be to measure rates of regolith transport and erosion. We employ these to test transport rules at the Shale Hills Critical Zone Observatory (SSHO) and 27 other first-order watersheds in the Susquehanna River Basin (SRB). Our results from SSHO imply that subtle differences in insolation between north- and south-facing slopes impact the frequency of dilational regolith transport processes (e.g., freezing-thawing cycles), which in turn modulates the efficiency of regolith production and downslope transport. As a result, lower hillslope gradients evolve on south-facing hillslopes as compared to their north-facing counterparts. Despite this asymmetry, mass fluxes are equivalent on north- and south-facing hillslopes, and correspond with catchment-wide lowering rates of 20 – 30 m/My. Comparisons of $^{10}$Be-derived erosion rates with ridgetop curvature measurements suggest near-equilibrium topography at SSHO. Comparison of $^{10}$Be-derived erosion rates and ridgetop curvature measurements at other watersheds in the SRB suggests that regolith diffusivity is similar on ridgetops formed in Piedmont schists, Valley and Ridge shales, and Valley and Ridge sandstones. Watersheds in the Appalachian Plateau, however, exhibit characteristics of a recent transient increase in erosion rate, indicating that ridgetop curvature and erosion rates are out of equilibrium. Our results suggest that tectonic influence persists in the Appalachian Plateau, where elsewhere the history of periglacial climate sets topographic expression.

Session No. 329

P5. Appalachian Geomorphology II
Wednesday, 4 November 2015: 1:30 PM-5:30 PM
Room 327/328/329 (Baltimore Convention Center)
Geological Society of America *Abstracts with Programs.* Vol. 47, No. 7, p.831

## *Wednesday, 4 November 2015*

Paper No. 329-4
Presentation Time: 3:15 PM

# REGOLITH PRODUCTION AND TRANSPORT IN THE SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY: INSIGHTS FROM U-SERIES ISOTOPES

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Regolith production contributes to important Critical Zone processes such as nutrient cycling, carbon sequestration, and erosion. Over the long term, the rates of regolith production and erosion combine with tectonic uplift to control the evolution of landscapes. Uranium-series isotopes offer one of the few available but powerful tools to quantify regolith production rates and timescales. Here, we present a study of U-series isotopes in regolith developed on shale bedrock at the Shale Hills Critical Zone Observatory in central Appalachian region. To investigate the timescales of regolith formation on hillslopes with contrasting topographic aspect, we measured U-series isotopes in regolith profiles from north- and south-facing hillslopes. The north-facing hillslope has a slope gradient of ~20°, slightly steeper than the south-facing hillslope (~15°). The regolith samples display significant U-series disequilibria resulting from shale weathering. Based on the U-series data, the rates of regolith production on the two ridgetops are indistinguishable (40±22 vs. 45±12 m/Ma). However, at downslope positions, the regolith profiles on the south-facing hillslope are characterized by faster regolith production rates (50±15 to 52±15 m/Ma) and shorter weathering durations (12±3 to16±5 ka) than those on the north-facing hillslope (17±14 to 18±13m/Ma and 39±20 to 43±20 ka). The south-facing hillslope is also characterized by faster chemical weathering rates inferred from major element chemistry in regolith. These results suggest an influence of aspect on regolith formation: aspect affects such variables as temperature, moisture content, and evapotranspiration in the regolith zone, causing faster chemical weathering and regolith formation rates on the south-facing side of the catchment. Such a difference is inferred to have been especially significant during the periglacial period (~15 ka). At that time, the erosion may have denuded the south-facing hillslope of regolith but not quite stripped the north-facing hillslope. A linear mass transport model of

hillslope evolution and response timescales shows that the ridge tops of Shale Hills are in geomorphologic steady state but the current landscape on the hillslopes is likely disturbed by the climate shift of the Holocene periglacial conditions.

Session No. 329

P5. Appalachian Geomorphology II
Wednesday, 4 November 2015: 1:30 PM-5:30 PM
Room 327/328/329 (Baltimore Convention Center)
Geological Society of America *Abstracts with Programs.* Vol. 47, No. 7, p.832

## ***Wednesday, 4 November 2015***

Paper No. 329-5
Presentation Time: 3:45 PM

# TOPOGRAPHIC AND COLLUVIAL SIGNATURES OF LITHOLOGY, BASE LEVEL, AND CLIMATE IN THE SHAVERS CREEK WATERSHED, PENNSYLVANIA

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Integrative models of critical zone processes aim to provide a framework for interpreting the climatic and tectonic histories of landscapes over geologic time, and for predicting landscape and ecosystem response to short-term changes in climate and land use. At the Susquehanna Shale Hills Critical Zone Observatory in central Pennsylvania, the overprinting of structural, lithologic, climatic, and base level controls on landscape form present both challenges and opportunities for testing such critical zone models. Here we present preliminary geomorphic analyses of the Shavers Creek watershed (164 $km^2$), focusing on a comparison of the recently instrumented Garner Run sub-catchment (1 $km^2$; predominately underlain by sandstone bedrock) and the Shale Hills sub-catchment (0.1 $km^2$; underlain by shale bedrock). Using a combination of lidar topographic analysis and detailed field mapping, we note three main observations that merit further research. First, hillslopes at Garner Run are less steep than at Shale Hills, in contrast to expectations of stronger rock supporting steeper topography. We hypothesize that this is due to the isolation of the Garner Run sub-catchment above a prominent stream knickpoint, and that local baselevel fall may be up to three to four times lower than in Shale Hills. Second, there is a strong imprint of Pleistocene periglacial processes at the Garner Run sub-catchment, both in the topographic expression of solifluction lobes, and in the extensive coarse grained colluvium and

boulder fields that cover hillslopes. On these hillslopes, we find aspect and slope-dependent variations in the surface texture and grain size of colluvial material that likely impart a strong control on patterns of infiltration, runoff, and vegetation. Third, throughout Shavers Creek there is a strong lithologic control on drainage density and hillslope length; hillslopes underlain by sandstone are five to ten times as long as shale hillslopes, potentially as a result of the changes in hillslope hydrology described above.

Session No. 329

P5. Appalachian Geomorphology II
Wednesday, 4 November 2015: 1:30 PM-5:30 PM
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