The Pennsylvania State University

GSA Northeastern Section Meeting Planner for Susquehanna Shale Hills Critical Zone Observatory

Lancaster Marriott at Penn Square, Lancaster, PA, USA

2014

SSHCZO Northeastern Section - 49th Annual Meeting (23–25 March)

Sunday, 23 March 2014

Monday, 24 March 2014

BRANTLEY, S.L., LIN, Henry, SULLIVAN, Pamela L., GU, X., HASENMUELLER, Elizabeth A., and KAYE, Jason P. (2014): **EXPLORING HOW ROCK TURNS TO REGOLITH AT THE SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY, CENTRAL PENNSYLVANIA.**

Paper No. 33-1
Presentation Time: 8:05 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract

At the Susquehanna Shale Hills Critical Zone Observatory (CZO) we are investigating the physical and chemical characteristics of Rose Hill formation shale from tens of meters of depth to the land surface. The shale has disaggregated into a layer of augerable soil that mantles the landscape and varies in thickness from tens of centimeters to several meters throughout the watershed. At the ridgetops, this soil largely formed in place, but along hillslopes the soil creeps downslope. Water flow through the unsaturated soil along hillslopes is considered to be largely vertical but flow also occurs laterally at the interfaces of soil horizons marked by permeability contrasts. Water also infiltrates into the fractured bedrock underlying the soil, sometimes by flowing through macropores in the soil that allow water to bypass the porous soil matrix. The shale bedrock contains quartz plus illite, chlorite, and minor feldspar that weather to form secondary clays including kaolinite and interlayered vermiculites. Minor concentrations of pyrite and ankerite are observed at tens of meters of depth under the ridgetops. Depletion of sulfide and carbonate minerals in the upper layers may document reaction fronts that roughly correspond to the regional water table. In other words, infiltration of water may have caused oxidative dissolution of pyrite and ankerite (down to tens of meters of depth under ridgetops and meters beneath the valley floor). Porosity measured in rock chips and core from depth are generally lower than porosity measured in rock chips collected from the soil. Roots are observed to penetrate into the upper fractured layer of bedrock that underlies the augerable soil. The transformation of bedrock to soil in this watershed begins near the regional water table and is accelerated by biological processes at the land surface.

PETERS, Stephen C., PAZZAGLIA, Frank J., BLAKE, Johanna M.T., and DYKMAN, Jordan Nicole, (2014): CHEMICAL WEATHERING AND SOIL FORMATION FROM MULTIPLE PARENT MATERIALS IN CENTRAL PENNSYLVANIA.

Paper No. 33-2
Presentation Time: 8:25 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract
Soil formation can be considered as a sequence of events, including the initial mechanical disaggregation of bedrock and saprolite, followed by transport and deposition of colluvium by multiple processes. Once deposited the regolith undergoes alternating periods of quiescent pedogenesis and disruptive events that rework the soil structure. These events are recorded in hillslope stratigraphy, including their soils and paleosols.

In this work, we report on the evolution of soils developing through complex colluvial stratigraphy at two sites in central Pennsylvania. The hillslope stratigraphy in the Shale Hills CZO consists of thin (< 2 m) shale chip colluvium in the swales and very thin (<1 m) rubble shale colluvium on the interfluves underlain by the Rose Hill Shale. In the Millheim Narrows of central PA thick colluvial wedges (>4m) have been deposited on the Bald Eagle Sandstone.

In the shallow soils of the Shale Hills watershed we find that the bedrock-regolith contact is marked by a thin (several cm) saprolite with distinct gleyed mottles. Above this saprolite, in the swales, is one or more deposits of well-sorted 0.1 – 2 cm angular shale chips, interpreted as periglacial sorted talus (grèzes littés) that can exceed 2 m in thickness. In the thicker soils of the Millheim Narrows site, we find a 2 m thick highly weathered colluvium with saprolitized clasts and a deep red (5 - 2.5YR) color with patchy manganese staining. Above this deposit is a brown colluvium with poorly weathered clasts. We present geochemical and grain size data from these parent materials to illustrate the degree of chemical weathering and pedogenesis and present one possible sequence of events consistent with these deposits.

DYKMAN, Jordan Nicole, PAZZAGLIA, Frank J., PETERS, Stephen C., and BLAKE, Johanna M.T (2014): ALIGNMENT AND DIVERGENCE OF PEDOLOGIC, GEOMORPHIC, AND GEOCHEMICAL DATA FOR HILLSLOPE SOILS IN CENTRAL PA.

Paper No. 33-3
Presentation Time: 8:45 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract
Hillslope form and process in tectonically stable landscapes delicately reflect the driving forces of climate, hydrology and weathering acting on the resisting forces of rock-type and structure. Critical Zone Observatories and surrounding regions offer new opportunities to explore hillslope stratigraphy, including soils and paleosols that are an integrated record of these forces over Pleistocene time scales. We are interested in reconstructing hillslope processes and documenting its steadiness or unsteadiness using the diverse, but complementary data sets of field soil geomorphology and bulk geochemical analysis. We aim to understand how these data sets align or diverge in reconstructing hillslope processes. Here, we report on three hillslopes underlain by variable rock type and exhibiting visually obvious differences in stratigraphy. Within Millheim Narrows thick colluvial wedges (>4m) have been deposited on ridge flanks underlain by Bald Eagle Sandstone. These deposits possess deep-red paleosols with visually distinct horizon boundaries. In contrast, hillslope stratigraphy in the Shale Hills CZO that is underlain by the Rose Hill Shale consists of thin (< 2 m) shale chip colluvium in the swales and very thin (<1 m) rubble shale colluvium on the interfluves.. Similarly, hillslopes in the watershed north of the CZO consist of thin (<1m) rubble shale colluviums that have accumulated in toe slope and valley floor positions. We describe colluvial and soil stratigraphy in the field, using standard NRCS criteria. Soil samples taken at 10 cm intervals were wet sieved for particle size distribution analysis and finely pulverized for bulk geochemistry analysis. The pulverized samples were fluxed with lithium metaborate, dissolved in nitric acid and analyzed by ICP-MS. Resulting tau plots show that there is good correlation among the geochemical and field stratigraphic data for the CZO hillslope stratigraphy despite the fact that these exposures lack the obvious buried soils characteristic of the Millheim Narrows site. We are broadening our geochemical analysis to include iron species with the intent of further developing independent field and geochemical criteria for the determination of diverse hillslope and weathering processes over the time represented by preserved stratigraphy.

WEST, Nicole and KIRBY, Eric (2014): ASYMMETRIC TOPOGRAPHY REFLECTS VARIABLE TRANSPORT EFFICIENCY ON SOIL-MANTLED HILLSLOPES IN THE CENTRAL APPALACHIANS.

Paper No. 33-4
Presentation Time: 9:05 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract
Variations in microclimate and their influence on soil moisture and cohesion are commonly invoked to explain topographic asymmetry in a variety of landscapes. Despite these assertions, no direct measures of erosion or transport efficiency have been reported for hillslopes of opposing aspect in a single valley. Here, we present an analysis of 131 meteoric ^{10}Be measurements from regolith and bedrock to quantify mobile regolith flux and test the utility of different transport rules within the Susquehanna Shale Hills

Critical Zone Observatory (SSHO), in central Pennsylvania. Regolith samples were collected from north- and south-facing hillslopes in three en echelon watersheds in and adjacent to the SSHO. Hillslopes are mantled by thin (30-80 cm), clay-rich, unstructured regolith that directly overlies fractured and weathered bedrock on gently-sloping south-facing hillslopes; on steeper, north-facing hillslopes regolith overlies a 1 – 2 m-thick layer of coarse colluvium. Meteoric ^{10}Be data show that along all six hillslopes, mobile regolith fluxes are similar and increase linearly with distance from ridgecrests. Along ridgelines at SSHO, where mobile regolith thickness is uniformly thin, flux is linearly proportional to local gradient. At lower positions on the hillslopes, where mobile regolith thicknesses are greatest, regolith fluxes depend on both local gradient and the depth of mobile regolith. Our data imply that in order for mobile regolith flux on shallow, south-facing hillslopes to keep pace with fluxes on steep, north-facing hillslopes, transport efficiencies must be greater on south-facing hillslopes by nearly a factor of two. Our results provide systematic evidence that the critical zone responds to aspect-related microclimate differences by modulating transport efficiency. We suggest that the observed topographic asymmetry in these watersheds has evolved as a consequence of sustained differences in the efficiency of regolith transport over geologic time.

WHITE, Tim, SHARKEY, Sarah, and DERE, Ashlee L (2014): ARBORTURBATION RATES IN THE APPALACHIAN MOUNTAINS.

Paper No. 33-5
Presentation Time: 9:25 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract

Arborturbation, or tree throw, the upheaval of soil and sometimes bedrock in the root mass of a fallen tree, is a major process in overturn and downslope transport of soil and shallow bedrock in mountainous regions. Reported here is a quantification of tree throw along a climosequence of 5 sites in the Appalachian Mountains associated with the Susquehanna-Shale Hills Critical Zone Observatory - sites were studied in New York, Pennsylvania, Virginia, Tennessee, and Alabama. The study included field measurements of individual tree throws within a 120-meter diameter search area centered on soil pits on ridges on the Rose Hill Shale and coeval strata of similar composition. The following observations were made for each tree throw observed at each study site: GPS location, tree girth, relative tree age, tree type, dimensions of pit, azimuth of fall, and slope and azimuth of maximum slope. These observations allowed quantification of the volume and distance of transport of sediment per event, and the number of events/area/time.

Slope and prevailing wind direction do not control the majority of arborturbation events in this study. The total number of tree throws decreases while sediment flux by tree throw generally increases from

north to south. Larger trees evacuate larger pits, but interestingly there is no observed increase in the average girth of trees to account for the discrepancy between total tree throws and sediment flux. However, the depth to a root limiting layer and distance from the center of a root wad to the center of an excavated pits increases from north to south – deeper roots excavate more soil and deeper soils generally exist in warmer climates.

The measurements of tree throw help to quantify erosion rates. Specifically, the observations verify formulations of sediment flux due to tree throw as presented in Gabet et al. (2003), The effects of bioturbation on soil processes and sediment transport, Annu. Rev. Earth Planet. Sci., 31, 249-73. The sediment fluxes reported here range from 1.8 X 10-5 m2/m/y to 2.1 X 10-4 m2/m/y. The highest values are comparable to sediment flux rates from tree throw reported in the literature whereas the lower values compare well to long-term erosion rates for the Appalachian Mountains determined using cosmogenic radionuclide analyses.

ANDREWS, Elizabeth M., DERE, Ashlee L., and WHITE, Timothy (2014): IN SITU MEASUREMENTS TO QUANTIFY PRESENT DAY SHALE WEATHERING RATES.

Paper No. 33-6
Presentation Time: 10:00 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract

Direct measurement of weathering rates is a difficult task though the data achieved from such measurements could be invaluable as we strive to understand soil production and erosion rates in the Critical Zone. To study weathering rates, a latitudinal transect of six sites was selected in the Appalachian Mountain region (New York, Virginia, Tennessee and Alabama), with end member sites in Puerto Rico and Wales. All of these locations share a similar shale bedrock parent material while the temperature and average rainfall at each site vary. Small shale chips measuring approximately two centimeters by two centimeters were cleaned and weighed, sewn into mesh bags and inserted at different depths into the wall of soil pits. After two years, the mesh bags were removed from the ground and the shale chips were reweighed to determine two-year mass loss. Subsequently, binocular microscopy was used to compare the before and after characteristics of the shale chips through comparison to photographs taken of each chip prior to burial. Based on observations of lost fragments and excessive mass loss values, 35% of the original buried chips were deemed unusable for our evaluation. The shale chips buried in Wales showed the lowest weathering rates around 10 mg per two years, which is similar to the 2 year mass loss value of 8.1 mg published by earlier researchers. Samples from Puerto Rico have at least two times more mass loss than those from Wales. The Puerto Rico values are also lower than those found for Malaysia by previous researchers, but our microscopic observations indicated soil particles remain bound to the shale chip edges after washing, thus our mass loss values for

Puerto Rico are damped and could in fact be higher. The Appalachian Mountains sites display weathering rates that lie between our end member rates from Wales and Puerto Rico. Admittedly, variability in this data set is high. However, taken on the whole, an average weathering rate of 9.9 m Ma-1 can be calculated from this data set, a number that is comparable to erosion rates calculated using cosmogenic radionuclide assays.

DERE, Ashlee, WHITE, Timothy S., and BRANTLEY, Susan L. (2014): QUANTIFYING SHALE WEATHERING RATES AS A FUNCTION OF CLIMATE.

Paper No. 33-7
Presentation Time: 10:20 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract

Weathering is an important process for landscape evolution in the Critical Zone but rates are not well quantified, especially as a function of climate. A transect of sites with varying mean annual temperature and precipitation has been established in the northern hemisphere as part of the Susquehanna Shale Hills Critical Zone Observatory (SSHO) to investigate the influence of climate on shale weathering. The transect consists of end members in Wales and Puerto Rico as well as sites in the Appalachian Mountains, including New York, Pennsylvania, Virginia, Tennessee and Alabama. All sites are underlain by shale, the dominant lithology amongst sedimentary rocks on Earth and an important parent material weathering to form soil. Weathering rates across these sites were determined using several different approaches. At the coldest and most northerly site in Wales, the only site with over 25 years of weekly stream and precipitation chemistry available, a catchment mass balance approach was used to calculate a shale weathering rate of 7.8 m Ma-1. At all transect sites, weathering rates were calculated for ridgetop and slope topographic positions using soil geochemical profiles. On ridgetops, where water flow is largely vertical through the soil profile, the extent of chemical depletion at the soil surface increases from north to south. We observe a temperature dependence of Na loss, a proxy for feldspar weathering, across the transect with an apparent activation energy of 117 kJ mol-1. Feldspar weathering on ridgetops progresses from kinetically limited (Wales to Alabama) to transport limited in Puerto Rico. In the case of Mg loss, a proxy for chlorite weathering, we also observe a temperature dependence, with an apparent activation energy of 60 kJ mol-1. On slopes, soils show chemical depletion similar to that of the ridgetop profiles but soils are shallow (~70 cm) and thickness does not vary much along the transect. In contrast, the depth of ridgetop soils increases from shallow soils (~ 30 cm) in Wales and Pennsylvania to increasingly deep soils to the south (632 cm in Puerto Rico). These observations can be compared to geochemical models of regolith weathering to better predict the impact of climate change on soil formation and landscape evolution.

SULLIVAN, Pamela L., GODDÉRIS, Yves, SHI, Yuning, SCHOTT, Jacques, DUFFY, C.J., and BRANTLEY, Susan L. (2014): QUANTIFYING CLIMATE CONTROLS ON SHALE WEATHERING IN THE CRITICAL ZONE.

Paper No. 33-8
Presentation Time: 10:40 AM

Session No. 33
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes
Monday, 24 March 2014: 8:00 AM-11:40 AM

Abstract

Comprising 25% of the continental landmass, Shale acts as a major sink of atmospheric CO2 and source of bicarbonate to the ocean. To explore how climate controls shale weathering we link meteorological (NLDAS-2), land-surface hydrological (Flux-PIHM), and geochemical (WITCH) models to project solute fluxes from the critical zone. To explore the effects of climate variables we compared soils on the sun-facing and shaded hillslopes of the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO). By predicting the observed soil water Mg+ concentration, WITCH successfully captured the weathering of the Mg-rich clay minerals (i.e., Illite and Chlorite) found in Shale. Our next steps will be to explore how climate evolution controls shale weathering by comparing soils along a shale ridge top climosequence that spans from Wales to Puerto Rico (Dere et al. 2013). The eventual goal is to utilize our understanding of the climatic controls on shale weathering profiles and solute chemistry from these explorations to "earthcast" the next hundred years.

PITMAN, Lacey, NYQUIST, Jonathan, TORAN, Laura, and LIN, Henry (2014): GROUND-PENETRATING RADAR IMAGES HYDROLOGICAL PROCESSES WITHIN THE UNSATURATED ZONE AT THE SUSQUEHANNA-SHALE HILLS CZO.

Paper No. 57-1
Presentation Time: 1:30 PM-5:35 PM

Session No. 57--Booth# 40
S2A. Origin and Evolution of the Appalachian Critical Zone. I. Physical, Chemical, and Biological Processes (Posters)
Monday, 24 March 2014: 1:30 PM-5:35 PM

Abstract

Dye tracer and ground-penetrating radar (GPR) were used to image preferential flow paths in the unsaturated zone on hillslopes in two adjacent watersheds within the Susquehanna-Shale Hills CZO. At each site we released 50 L of water mixed with brilliant blue dye (4 g/L) into a trench cut perpendicular to the slope to create a line infiltration source (100 cm long by 10 cm wide by 18 cm deep). GPR (800 MHz antennae with constant offset) was used to monitor the movement of the dye tracer down slope on a 100 cm x 20 cm grid with a 5 cm line spacing. The site was then excavated and the stained

pathways photographed. We saw a considerable difference in the pattern of shallow preferential flow between the two sites despite their similar positions on the slope. Both sites showed dye penetrating down to bedrock (~50 cm); however, lateral flow migration between the two sites was different. At the first site lateral flow migration was ~50 cm and was fairly evenly dispersed. At the second site lateral flow was ~35 cm, dye was barely visible until the excavation reached ~10 cm, and there was more evidence of distinct fingering. Factors that may have contributed to the different flow patterns include antecedent soil moisture conditions, soil structure, clay content, sediment size, root density, fracture density and fracture orientation. Comparison of the radargrams with the dye patterns showed that although GPR captured the general extent of the vertical and lateral flow of the dye, it did not have sufficient resolution to resolve the fine scale fingering.

Tuesday, 25 March 2014

SNYDER, Daniel, NEAL, Andrew, and BRANTLEY, Susan (2014): IMPACT OF OIL AND GAS INDUSTRY WASTEWATER ON WATER AND SEDIMENT CHEMISTRY IN ONE STREAM IN WEST-CENTRAL PENNSYLVANIA.

Paper No. 70-12
Presentation Time: 8:00 AM-12:00 PM

Session No. 70--Booth# 55
T22. Marcellus and Utica Shales: Geology, Natural Gas Production, and Water Resources Issues (Posters)
Tuesday, 25 March 2014: 8:00 AM-12:00 PM

Abstract
Hydraulic fracturing fluid is composed of large volumes of water that contain roughly 1% chemical additives, and proppant. Fracking fluid is injected during shale gas development and returns to the land surface mixed with formation waters produced during gas extraction. These waters are treated several ways, including processing at centralized waste treatment (CWT) facilities. Treated wastewater from conventional oil and gas wells are discharged at Blacklick Creek, PA, according to recommended PA water standards. However, the treatment plant has been subject to fines from the EPA. Water and sediment chemistry near the discharge point were tested in several ways: direct measurement of electrical conductivity (EC), UV/visible spectrometry of in-stream water, and laboratory analysis. Laboratory analysis included dissolved organic carbon (DOC), major anions, and cations, and metals. Preliminary results indicated very high salt concentrations downstream from the treatment discharge, and spectral results suggest the presence of organic compounds in the effluent. Water analyses will be compared to chemical analyses of the sediments of the creek.