GSA 2013 Annual Meeting Planner for SSHCZO

125th Anniversary Annual Meeting & Expo

27 – 30 October 2013 Denver, Colorado USA

Monday, 28 October 2013: 8:00 AM-12:00 PM
Colorado Convention Center Room 207

Paper No. 102-5
Presentation Time: 9:10 AM

GEOPHYSICALLY-MONITORED DYE TRACER TEST OF INFILTRATION IN THE UNSATURATED ZONE AT THE SHALE HILLS CZO

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We conducted a dye tracer test of artificial infiltration and monitored the hydrologic process using ground penetrating radar (GPR) on a hillslope at the Shale Hills CZO. After the geophysical surveys were conducted, the site was excavated to photograph the dye pathways. The goal of the project was to improve the understanding of how GPR can be used to interpret infiltration by comparing GPR images and photographed dye pathways and to evaluate the importance of the soil-bedrock interface and saprolite fabric on infiltration pathways. Brilliant blue dye (4 g/L) was used as the tracer, and 50 L was injected into the unsaturated zone through a 1 m long trench on a hillslope. We performed dye injection at two sites, one under wet antecedent conditions and one initially dry. A 3D GPR survey with an 800 MHz antenna was conducted downslope of the trench on a 1 m by 2 m grid at tightly spaced 0.05 m intervals. While GPR does not directly image the dye, its signals respond to changes in soil moisture content and changes in radar propagation in saprolite versus bedrock. Mapping the bedrock is important because its low permeability may control flow paths. The GPR bedrock map shows a highly irregular surface and shallow bedrock (approximately 0.5 m depth). The dye tracer photographs show preferential flow paths at both tracer test sites. Dye pathways were anisotropic and strongly influenced by the saprolite fabric (oriented along strike). Under wet antecedent conditions, dye also followed root traces but under dry conditions, only structural fabric controls were observed. GPR radargrams showed a fingering pattern similar to the dye trace photographs, but with less obvious resolution of the structural fabric. The depth of penetration of the dye (approximately 0.5 m) and lateral migration (about 0.2 m) were also captured by the radargrams. Although the depth of penetration was controlled by bedrock, the fingering observed in the dye did not seem to be influenced by undulations in the bedrock but was set by the fabric encountered in the saprolite. The GPR provided a rapid method for mapping bedrock, which was an important control on depth of infiltration. GPR also suggested fingering occurs, but detailed pathways were difficult to resolve without dye tracing and excavation.

Monday, 28 October 2013: 1:00 PM-5:00 PM
Colorado Convention Center Mile High Ballroom 2C

Paper #
Start Time
165-1
1:00 PM
DRILLING AND GPR IN THE RíO ICACOS WATERSHED OF THE LUQUILLO CZO, PUERTO RICO: WEATHERING PROCESSES AND ARCHITECTURE OF THE DEEP CRITICAL ZONE

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In the Río Icacos drainage, Luquillo Mountains, Puerto Rico, the Río Blanco quartz diorite intrusion oxidizes during weathering to form concentric onion-skin like layers (rindlets) around relatively unweathered bedrock blocks (corestones). These observations, and the general weathering model, are derived from outcrops, but drilling has also revealed sequences of corestones and rindlets in the subsurface. Results from a new drilling project on the East Peak Ridge, a narrow spine separating the Río Icacos and Río Mameyes watersheds, provide additional information on the spatial distribution of rindlets and the geometry of the downward propagating oxidation front near its leading edge. Drilling was preceded by a ground-penetrating radar (GPR) survey at this site and elsewhere within the adjacent Río Icacos and Río Mameyes watersheds, encompassing 3 lithologies: quartz diorite, volcaniclastic, and hornfels grade metavolcaniclastic. On East Peak Ridge, drilling targeted the hornfels lithology but quartz diorite was encountered below the saprolite at ~14 meters below land surface (mbls). Some of the saprolite appears to be derived from the hornfels, however, suggesting that we drilled through the geologic contact. Drilling revealed three incipient quartz diorite corestones separated by thick zones of highly weathered material. Rindlets had not formed at depths shallower than ~38 mbls. Evidence of oxidation, noted by the existence of red fractures, was found within the saprolite and in the hard rock. A red fracture at 34 mbls was recovered from within the saprolite above the third incipient corestone. The oxidative fracture in the saprolite may act as a conduit in the low permeability material, allowing oxygen to reach the deeper hard rock where fractures are becoming visible (38 mbls). Preliminary results suggest that GPR works well on regolith derived from quartz diorite and volcaniclastic lithologies. On the hornfels, the signal becomes quickly attenuated. The thickness and mineralogy of the saprolite may control the propagation of the oxidation front. Outcrop, drilling, and GPR allow us to couple geological observations with geochemistry to formulate a conceptual model for the architecture of deep weathering in the Río Icacos watershed, and at its margins which may be controlled by lithological differences.

165-3
1:35 PM
THE ARCHITECTURE OF DEEP WEATHERING AT TWO CZOS: GROUNDWATER, REGOLITH, AND SOLUTES AT SUSQUEHANNA SHALE HILLS AND LUQUILLO EXPERIMENTAL FOREST

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To study processes in the deep critical zone, we have undertaken drilling projects to return samples of deep regolith and weathering fluids. Samples from the deep critical zone at both the Susquehanna Shale Hills (PA) and Luquillo (P.R.) Critical Zone Observatories (CZO) confirm the complex architecture of weathering environments and underscore their relationship with groundwater hydrology. Lithology is a major control on these processes: fracture density, orientation, and mineralogy are important components of this lithological control. At both CZOs, we hypothesize that a relatively deep oxidation front is the leading reaction that is capable of initiating deep weathering by increasing bedrock porosity and lowering pH of the weathering fluids. In the Luquillo CZO, these efforts are focused on the Río Icacos watershed where quartz diorite is weathered in fractures at depth, transforming to concentrically weathering corestones and eventually saprolite at decreasing depths. Water chemistry from three groundwater wells in the corestone zone (~15 m depth) indicates different extents and types of water/rock reactions taking place in close proximity. To constrain groundwater residence times we have begun to study anthropogenic tracers (CFCs, SF_6, ^3H), which indicate that the sampled groundwater has spent <20 years in the subsurface. The groundwater characterized here is similar in chemistry to that of baseflow of the Río Icacos, but concentrations of Mg and Si in groundwater are not completely consistent with baseflow concentrations. We interpret this to indicate that a pool of groundwater with low water/rock ratios has not been sampled, and must contribute to solute flux in Río Icacos baseflow. This might result from unsampled groundwater environments or from longer groundwater residence times in environments similar to those sampled. At Shale Hills CZO, groundwater sampled in the valley floor at ~15 m depth has significantly higher solute concentration than the adjacent stream. Here, groundwater in fractured shale has a flow weighted mean age of ~25 years whereas water in the stream has a residence time of less than one year. If the efflux of this groundwater in the subsurface is similar to the stream, weathering and solute export may be dominated by groundwater at Shale Hills.

165-8

2:50 PM

ASSESSING THE EXTENT OF REACTION VERSUS DEPTH AT RIDGETOPS AND HILLSLOPES TO UNDERSTAND CONTROLS ON DENUDATION

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Landscape curvature and regolith chemistry responds to both tectonic and climate factors. To explore this, we are studying how topographic position and climate affect depth and extent of weathering. We present results from field observations and theoretical models of weathering for ridgetop (one-dimensional) and hillslope (two-dimensional) examples. The model was developed describing steady-state regolith production caused by mineral dissolution (Lebedeva and

Brantley, 2013). The hillslope model shows that when erosion rates are small and vertical porefluid infiltration is moderate, the convex hill weathers at both ridge and valley in the erosive transport-limited regime. For this regime, the reacting mineral is weathered away before it reaches the land surface: in other words, the model predicts completely developed element-depth profiles at both ridge and valley. In contrast, when the erosion rate increases or porefluid velocity decreases, denudation occurs in the weathering-limited regime. In this regime, the reacting mineral does not weather away before it reaches the land surface and simulations predict incompletely developed profiles at both ridge and valley.

Model predictions suggest that an increase in Precipitation – Evapotranspiration for either completely or incompletely developed profiles will cause both the thickness of regolith and thickness of the reaction front to increase. In contrast, an increase in temperature causes an increase in the dissolution rate constant which in turn causes a decrease in the thickness of the reaction front for both types of profiles.

To understand the importance of climate and topographic positions, these model-derived ideas will be compared to i) a climosequence of soils developed on loess along the Mississippi valley, ii) a climosequence of soils developed on shale, iii) soils developed on shale on the north and south sides of an east-west trending catchment (the Susquehanna Shale Hills CZO).

Lebedeva, M.I. and Brantley, S.L., 2013, Earth Surf. Process. Landforms, DOI:10.1002/esp.3424

165-12
4:10 PM

QUANTIFYING ASPECT CONTROL ON TRANSPORT EFFICIENCY AND MOBILE REGOLITH FLUX AT THE SUSQUEHANNA SHALE HILLS CRITICAL ZONE OBSERVATORY

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Feedbacks between climatic, hydrologic and biologic activity have potential to influence soil transport efficiency on hillslopes with varying aspect. However, few studies show a systematic influence of aspect on transport efficiency across a range of hillslope gradients in forested landscapes. Here, we present an analysis of 131 meteoric ^{10}Be measurements from regolith and bedrock to quantify rates of 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. We observe a systematic asymmetry in hillslope gradients across these watersheds: north-facing hillslopes are steeper than south-facing hillslopes, spanning a range of ~10 – 25°. Hydrologic, geochemical and geophysical observations at SSHO reveal that mobile regolith on south-facing hillslopes is thin and subject to pronounced wetting and drying cycles, while thicker mobile regolith on north-facing hillslopes retains moisture. 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 hillslope positions,

where mobile regolith thicknesses are greatest, regolith fluxes depend on the product of local gradient and mobile regolith thickness. This transition occurs on all six hillslopes at a mobile regolith thickness of approximately 50 cm. 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, which is directly observable in regolith transport rates and hillslope gradients at SSHO.

Tuesday, 29 October 2013: 8:00 AM-12:00 PM
Colorado Convention Center Room 503

Paper No. 212-11
Presentation Time: 11:05 AM

CHEMICAL WEATHERING AND SOIL FORMATION FROM MULTIPLE PARENT MATERIALS IN A COMPLEX REGOLITH, SHALE HILLS, PENNSYLVANIA

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Weathering of bedrock to create saprolite, regolith, and soil is commonly envisioned to operate on in-situ, uniform parent material. A chemical weathering front produces saprolite and eventually regolith, which then participate in hillslope creep and soil formation processes. However, many hillslopes in diverse climatic settings do not replicate these conditions. Weathering and pedogenesis are not steady process that produce hillslopes of continuously mixing and creeping soil directly from bedrock. Rather, the initial mechanical disaggregation of bedrock and saprolite can be followed by periods of transport and deposition of colluvium by multiple processes, followed by alternating periods of pedogenesis and stochastic events that disrupt the soil structure. Both the pedogenesis and the disruptive events are recorded in hillslope stratigraphy, including their soils and paleosols.

In this work, we report on the geochemical evolution of soils developing through complex colluvial stratigraphy in a swale of a small, shale-bedrock watershed in central Pennsylvania (Shale Hills CZO Experimental 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. We present preliminary grain size and elemental depletion profiles through these parent materials to illustrate the degree of chemical weathering and pedogenesis. The diverse transported parent materials provide significantly different textural and hydrological pathways for pedogenesis, which we contend should have a first-order feedback on weathering profile geochemistry and long-term hillslope form.