GSA Southeastern Section - 62nd Annual Meeting (20-21 March 2013)
San Juan, PR Caribe Hilton
LCZO Presentations

T11. Critical Zone Processes and the Geology of Puerto Rico

Session No. 4
Wednesday, 20 March 2013: 8:00 AM-12:00 PM
Caribe Hilton Conference Room 3–5

APPLICATION OF STABLE CALCIUM ISOTOPES TO CA CYCLING AT THE LUQUILLO CRITICAL ZONE OBSERVATORY

Paper No. 4-1
Presentation Time: 8:10 AM

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Stable Ca isotopes are an emerging tracer of Ca cycling in terrestrial ecosystems. The δ44Ca of streamwater should reflect internal sources of Ca while the δ44Ca of the soil exchange pool should reflect the relative magnitude of external Ca inputs, Ca uptake by plants and Ca return to the soil pool. We are measuring stable Ca isotope ratios in streamwater and soil cation exchange pools at two watersheds (Bisley I and Rio Icacos) underlain by contrasting lithologies, which comprise the LCZO. Our preliminary data indicate a first order contrast in δ44Ca patterns between these tropical sites and temperate sites that have been studied previously. Most rocks (the ultimate source of Ca to ecosystems) have δ44Ca ≈ -1‰ relative to the seawater standard. In northeast US forests (New York, Massachusetts, New Hampshire), both soils and streamwater tend to be similar to or isotopically lighter than rock and atmospheric sources of Ca. In contrast, our data from the LCZO sites indicates soil pools and streamwaters are isotopically similar to or heavier than rocks. Sea salt aerosol is a external source of heavy Ca in some systems, but previous work based on $^{87}Sr/^{86}Sr$ and Sr/Ca seems to discount this as a significant Ca source at the LCZO. Instead this discrepancy may be related to fundamental differences in plant-soil Ca cycling. Furthermore, our preliminary data suggest differences between the litholigcally contrasting LCZO sites. At Bisley I (volcaniclastic), δ44Ca in the soil exchange pool is heaviest (-0.02‰) at 0-5cm and lighter (-0.71‰) at 5-10cm depth. Baseflow δ44Ca (-1.00‰) likely reflects Ca from deep weathering of primary minerals, while heavier δ44Ca (-0.69‰) at storm flow suggests significant export of soil Ca. At Icacos (granodiorite), shallow soil δ44Ca (-0.71‰ at 0-8cm) is not as light as Bisley. Baseflow δ44Ca at Icacos is similar to Bisley (-0.89‰), though does not change significantly during stormflow (-0.92‰). Isotopically heavy Ca (relative to inputs) in the near-surface exchange pool and in streamwater at Bisley may reflect a non-steady state Ca cycle where uptake of light Ca by plants is greater than Ca return to soil, leaving the soil Ca pool isotopically heavy. That Icacos δ44Ca values are similar to rock may reflect high Ca input fluxes relative to plant uptake, suppressing the impact of vegetation fractionation.

QUANTIFYING THE EFFECTS OF LITHOLOGY AND URBANIZATION ON CONCENTRATIONS OF ORGANIC AND INORGANIC CARBON IN COASTAL MONTANE TROPICAL RIVERS

Paper No. 4-2
Presentation Time: 8:30 AM

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Coastal montane tropical rivers are thought to play a disproportionately large role in the global delivery of carbon from terrestrial watersheds to the world ocean. As part of the Luquillo Critical Zone Observatory, we are sampling DIC, pCO2, POC, DOC, and the optical characteristics of DOC weekly in three coastal rivers in Puerto Rico, building on a longer-term (decadal) record of weekly solute sampling. The rivers drain volcaniclastic terrain with forest cover (Rio Mameyes), volcaniclastic terrain with urban cover (Rio Piedras), and quartz diorite with forest cover (Rio Icacos). Weathering rates are rapid in each landscape, resulting in substantial concentrations of DIC. Results show a strong dependence of concentrations on stream discharge in each river, and a larger range of DOC concentrations in the quartz diorite than the two volcaniclastic terrains. Initial estimates suggest that fluxes of both organic and inorganic carbon are approximately equal in each watershed, but the balance between organic and inorganic carbon shifts toward dominance by organic fractions at high flow.

MINERALOGICAL TRANSFORMATIONS DURING SHALE WEATHERING FROM PUERTO RICO TO WALES

Paper No. 4-6
Presentation Time: 10:10 AM

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Soil is the essential material that sustains all terrestrial life on Earth, yet the processes by which soil forms from parent rock are not well understood. To investigate factors controlling soil formation, we established a transect of sites across a climate gradient as part of the Susquehanna-Shale Hills Critical Zone Observatory (SSHO). To minimize variables influencing soil production, sites were located on organic-poor, iron-rich Silurian-age shale and include cold and wet sites in Wales, New York and Pennsylvania and warm and wet sites in Virginia,

Tennessee and Alabama. A site in western Puerto Rico provides a warm/wet end member for the transect that is underlain by a geochemically similar, but younger, shale than the other transect sites. Here, we present geochemical and quantitative mineralogical data that will be useful in modeling weathering processes and mineral transformations across this transect.

Parent shales across the transect have a mineral assemblage dominated by quartz, illite and chlorite. One exception is the site in Puerto Rico, where the parent shale contains up to 50% calcite in contrast to the < 1% calcite observed at the other sites. Sodium is largely present in plagioclase feldspar, which generally constitutes < 5% of the shale mineralogy. Plagioclase feldspar weathering increases from north to south, with 20% of plagioclase feldspar weathered at the soil surface in Wales and 100% of plagioclase feldspar weathered in Puerto Rico soil profiles. Soils in Alabama and Puerto Rico – the most intensely weathered sites in the transect – show considerable mineral transformations from the parent rock to the soil surface with kaolinite increasing 20 to 30% and iron oxides increasing up to 10%. In comparison, the northern sites exhibit increases of roughly 5% and 2% in kaolinite and iron oxides, respectively. The weathering of feldspar at depth may initiate profile development; however, the weathering of chlorite and illite, which constitute roughly 50% of the parent shale mineralogy, is more likely controlling the depth of augerable soil at all sites across the climosequence. Quantifying the mineral weathering reactions across the transect will help us understand both the impact of climate on weathering rates and the depth to which weathering influences soil mineralogy at the Earth's surface.

FOREST REGENERATION AND STREAMFLOW IN PUERTO RICO: A MULTIPLE-CATCHMENT ANALYSIS

Paper No. 4-7
Presentation Time: 10:30 AM

BECK, H.E.[1], **BRUIJNZEEL, L.A.**[1], VAN DIJK, A.I.J.M.[2], SCATENA, Frederick N.[3], SCHELLEKENS, J.[4], and MCVICAR, T.R.[5], (1) Critical Zone Hydrology Group, VU University Amsterdam, De Boelelaan 1085, Amsterdam, 1081 HV, Netherlands, l.a.bruijnzeel@vu.nl, (2) Fenner School of Environment and Society, Australian National University, Canberra, ACT 0200, Australia, (3) Dept. of Earth and Environmental Science, University of Pennsylvania, Philadelphia, PA 19104, (4) Inland Water Systems Unit, Deltares, Delft, 2300 MH, Netherlands, (5) CSIRO Land and Water, Canberra, ACT 2601, Australia

Little is known of the effect on streamflow (*Q*) of regrowing tropical forest. Puerto Rico has experienced widespread abandonment of pasture and croplands, followed by natural forest regrowth since the 1950s. This paper examines the impacts of forest regrowth on several streamflow metrics for 12 meso-scale catchments (23-346 km^2; mean annual rainfall 1720-3422 mm) in Puerto Rico with long (33-51 yr) and simultaneous records for *Q*, precipitation (*P*), potential evapotranspiration (PET), and land cover. A simple spatially-lumped, conceptual rainfall-runoff model using daily *P* and PET time series as inputs (HBV-light) was used to simulate *Q*for each catchment. Annual time series of observed and simulated values of nine *Q* metrics were calculated; four metrics related to hydrological processes and five to the annual frequency distribution of *Q*. A least-squares trend was fitted through annual time series of the residual difference between observed and simulated time series of each metric. From this the total change *Â* was calculated, representing the change in each metric after controlling for climate variability and carry-over storage effects between individual years. Negative values

of $\hat{A}$ were found for most catchments and *Q* metrics, suggesting enhanced actual evapotranspiration following forest regrowth. However, correlations between changes in urban or forest area and values of $\hat{A}$ were insignificant ($p \geq 0.091$) for all catchments and *Q* metrics. This suggests there is no convincing evidence that changes in the chosen *Q* metrics in these Puerto Rican catchments can be ascribed to changes in urban or forest area. These results are in line with previous studies of *meso- and large-scale* (sub-)tropical catchments, which generally found no significant change in *Q* that can be attributed to changes in forest cover. Possible explanations for the apparent lack of a clear signal include: errors in land-cover, climate, and *Q* data; changes in forest area occurring mainly in the less rainy lowlands; and heterogeneity in the hydrological response of individual catchments. Different results were obtained for different catchments, and using a smaller subset of catchments could have led to different conclusions. These findings highlight the importance of including multiple catchments in land-cover impact analysis at the landscape scale.

PRECIPITATION PATTERNS AND STREAMFLOW RESPONSE IN THE LUQUILLO MOUNTAINS, EASTERN PUERTO RICO

Paper No. 4-9
Presentation Time: 11:10 AM

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Watersheds in the Luquillo Mountains of Puerto Rico have abundant rainfall and stream discharge and provide a crucial water supply for the island. However, water availability may be affected by projected changes in regional temperature and atmospheric dynamics due to global warming. To help determine the links between climate and water availability, precipitation patterns were analyzed, and stable-isotope signatures of precipitation from different seasonal weather systems were established to identify those that are most important in maintaining streamflow and groundwater recharge. Long-term isotopic measurements indicate a disproportionately large contribution of trade-wind orographic precipitation to streamflow, highlighting the importance of this climate pattern to the hydrology of the watersheds. Groundwater isotopic composition suggests a slightly higher contribution from convective precipitation, but still smaller than in total rainfall. At the Rio Icacos site (640 m), the average length of time between rain events was 15 h, and 45% of rain events were <2 mm, reflecting the frequent small rain events of the orographic rainfall weather pattern. Analysis of precipitation at 15-minute resolution from 1992-2012 showed an increasing trend in monthly rainfall amount, while Caribbean radiosonde data showed an increase in precipitable water below 500 hPa. Rain event intensity distributions for 1992-2002 compared to 2002-2012 showed fewer low-intensity events and more medium-intensity events in the latter period. Annual stream discharge over the same period varied substantially, and was greatest in years of large storms; there was no statistically significant trend over the time period. Hydrograph separation experiments yielded information on stormflow characteristics; contributing sources were determined from water isotopes and solute chemistry. Streamflow response to rain events suggested relatively small hillslope storage capacity, so that prolonged droughts may affect these headwater areas. The evidence that trade-wind orographic showers contribute a high proportion of stream baseflow indicates that the area may undergo a change in water supply if orographic precipitation dynamics in the Caribbean are affected by future climate change.

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Session No. 17--Booth# 59
T11. Critical Zone Processes and the Geology of Puerto Rico (Posters)
Wednesday, 20 March 2013: 8:00 AM-5:30 PM
Caribe Hilton San Cristobal Ballroom

CHANGES IN EROSION RATE AND EROSION PROCESSES INDUCED BY THE PASSAGE OF HEADWARD MIGRATING KNICKPOINTS IN THE LUQUILLO CZO: INSIGHTS FROM DETRITAL COSMOGENIC ^{10}BE

Paper No. 17-2
Presentation Time: 8:00 AM-5:30 PM

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The modern island of Puerto Rico started to lift up from near-sea level some 4 Ma ago. Pervasive planation surfaces, interpreted as either ancient wave-cut platforms or peneplains are found over most of its mountainous highlands and are progressively dissected by erosion. As a result, the relief of Puerto Rico is dominated by transient landscapes where relict platform remnants undergo limited erosion. River knickpoints, migrating headward along the main streams propagate into this relict landscape a wave of renewed erosion.
In the Luquillo Mountains, the most prominent knickpoints are found along streams that drain the Rio Blanco batholith, an Eocene stock of quartz diorite. The lips of these knickpoint all stand at the same elevation (~600m), which is also the elevation of one of the uplifted wave-cut platform. They do not correlate with lithological changes and likely nucleated at the coast when uplift of the wave-cut platform started. They separate a slowly-eroding relict upland region from faster eroding lower slopes. We used in situ ^{10}Be concentrations in river-borne quartz to compare erosion rates above and below the knickpoints. We find that over timescales of 10^4-10^5 years the lower slopes are eroding three times faster.

The change in erosion rate is also associated with a change in the dominant erosional processes, as reflected by the grain-size dependency of ^{10}Be concentration in quartz sediments and the hillslope morphology revealed by analysis of a recently acquired LiDAR DEM. The uplands exhibit a strong variation in the ^{10}Be concentration as a function of sediment grain size, which reveals a deepening landscape with faster erosion of slopes than the intervening ridge tops. Erosion is focused into deep coves were seepage and mass-wasting progressively dismantle a deep saprolite. Downstream of the knickpoint lips, such coves are absent, hillslopes are straight, ridge crests are narrow and the ^{10}Be dependency with grain size is less pronounced, indicating a better coupling between ridge, slope and river erosion rates. Collectively, these observations indicate a shift from chemical weathering dominated erosion upstream of the knickpoints to mechanical weathering dominated landscape below the knickpoints.

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Session No. 22
T20. The Shoreline of Puerto Rico: Session in Honor of Jack Morelock
Wednesday, 20 March 2013: 3:00 PM-5:30 PM
Caribe Hilton Salón Tropical

THE APPLICATION OF $\delta^{13}C$ AND C/N OF MANGROVE SEDIMENTARY ORGANIC MATTER TO RECONSTRUCT FORMER RELATIVE SEA LEVEL AND PALEOENVIRONMENT, PUERTO RICO

Paper No. 22-3
Presentation Time: 3:45 PM

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Reliable, quantitative proxies of former relative sea-level (RSL) and paleoenvironmental change are critical in integrating geologic and historical records into predictive models in order to better understand the response of coastal systems to marine inundation. The defining characteristic of a sea-level indicator is its systematic and quantifiable relationship to elevation with respect to the tidal frame. Microfossils (e.g. foraminifera, diatoms) are used to reconstruct Holocene sea level because of their potential for providing high-resolution archives of RSL; however, these biological proxies are somewhat limited due to spatial restrictions and poor preservation in the sedimentary record of temperate and more notably tropical environments. In this study, we aim to overcome the confines of existent indicators by adapting the use of stable carbon isotopes and carbon to nitrogen ratios of bulk sedimentary organic material to a tropical coastal setting. We sampled dominant vegetation and surface sediment along 8 transects taken through tidal flat, mangrove, and freshwater depositional environments from 4 sites in Puerto Rico. We find statistically distinct ranges in $\delta^{13}C$ and C/N corresponding to these vertically zoned depositional environments. In addition, a 2.5 m core obtained from one of the sites in Rio Grande demonstrates changes in $\delta^{13}C$ and C/N representative of a shift in depositional environment from tidal flat to mangrove that is in agreement with changes in the lithology and foraminiferal assemblages in the core. ^{210}Pb accumulations and ^{14}C analysis provide a chronology for these paleoenvironmental changes and enabled reconstruction of Late Holocene RSL. The good agreement between the geologic RSL reconstruction and nearby San Juan tide gauge record, an independent measure of former RSL, validates the $\delta^{13}C$ and C/N-based reconstruction method.

Our analysis suggests that $\delta^{13}C$ and C/N together serve as a suitable sea-level indicator in the tropics because they hold a systematic relationship to tidal elevation that is identifiable in the sedimentary record. This work provides alternative means for filling gaps in data associated with other proxies, as well as provides the first validated reconstruction of Late Holocene RSL change using the $\delta^{13}C$ and C/N of mangrove sedimentary organic matter.

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