Peters – SSHO CZO seed grant

Project Title: Reconciling physical and chemical profiles in the complex soils of the Shale Hills CZO
Project PIs: Stephen Peters (co-PI), Frank Pazzaglia (co-PI)

Statement of proposed work
In a series of recent, influential publications, geoscientists have resurrected and further defined long-standing paradigms of bedrock weathering to saprolite, and the processes and rates of erosion on convex hillslopes, and how they influence landscape evolution (reviewed in Heimsath et al., 2012). Implicit in these studies is the notion that soil is a dynamic layer that responds to boundary conditions like substrate, climate, and tectonics, but has little or no memory, or stated another way, has no stratigraphic record of those changes. However, there is a large body of literature (Gile et al., 1981; reviewed in Birkeland, 1999) and field observations that show that soils do have a stratigraphic memory of changing substrate, climate, hydrology, and tectonics. This stratigraphy records the hydrologic, biogeochemical, and physical processes that define the critical zone and are how a soil is distinct from debris or saprolite.

The central testable idea in this proposal is to demonstrate that both within and between sites, soil stratigraphy and morphology record the matrix of critical zone processes. The simple model of "bedrock conversion to soil" is not a single-step process that produces a hillslope of continuously mixing and creeping soil. Instead, the initial mechanical disaggregation of saprolite is followed by alternating periods of quiescent horizon formation and stochastic events that disrupt the soil structure. Both the horizon formation processes and the disruptive events are recorded in the soil stratigraphy. In some settings, the soils formed by this unsteady pedogenesis are separated by distinct unconformities, indicative both of the fidelity of soil memory and the magnitude of environmental change that impact the chemical, physical, and biologic processes in the critical zone.

The principal investigator's long term goals are to describe soil stratigraphy and morphology for soil mantled hillslopes in three diverse CZOs – Puerto Rico, the Shale Hills, PA, and Valles Caldera, NM. These sites offer a range of substrates and climate regimes. The hope is to demonstrate the varying importance of physical and chemical processes by examining geochemical mass balance on hillslopes with distinct stratigraphy vs. those where stratigraphy is absent or weakly expressed. For this effort, the PIs anticipate pursuing NSF funding after this pilot project.

The immediate goal, this proposal, marks the first step of that process – to study and document that process at SSHCZO. The long-term plan would follow in subsequent field seasons informed by the results obtained at the SSHCZO.

Finally, the arguments that transpire in the literature often take long periods of time, and do not always reconcile the geochemical data with pedology and Quaternary stratigraphy. By placing a geomorphologist (Pazzaglia) with soil geomorphic experience in the field at the same time and location as a geochemist and hydrologist (Peters), progress will hopefully be made rapidly on this long-standing debate.

Methodology

The scope of work for this proposal will include a short field season to measure and sample a soil catena in the SSHCZO. During a visit to the SSHCZO in 2010, Peters and Pazzaglia were impressed by the complexity of hillslope and soil stratigraphy exposed in one open pit near the midslope position. The plan is to get a more synoptic view of this stratigraphy by hand-excavating a series of soil pits down to bedrock, where possible. The PIs anticipate excavating 9 pits arranged roughly as a cross in both slope-transverse and slope-parallel orientations with the pit at the center of the cross serving both profiles. From the soil pits, the PIs will describe the soil morphology following standard NRCS criteria and in the context of Quaternary stratigraphy of the hillslope, being careful to note influence of parent material, provenance, and allostratigraphy (Ciolkosz et al., 1999; Pollock et al., 2000). The PIs plan to compare these observations with the geochemical evolution of the soil profile, most of which the PIs will assemble from the studies already completed at the site (Jin et al 2010; Ma et al., 2011, Jin et al., 2012). The PIs will sample each soil horizon in each pit for to assemble a simple geochemical mass balance. Assuming that most profiles will have ~5-6 horizons, ~50 samples are needed for the bulk geochemical analysis. The PIs will work with the site manager to avoid disturbance of existing experiments and ensure the long-term viability of the CZO.

The multi-day field expedition will occur during July 2013, with followup discussion and evaluation in August 2013. The participants in the field session would include faculty members Stephen Peters, and Frank Pazzaglia, and two early career female Ph.D. graduate students. One month of support is requested for graduate student Johanna Blake. The second graduate student, Helen Malenda, is internally supported by Lehigh. The PIs seek modest field support for travel and lodging (camping) for the duration of the study.

Proposed SSHO Interactions

The proposed work dovetails into existing progress made by the weathering and soils group led by Dr Brantley, the Hydropedology group led by Dr Lin, and the geomorphology group led by Dr Kirby. It has further bearing on parallel studies that report new results for long-term hillslope erosion rates assembled from isotopic (Dosseto et al., 2008) and cosmogenic data (Portenga et al., 2013). To help in the sampling efforts, it would help the project if a member of one of these teams, or the site manager, could accompany the PIs for one day to locate existing sample plots and point out sensitive areas with ongoing long-term experiments. Publications resulting from this work would include the PIs on this proposal, plus researchers from the CZO who play an active role in data analysis and interpretation. Samples obtained by this project will be archived according to NSF rules, either at Lehigh, or sent to PSU for archiving as part of the CZO record. Data reported in the final report, including electronic copies, will be delivered to the CZO for publication online.

Deliverables

(1) Full field soil stratigraphy and morphology descriptions of the 9 pits
(2) Longitudinal and transverse cross-sections of the hillslope showing the Quaternary stratigraphic relationships between soil, colluvium, unconformities, and bedrock.
(3) A reconstruction of the regolith production, transport, erosional, and pedogenic processes that have created the SSHCZO hillslope.

(4) Comparison of the physical production measurements with geochemical mass balance of the transverse and longitudinal profiles.

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