Deep Weathering at the LCZO

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Projects

- Observation wells: “The Drilling Project”: H1, H3, H4?
- Deep saprolite weathering profiles: H1, H3, H4
- Weathering on landslide chronosequence: H1, H2, H3, H4?, H6
LCZO Drilling Project as of May 21, 2010, 9:30 am.
Outline

- Why?
- Where?
- Who?
- Work Plan
  1. Drilling
  2. Geophysics
  3. Sampling System
  4. Products and Analysis
- Budget, Funding, Scheduling
Why? - We don’t know:

1. Depth of fracturing (depth of critical zone) and fracture distribution and sizes
2. Depth of weathering/ depth of corestones
3. The character of bedrock-weathering interface in the volcaniclastics
4. Groundwater chemistry, recharge rates, response
5. Correlation between groundwater and climatic variations (e.g., temp, pptn, ET) as known for surface waters.
   - Surface waters respond on shorter timescales.
   - Groundwater signals should reflect integration of climate variables on a longer timescale.
Where?

- Will drill in roads to minimize environmental impact.
- Wells will be located near well-studied sites and gages to facilitate interpretation of data and applicability to ongoing research.

Sites:

1. **QUARTZ DIORITE**: On 191 between Guaba gage and trail to LG sites 1,2,3 (old USGS lysimeter sites).
2. **VOLCANICLASTIC**: On Bisley road, just before B1 gage, aligned with ridge containing Buss B1S1 lysimeter field.
3. **VOLCANICLASTIC**: On Bisley road, between B1 gage and entrance to lower tower trail.
Where? - Why these sites?

- Near to existing depth profiles through entire soil+saprolite (chem, mineral, pore water, microbio)... thus drilling cores will provide complete depth profiles through the CZ.

- Bisley 1 likely contains 2 dominant rock-types:
  1. Quartz-rich volcaniclastic (under ridges, forms saprolite)
  2. Quartz-poor volcaniclastic (in streams, washes away during weathering b/c insufficient quartz to form saprolite)

- Adjacent to gaged streams
Who?

- Me: coordinate project, groundwater and core geochemistry, mineralogy, some petrology
- USGS Borehole Geophysics Group: Carole Johnson
- A groundwater hydrologist TBA
- Sue Brantley: neutron scattering (porosity), some petrology
- Marjorie (Jorie) Schulz, USGS Menlo Park: Core collection and archive, petrology
- Andy Kurtz: groundwater Si/Ge isotopes, hydrologic model
- Martha Scholl: groundwater O₂ isotopes
Workplan: Overview

- Drill holes in the roads in Icacos and Bisley watersheds
- Collect solid rock cores during drilling
- Conduct geophysical logging
- Install Waterloo semi-permanent packer systems to isolate water-bearing fracture zones for monitoring and analysis
- Analyze collected samples
Workplan: Drilling

- Drilling to 100-150’
- ‘Overburden’ (disaggregated material, e.g., saprolite) will be cased in 4” diameter PVC.
- Solid rock portion will remain un-cased.
- ~2.5” Cores will be collected from rock during drilling.
- Well heads will be enclosed in cement casements flush with road surface that will permit access and road traffic.
Workplan – Geophysics

- Immediately after drilling each hole, Carole Johnson will collect data to determine:
  1. Fracture distribution and apertures
  2. Bedrock permeability
  3. Transmissivity of the dominant fracture zones
  4. Porosity

- Fracture locations and transmissivity data will be used to choose zones of interest for sampling and monitoring within each well. Waterloo systems will be assembled on site to access our zones of interest.
Workplan – Waterloo System

- Semi-Permanent, multilevel groundwater monitoring and sampling system made by Solinst Canada Ltd.
- Will require a small truck-mounted winch, but installable without company assistance.
- Will install pressure transducers to monitor water levels within each major fracture zone.
- We’ll be able to collect groundwater samples from different fracture zones on demand.
Workplan – Products and Analysis

- **Solid cores** will provide samples of un-exposed weathering interface surfaces, deep fractures, fresh bedrock, and give us an idea of the lithologic variability.

- Core analysis: thin sections, bulk chemistry, mineralogy, neutron scattering (pore size distributions, surface area, roughness).

- Buss, Brantley, Jorie Schulz, Katya Bazilivskaya (Penn State).

- Archived samples will eventually be available from the USGS and indexed online.
Workplan – Products and Analysis

- **Geophysical, water chem, & water level data** will provide:
  - Inputs to hydrologic, mass balance, weathering and fracturing models
  - Bedrock-weathering contributions to stream flow and chemistry
  - Groundwater response to storm events
  - Groundwater recharge rates
  - Information on groundwater transport (flow paths, rates??)
  - A climate signal?

- (Buss, Kurtz, Brantley, Scholl, McDowell, and ?)
Budget, Funding, Scheduling

- Drilling, coring, geophysics, and sampling system funded by the USGS.
- We have the USFS permit, the USGS funding and contracts.
- Plan to use LCZO funds for much of the post-drilling analyses (e.g., mineralogy, geochemistry, modeling)
- Original schedule was June 1-13, 2010. Waterloo system not ready yet. Considering dates in July 2010. May have to postpone until next year.
Deep Saprolite Weathering Profiles

U.S. Department of the Interior
U.S. Geological Survey
It all starts with weathering…

- How does rock become soil?
- How is the critical zone *formed* and *maintained* on a landscape?
- How do weathering processes and rates differ between lithologies?
- What happens to the mineral nutrients produced by weathering processes?
Deep Saprolite Weathering Profiles

- Lots of data for Rio Icacos: soil to saprolite to bedrock
  - White et al., 1998
  - Murphy et al., 1998
  - Schulz and White, 1999
  - Turner et al., 2003
  - Buss et al., 2005, 2008

- Now collecting some similar data for Mameyes (Bisley)
  - Infrastructure
  - Data gathering and analysis
  - Comparison to Rio Icacos
  - Mg-Li isotopes
Infrastructure: Installations in Bisley

5 sites, <18 m depth

- 38 Nested suction soil water samplers ("lysimeters")
- 4 tensiometers
- 9 soil gas samplers
- Rainfall collectors: 2 open fall, 2 throughfall
Installation of Regolith Instruments by Manual Augering

Rio Icacos
5 sites, <7 m depth
• 40+ lysimeters
• 30+ tensiometers
• 18+ gas samplers
  (mostly defunct)

Rio Mameyes
5 sites, <18 m depth
• 38 lysimeters
• 4 tensiometers
• 9 gas samplers

USGS
Data Collection

- Chemistry of soil pore waters with depth (~monthly)
- Total chemistry and exchangeable cations of solids with depth
- Quantitative mineralogy with depth
- Moisture content with depth
- Bulk density with depth
- Oxygen and CO2 with depth
- Extractions for P with depth
- Microbiology (Penn State)
- Sampled (wood and leaves) of dominant plants (with Penn State)
- Collected one storm event Bisley 1 stream samples: chemistry
- Petrology (with Penn State)
Comparisons to Rio Icacos

Also comparing to similar site in Guadeloupe: volcaniclastic debris and ash flows.

- Saprolite more weathered in Bisley
- Saprolite chemistry more variable in Bisley although mineralogy is simpler
- Bedrock more variable in Bisley
- Finer grain size in Bisley
- Saprolite thicker in Bisley
- Porewater residence time shorter in Bisley
- Density variable by site in Bisley
- Mg and K gradients in RI porewater reflect biotite weathering. Mg (no K) gradient in Bisley reflects?
Mg gradient in Rio Icacos: Biotite weathering

White et al., 1998
Mg gradient in Bisley: not biotite, but what?

![Graph showing Mg and K concentration versus depth](chart.png)
Mg gradient in Bisley: not biotite, but what?

- No Mg containing minerals identified in the saprolite
- Mg correlates with kaolinite in quantitative XRD work (Handlens and Rock Jock)
- No other clays found even with detailed XRD
- Mg in exchangeable cation fraction, but not enough
Excess Mg relative to Cl typically reflects weathering input.

Complicated Mg signal in shallower zone.
**Mg Isotopes in Bisley Porewater**

Looks like a weathering profile

Collecting more Mg isotope data:
- Porewaters
- Solids
- Plants
- Rain
- Stream water
- Exch cations
Mg + Li isotopes

Li substitutes for Mg in minerals

Isotopes appear to have similar trends during weathering reactions (but of different sign)

But Li is not a biological nutrient like Mg

Hypothesis is that Li will not fractionate by biological processes

Potential dual tracer to separate the geologic and biologic components of the Mg cycle.

Li isotope analysis is very tricky and uncommon as of yet
Weathering on a Landslide Chronosequence

Heather Buss
Sue Brantley
Jane Willenbring
Art Johnson
and …???