PETROGRAPHY OF THE GNEISSES FROM THE MARY LOU QUARRY IN CLINTON, SC: IMPLICATIONS FOR QUANTIFYING MINERAL COMPOSITIONS IN THE CRITICAL ZONE CONT.

Tyler Cannida | Dr. Paul A. Schroeder (mentor) | University of Georgia Department of Geology, Athens, GA 30602-2501
tec91424@uga.edu

Abstract

The environments between tree tops and deep bedrock that are influenced by meteoric waters is called the critical zone. Critical zone observatories (CZO) are sites designed to study biogeochemical interactions that occur in time scales from seconds to geological millennia and spatial scales from microns to kilometers. The CZ is important to many terrestrial life (including humans), however the physical and chemical properties and their function are not always well characterized. In particular, CZ science is challenged to accurately quantify mineral assemblages that occur in the subsurface. Soil quality in terms of nutrient capacity and water availability are closely related to the parent rock material, which weathering process act upon. Stage 1 implemented X-ray powder diffraction and thin section analysis as approaches to quantifying minerals. Although the techniques are based on different principles, the quantitative result should agree. It is hypothesized that the two methods will agree in outcome, given assumptions about mineral stoichiometry. To test this hypothesis, thin sections were analyzed using energy dispersive X-ray spectroscopy (EDS) to conduct composition analysis. Three samples were collected from the deep Mary Lou aggregate quarry to provide a basis to evaluate unaltered parent rock. In these slides, K-feldspar was of interest due to it being an indicator of weathering. Results are intended to highlight the differences in each approach and reconcile the inadequacies between the techniques. Reconciling these differences can lead to understanding the range of feldspar mineral composition variation in both small and large landscape scales.

Background and Location

Research began at the Mary Lou Quarry at the Calhoun CZO site in Clinton, South Carolina. This area encompasses rock, soil, water, and organic matter in which information about the quantity and quality of life sustaining resources are available. The Calhoun site focuses on restoring areas affected by land degradation by ecohydrology recovery, biogeochemical decoupling, delayed oxidation of eroded soil organic carbon, human and CZ interactions, and forests impeded of redevelopment. Analyzing the parent rock, especially in the context of feldspars, is key in observing the transportation of nutrients and soil quality in which the question of land recovery and biogeochemical can be answered.

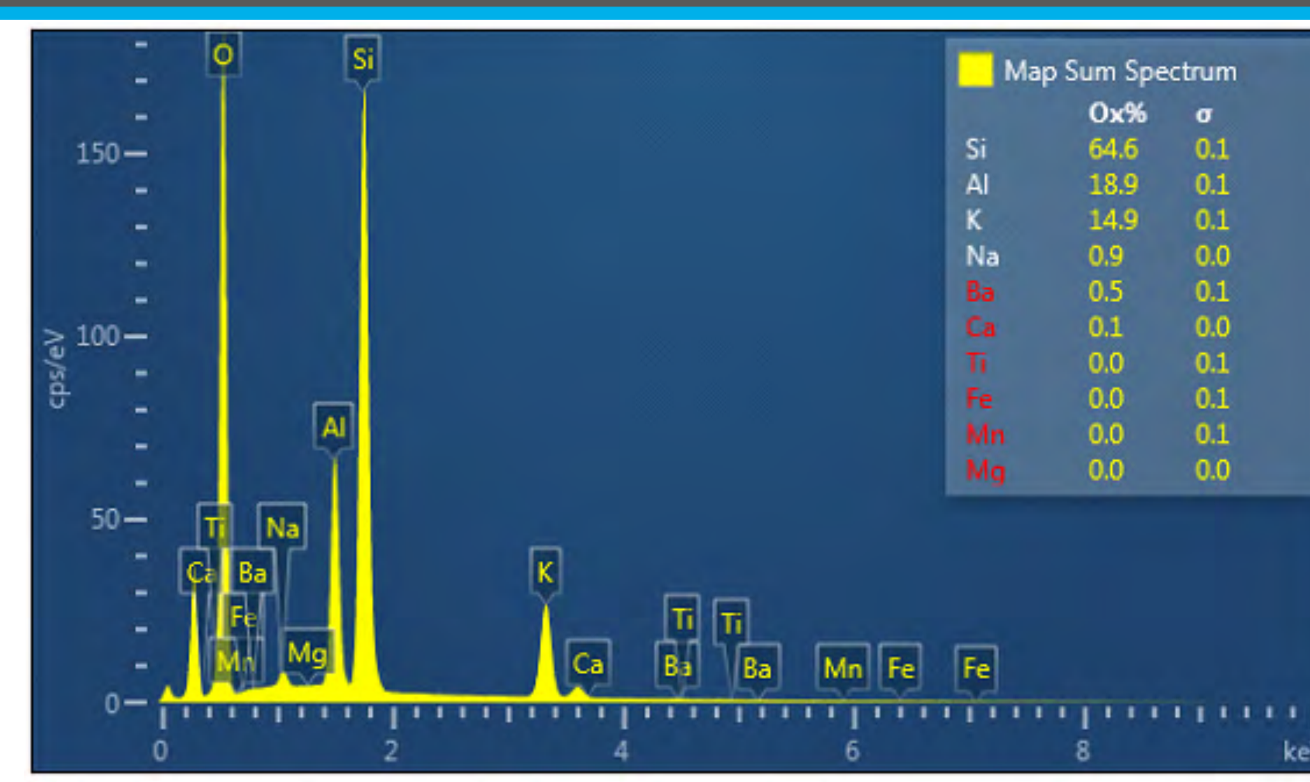
Location of the Calhoun CZO cite

Image of the Mary Lou Quarry

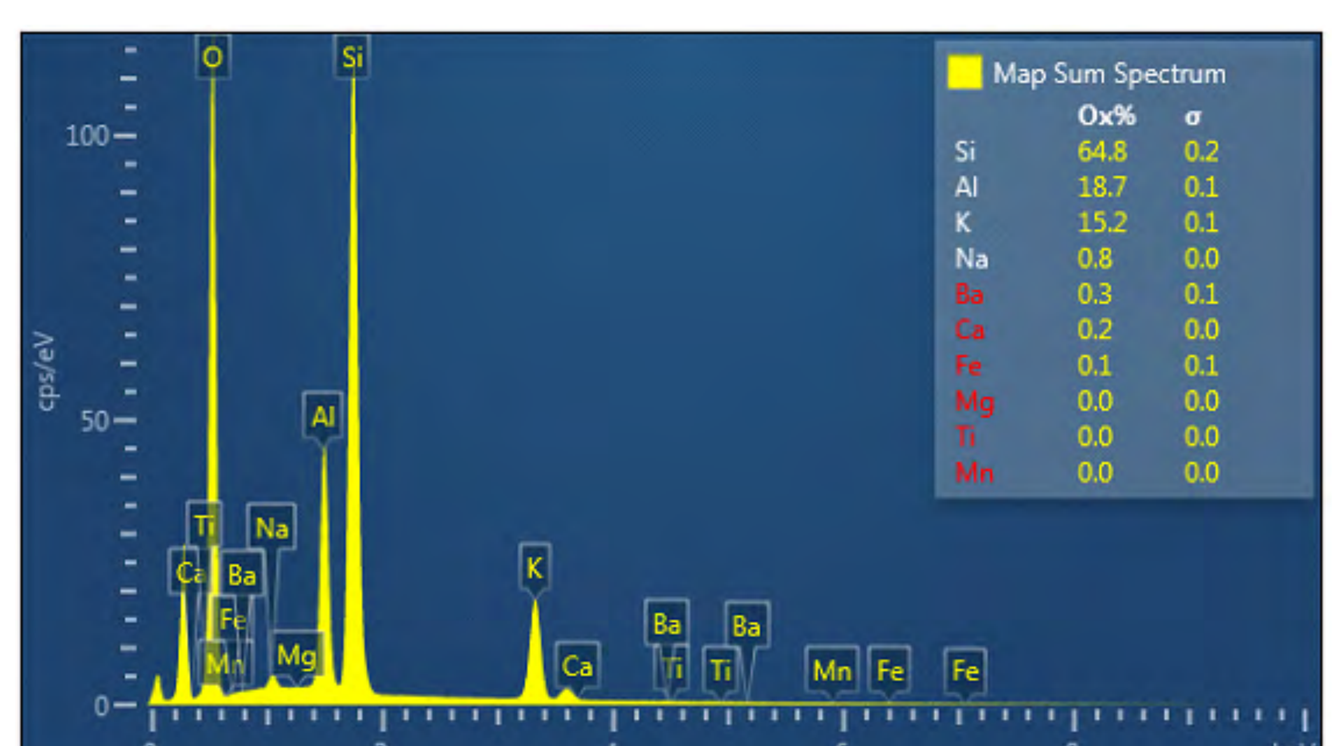
Methods

Thin sections were made from three samples made from the Mary Lou Quarry, each labeled Uga 1, Uga 2, and Uga 3. Thin sections were carbon coated and analysis included point counting of mineral abundance as well as XRD analysis in which the bulk mineral assemblage was obtained. Energy Dispersive X-ray Spectroscopy (EDS) was used to determine the composition of feldspars with in each sample. Before analyzing the samples, standards were measured to understand the element composition within the feldspars. The analyzed elements were K, Na, Al, Si, Mg, Ca, Ti, Ba, Fe, and O. The thin sections were taped down and placed in a FEI Scanning Electron Microscope (SEM) at a stage height of 10 mm using a 10 keV and a 14µm spot size. The rastered data was uploaded onto the computer program, Aztec. A low magnification picture was taken over a random spot on the thin section so the feldspars could be located. Once the desired location on the feldspar was obtained, the image was magnified 5000x. Aztec then calculated the oxide percentage of each element after external calibration. Since the thin sections were carbon coated, C was excluded from the analysis. A minute collection time was used for each scan. Uga 1 and 2 had eight scans while Uga 3 acquired seven.

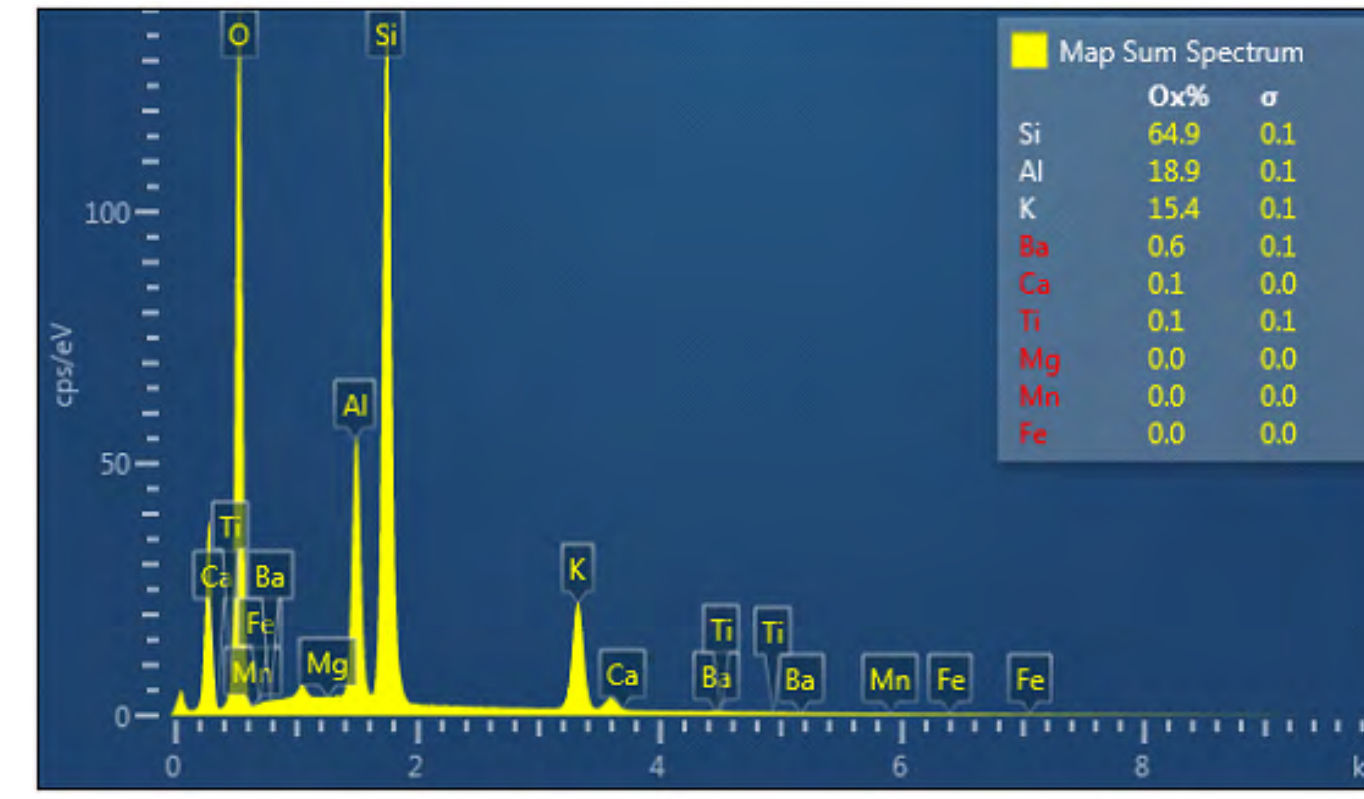
Results



Uga 1e as a representative EDS of the thin section.



Uga 2e as a representative EDS of the thin section.



Uga 3e as a representative EDS of the thin section.

Feldspar EDS analysis

UGA 1 $(K_{0.873}\ Na_{0.083}\ Ba_{0.016}\ Fe_{0.003}\ Ca_{0.005})\ Al_{1.023}\ Si_{2.983}\ O_8$

UGA 2 $(K_{0.898}\ Na_{0.052}\ Ba_{0.007}\ Fe_{0.003}\ Ca_{0.007})\ Al_{1.021}\ Si_{2.989}\ O_8$

UGA 3 $(K_{0.885}\ Na_{0.069}\ Ba_{0.015}\ Fe_{0.003}\ Ca_{0.005})\ Al_{1.023}\ Si_{2.977}\ O_8$

EDS analysis shows the overall chemical composition of feldspars in each sample.

Discussion and Conclusion

Averages and standard deviations were calculated for elemental abundance in each sample, which were reformatted as oxides. Structural recalculations were determined assuming 8 oxygen equivalent per unit formula, with Al and Si put in to tetrahedral sites and K, Na, Ba, Fe, and Ca in to octahedral sites. Standard deviations averaged 0.1%, thus making only K, Na, and Ba significant octahedral occupants. The average amounts of K, Na, and Ba in each sample were similar to one another.

These quantitative measures of feldspar compositions provide valuable constraints for weathering models that use mineral stoichiometry to determine the relative concentrations of cations released as nutrients into forested ecosystems. In particular, the hydrolysis of K-feldspars contribute to the consumption of acidity resulting in the production of bicarbonate and K, both of which influenced cycling of carbon and the exchange between above ground and below ground reservoirs in the critical zone.

Acknowledgments

- Special thanks to Dr. Schroeder for overseeing this research as well as Jay Austin and Alp Unal. Thank you to Eric Formo who taught and assisted in collecting EDS data. Thank you to Sophia Sanders for allowing me to use this poster template.

The fate of degraded biotites in the deep critical zone: Implications for the K-uplift hypothesis

Sophia Sanders | Dr. Paul A. Schroeder (mentor) | University of Georgia Department of Geology, Athens, GA 30602-2501
sophiachasonsanders@gmail.com

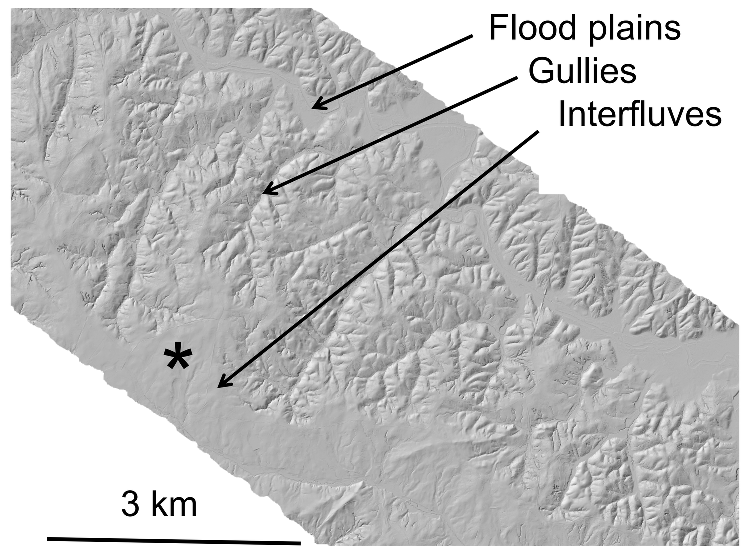
Abstract

The Calhoun, South Carolina Critical Zone (CCZO) research site provides valuable insight into the interactions between all biotic and abiotic components at the Earth's surface, where rock meets life. The critical zone encompasses everything that spans from the bedrock to the top of the trees. Biotite grains [$K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$] collected from a deep core in CCZO research site are able to reflect the cycling of potassium, a factor of plant nutrition, at various depths. As biotite weathers and iron in its composition oxidizes, potassium is released from the mineral in order to satisfy a charge balance. More intensely weathered biotite is hypothesized to contain lower relative abundance of potassium due to higher levels of oxidation . Potassium content of weathered biotite near the surface is hypothesized be less abundant as these layers are more heavily weathered and restructured to kaolinite [$(Al_2Si_2)O_5(OH)_4$]. Using the electron microprobe, sand-sized biotite grains were analyzed for their elemental composition using energy dispersive spectroscopy (EDS). Notably, weathered biotite grains displayed "frayed" ends when viewed perpendicular to the principle *c*-axis. Analysis of these weathered ends in comparison to less weathered grains yielded less relative percentage of potassium in the chemical composition. Near the surface more kaolinite grains were observed. Although the loss of potassium occurs, persistence of lower amounts of potassium in the near surface suggests that the degraded biotite can still serve as a stock for nutrient cycling. The leads to a new idea whereby the oscillating reducing and oxidizing cycle there is the potential for degraded biotite to act as refugia for potassium in the near surface.

Background and Location

The National Critical Zone Observatory is a National Science Foundation funded program created in order to study the portion of Earth used for resources. The Critical Zone encompasses the bottom of groundwater to the top of the trees, and focuses on the interactions of biological, geological, and hydrological systems on and near earth's surface. The observatory zone in Calhoun, South Carolina is one of nine observatories in the program and focuses on anthropogenic land degradation. The cycling of potassium via biotite weathering fits into the Critical Zone's vision by exploring the role of geological mechanisms in biological cycles, and the subsequent effect on the vegetation and production of resources.

Location map for SE United States and Calhoun Experimental Forest



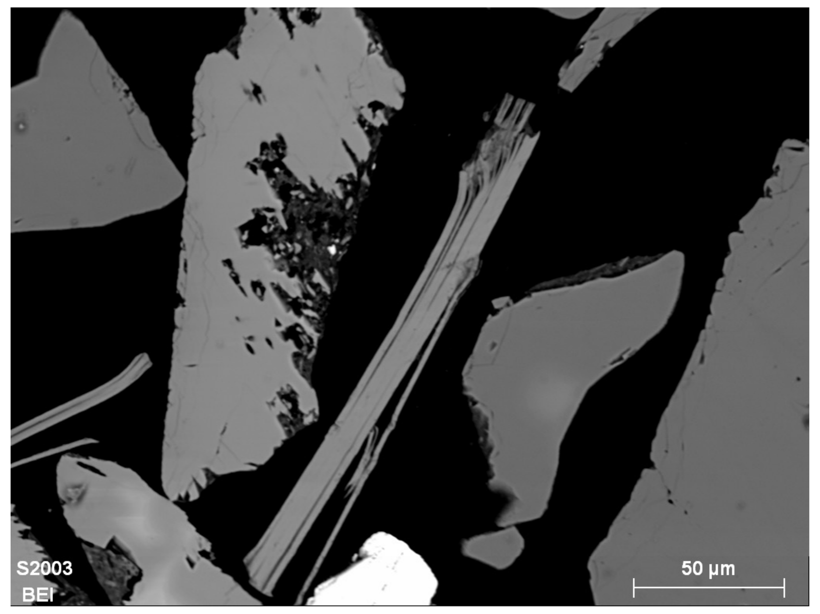
LiDAR data for the research site in Calhoun, South Carolina. * Drill site

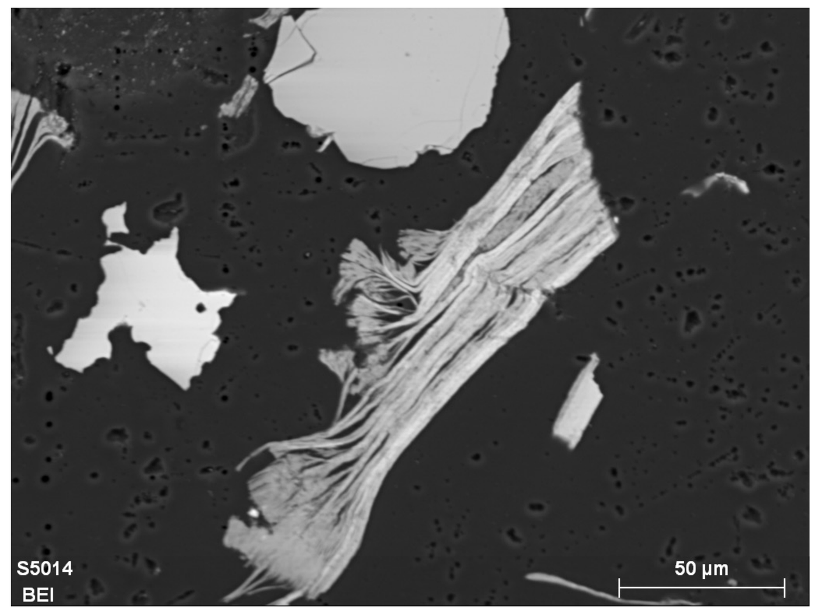
Methods

Loose grain sand-sized samples from a deep core of the Calhoun Critical Zone (Bacon et al, 2012) were collected at depths of between 0-6cm and 150-200cm. These samples were massed to approximately 0.10g and poured into a tube with a radius of .5 cm. The mold was filled approximately 0.5cm in depth of epoxy mixture. The epoxy mixture was 2 parts resin to 1 part hardener, and mixed for 2 minutes with a glass stirrer. Coated samples were left to dry on a hot plate for 24 hours. Then, samples were sanded for 10 minutes at 400 grit, 10 minutes at 1000 grit, 80 minutes at 5 microns, and 80 minutes at 1 micron. The samples were carbon coated. The polished epoxy samples were viewed with the electron microprobe. Each grain of interest was photographed at a processing speed of 10μs, then chemically analyzed with energy dispersive spectroscopy. Carbon, chlorine, phosphorus, and sulfur were excluded from analysis as their signal came from the epoxy.

Results

ID	Depth (cm)
S1	16
S2	46
S3	125
S4	225
S5	325
S6	580
S7	1143

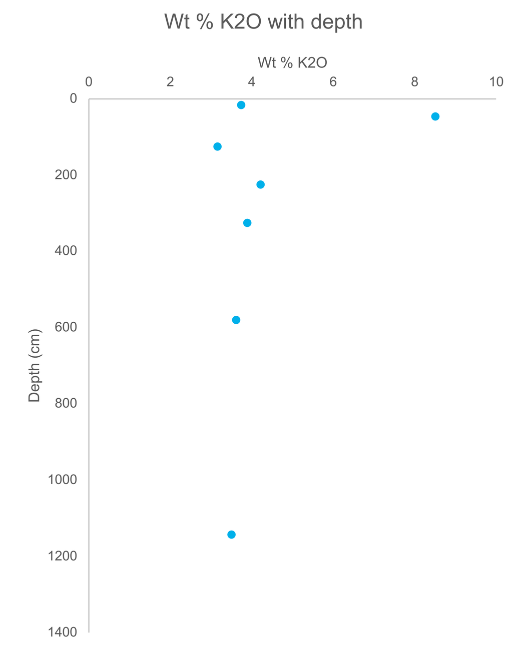


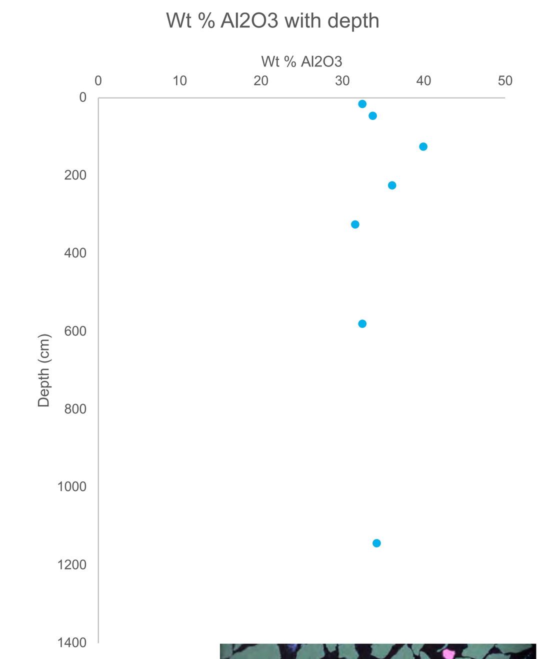


Above: Secondary backscatter electron image of weathered biotite (B) and feldspar (F) grains in S2, at depth = 46cm.

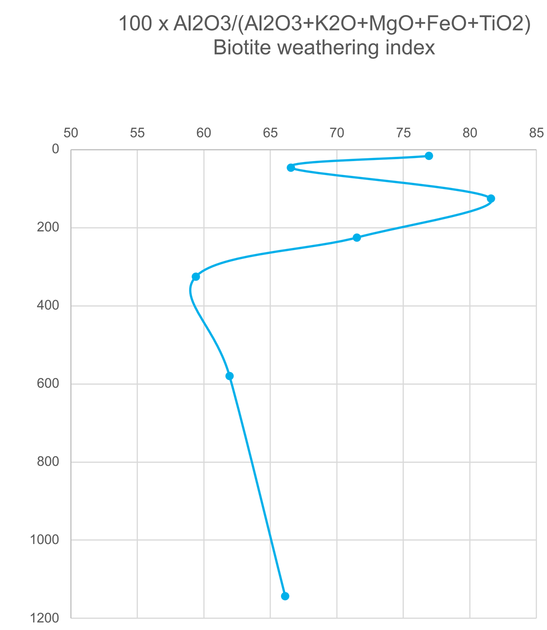
To the left: Secondary backscatter electron image of weathered biotite grain in S5, at depth = 325 cm.

To the right: Secondary backscatter electron image of weathered biotite grain from S7, at 1143 cm. Recent studies by Lybrand, et al (2019) support both biomechanical and biochemical mechanismsthat weaken the biotite structure through microbial-drive oxidation of Fe(II).





Weight percent of K_2O as a function of depth (left) . Weight percent of Al_2O_3 as a function of depth (right).



Biotite weathering index as a function of depth (left) . Composite EDS images for samples S1, S2, S3, S5, S6, S7 Green represents Si, red represents K, and blue represents Al. (right).

Discussion and Conclusion

- Grains were found to be altered to kaolinite at a high frequency, with interlayered biotite and kaolinite. This caused higher than usual measured Al_2O_3 values.
- The amount of measured potassium does seem to follow the concept of K-lift.
- A biotite weathering index reveals more intense chemical weathering of the regolith in the upper most 2 meters.

Works Cited

Austin, J., Perry, A., Richter, D., Schroeder, P.A. (2018) Modifications of 2:1 clay minerals in a kaolinite dominated Ultisol under changing land-use regimes. *Clays and Clay Minerals. Accepted.*

Bacon, A.R. Richter, deB, Beirman, P.R. Rood, D.H. (2012) Coupling meteoric ^{10}Be with pedogenic losses of ^{9}Be to improve soil residence time estimates on an ancient North American interfluve. Geology v40 847-850.

Lybrand , Rebecca A., Jason C. Austin, Jennifer Fedenko, Rachel E. Gallery, Erin Rooney, Paul A. Schroeder, Dragos G. Zaharescu, and Odeta Qafoku (2019) A coupled microscopy approach to assess the nano-landscape of weathering, Nature - Scientific Reports https://doi.org/10.1038/s41598-019-41357-0

Acknowledgments

I thank Drs. Paul Schroeder and Jason Austin for their guidance in this project. I would also like to thank Chris Fleisher for help with the polisher and the electron microprobe. This project was supported by the NSF critical zone observatory program (NSF EAR-GEO-1331846).