**Earth’s Critical Zone**

Geog 5241-002, Fall 2015

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Office hours by appointment on main campus or east campus

Class meeting time and place: 9:30-10:45 TTh, Guggenheim 201E

**Subject matter**

The Critical Zone is the near-surface region of Earth that supports life, and is best understood from a perspective that incorporates multiple interacting systems. For example, a talk I attended at last week’s Goldschmidt conference depicted chemical weathering as dependent on six different parameters: lithology—itself a geologic legacy, physical erosion, climate, biology, acid production, and hydrology (water residence time). Another example is characterization of watershed “currencies” of water, solutes, gases, sediment, biota, energy and momentum, which are passed between ecosystems, the subsurface, and atmosphere, as a way to understand climate or land use change. The CZ was highlighted in a National Research Council report in 2001 as deserving focused research attention using interdisciplinary tools.

The material we will cover draws on numerous disciplines from geophysics to microbiology, from geology to hydrology. We’ll find that we must span timescales from seconds to millions of years, and spatial scales from nanometers to kilometers.

**Goals**

This course is intended to a) introduce the CZ, b) explore a set of questions that address CZ problems, and c) connect your own research to critical zone science. The goal is to help you see new connections, and perhaps see your own discipline within a new light.

**Class structure**

The class will contain a mix of lectures and seminar style discussions. We will cover basics of disciplines relevant to the CZ through lectures. Seminars will be drawn from the recent literature, and will complement lectures. As part of your training, I will be asking you to lead our learning of at least one basic topic during the semester.

**Evaluation**

1) 30-minute teaching lecture on one aspect of science of the CZ (either choose a topic you know, or one that you want to learn well).

2) Lead discussion on at least one seminar day: help select papers to read, summarize key points of papers discussed.

3) Term paper, annotated bibliography, and presentation on topic of your choice.

**Introduction**

What is the critical zone?

CZ architecture

*Supporting papers*

NRC (National Research Council) (2001) *Basic Research Opportunities in Earth Science*. National Academy Press, Washington, 154 pp.

Anderson, SP, von Blanckenburg, F, and White, AF (2007) Physical and chemical controls on the critical zone. *Elements* 3: 315-319.

Brantley SL, Goldhaber MB, Ragnarsdottir KV (2007) Crossing disciplines and scales to understand the Critical Zone. *Elements* 3: 307-314.

**Question 1: How do catchments operate as hydrochemical filters and influence hydrologic partitioning?**

*Tutorials*

Transit times

Surface energy balance

Tree physiology and evapotranspiration

Hillslope hydrology

*Seminars and supporting papers*

Pangle, LA, Gregg, JW, McDonnell, JJ (2014): Rainfall seasonality and an ecohydrological feedback offset the potential impact of climate warming on evapotranspiration and groundwater recharge. *Water Resources Research* 50, 1308-1321, doi:10.1002/2012WR013253.

Godsey, SE, Kirchner, JW, and Clow, DW (2009): Concentration-discharge relationships reflect chemostatic characteristics of US catchments. *Hydrological Processes* 23, 1844-1864, doi: 10.1002/hyp.7315.

Dunne, T (1978): Field studies of hillslope flow processes. In: *Hillslope Hydrology*, (ed. MJ Kirkby), Wiley, London, 227-293.

**Question 2: Does slope aspect control the depth of the weathered profile? Is weathering controlled top-down or bottom up?**

*Tutorials*

Chemical weathering

Topographic fracturing

Frost cracking

Rare earth elements

*Seminars and supporting papers*

Brantley, S and Lebedeva, M (2011): Learning to read the chemistry of regolith to understand the critical zone. *Annual Reviews of Earth and Planetary Science* 39, 387-416, doi: 10.1146/annurev-earth-040809-152321.

Anderson SP, Dietrich WE, Brimhall GH Jr (2002) Weathering profiles, mass balance analysis, and rates of solute loss: Linkages between weathering and erosion in a small, steep catchment. *Geological Society of America Bulletin* 114: 1143-1158.

Rempe, D., and Dietrich, WE (2014): A bottom-up control on fresh-bedrock topography under landscapes, *PNAS* 111(18): 6576-6581.

St. Clair, J, Moon, S, Holbrook, WS, Perron, JT, Riebe, CS, Martel, S, Carr, B., Harman, C, Singha, K, and Richter, D (in press) Geophysical imaging reveals topographic stress control of bedrock weathering, *Science*.

Anderson, RS, Anderson, SP, and Tucker, GE (2013): Rock damage and regolith transport by frost: An example of climate modulation of critical zone geomorphology. *Earth Surface Processes and Landforms* 38: 299-316,doi:10.1002/esp.3330.

West, N, Kirby, E., Bierman, P., and Clarke, B.A. (2014): Aspect-dependent variations in regolith creep revealed by meteoric 10Be. *Geology* 6 (42): 507-510, doi:10.1130/G35357.1.

Ma, L, Jin, L, and Brantley, S (2011): How mineralogy and slope aspect affect REE release and fractionation during shale weathering in the Susquehanna/Shale Hills Critical Zone Observatory. *Chemical Geology* 290, 31-49, doi: 10.1016/j.chemgeo.2011.08.013.

**Question 3: Do organisms exert strong influence on critical zone architecture, or vice versa?**

*Tutorials*

Microbial ecology

Biogenic transport

*Seminars and supporting papers*

Richter, D. deB., and Billings, S.A. (2015) “One physical system”:  Tansley’s ecosystem as Earth’s critical zone.  *New Phytologist* 206: 900-912, doi: 10.1111/nph.13338.

Jenny, H, Arkley, RJ, and Schultz, AM (1969): The pygmy forest-podsol ecosystem and its dune associates of the Mendocino coast. *Madroño* 20, 60-75.

Binkley, D. (2015): Ecosystems in four dimensions. *New Phytologist* 206, 883-885.

Milodowski, DT, Mudd, SM, and Mitchard, ETA (2015): Erosion rates as a potential bottom-up control of forest structural characteristics in the Sierra Nevada Mountains. *Ecology* 96 (1), 31-38, doi: 10.1890/14-0649.1.sm.

Dietrich, WE, and Perron, JT (2006): The search for a topographic signature of life. *Nature* 439, 411-418, doi: 10.1038/nature04452.

**Question 4: Does fluvial incision control critical zone architecture?**

*Tutorials*

Bedrock rivers

*Seminars and supporting papers*

Berlin, MM, and Anderson RS (2007): Modeling of knickpoint retreat on the Roan Plateau, western Colorado. *Journal of Geophysical Research* 112, F03S06, doi: 10.1029/2006JF000553.

Crosby, BT, and Whipple, KX (2006): Knickpoint initiation and distribution within fluvial networks: 236 waterfalls in the Waipaoa River, North Island, New Zealand. *Geomorphology* 82, 16-38, doi: 10.1016/j.geomorph.2005.08.023.

Attal, M, Mudd, SM, Hurst, MD, Weinman, B., Yoo, K, and Naylor, M (2015): Impact of change in erosion rate and landscape steepness on hillslope and fluvial sediments grain size in the Feather River basin (Sierra Nevada, California). *Earth Surface Dynamics* 3, 201-222, doi: 10.5194/esurf-3-201-2015.

Fernandes, NF, and Dietrich, WE (1997): Hillslope evolution by diffusive processes: The timescale for equilibrium adjustments. *Water Resources Research* 33 (6), 1307-1318.

Pelletier, J, Barron-Gafford, A, Breshears, DD, Brooks, PD, Chorover, J, Durcik, M, Harman, CJ, Huxman, TE, Lohse, KA, Lybrand, R, Meixner, T, McIntosh, JC, Papuga, SA, Rasmussen, C, Schaap, M, Swetnam, TL, and Troch, PA (2013): Coevolution of nonlinear trends in vegetation, soils, and topography with elevation and slope aspect: A case study in the sky islands of southern Arizona. *Journal of Geophysical Research-Earth Surface* 118: 741-758, doi:10.1002/jgrf.20046.