Soil Geomorphology (Geog 525). Spring 2013.

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What is Soil Geomorphology? Geomorphic processes shape the Earth surface, and pedogenic processes produce soil horizons from parent material; this course deals with how these two groups of processes overlap and interact. That is, the work of geomorphic processes affects soil formation, for example, when stream sediment is deposited on an existing floodplain soil. At the same time, the development of soil horizons can alter the effectiveness of geomorphic processes such as hillslope erosion. Both geomorphic and pedogenic processes cannot really be separated from the rest of the ecosystems in which they occur; without land-based life of all kinds, Earth's landscapes and soils would be very different.

Course Overview. The first part of this course is organized around a series of process connections and interactions. We start with the basic soil-forming process of organic matter accumulation, discuss how it can be modeled as a function of time, taking into account ecosystem processes, and how we can test that modeling with soil *chronosequences*. We then add geomorphology, in the sense that we consider what happens to organic matter and its radiocarbon age as a soil erodes or as sediment is deposited on top of it. The same approach is then taken with bioturbation and other physical mixing and disturbance of soils: These processes have important roles in shaping both soils and landscapes and they have been extensively studied with both field observations and models. Finally, we consider the complex set of processes associated with water flow through soils, including weathering and movement of dissolved ions and mineral particles. These are traditionally emphasized in studies of soil genesis—for good reason—but here the goal is to place them in a broader geomorphological context, that is, where these soil-forming processes are occurring the landscape, how they are affected by geomorphic processes, and how soil formation can itself change the effectiveness of geomorphic processes. As a simple example, both water and soil can be redistributed down a hillslope, possibly increasing the water flow through soils at the foot of the slope and also transferring weathered material from upslope to downslope soils. As soils develop on the slope, however, they may change in ways that affect infiltration rates or the potential for soil erosion.

The second part of the course is a brief look at conceptual models of soil genesis. The most important topic here is how to add geomorphology to these models, that is, how to incorporate the interactions of geomorphic and soil-forming processes we have just discussed. The final section of the course deals with case studies of the concepts covered earlier, in specific geomorphic environments such as floodplains, dune fields, or glaciated landscapes.

Prerequisites. Soil Sci 325 or Geog/Soil Sci 431 or equivalent, and an intermediate level course in geomorphology, or consent of instructor.

Field Trip: A weekend field trip is tentatively planned for April. The date will be discussed in the first class period.

Readings. For many of the topics I've assigned readings from a textbook, *Soils: Genesis and Geomorphology*, by R. Schaetzl and S. Anderson (2005), Cambridge University Press. I've put a copy on reserve in the Geography Library. If you anticipate much future work in this area I recommend buying the book. The other *required* readings are a very important component of this class, and will usually be integrated into lectures, in-class discussion, and take-home exams. Required readings will usually be made available in electronic form on the password-protected Learn@UW site for this course. These readings included scientific research papers as well as excerpts from several books. I have included book sections or papers by scientists who have been especially influential in the field, so that you can learn their ideas from the original source.

Grading. The course grade will be based on two take-home essay exams (50% of semester grade), homework exercises (30% of semester grade), and a short term paper (20% of semester grade). The emphasis will be on evaluating students' ability to critically examine concepts covered in class, and to apply those concepts to new research problems. The homework assignments may include work with lab data, numerical models, and spreadsheet calculations, with interpretation of the results. The paper will be written on a topic agreed upon between the student and myself. After the topic is decided, I may give you one or more broad questions or conceptual problems that I would like you to address in the paper. Each paper should include adequate citation of the relevant literature. I would like to see some original thought and even some strong opinions on the topics you are writing about. **Papers Due: 5/15.**

Course Topics and Reading Assigments. Reading assignments are only listed for the first part of the semester. I will send out one or more additional reading lists for topics covered in the second part, and even the readings for the first may be revised a little if needed. See the attached bibliography for more complete references to the readings.

"*Methods*" topics involve hands-on, lab- or computer-based activities. Some, but not all, of these activities involve work that will be turned in as homework assignments. "*Discussion*" topics are those for which I will definitely set aside some time to discuss, seminar-style (feel free to discuss or raise questions about any other topics we cover, however).

1/22.

1. Introduction to the course. Examples of research in soil geomorphology and applications to other problems.
2. Review: Soil horizons and soil profiles. *Readings:* Jenny, 1980, Chapter 1; *Soils*, Chapters 1 and 2 (read these carefully if you haven't had a pedology course such as Soil Sci 325)
3. *Discussion:* Issues in recognizing soil horizons and other pedofeatures, using monoliths and cores

1/29.

1. Organic matter accumulation and turnover, and implications for radiocarbon age of soil organic matter. Evidence on OM accumulation from chronosequences. Effects of burial and erosion. *Readings:* Wang et al., 1996; *Soils*, pages 547-550; and page 600-618.
2. *Methods:* Use of organic matter models. **Homework Asssignment 1** handed out

2/5.

2. Pedoturbation and biomantle development**.** Ecological and physical controls on soil animal activity. Reconciling ubiquitous bioturbation with soil horizonation. Downslope movement of soil by pedoturbation. *Readings:* Hole, 1961; Paton et al., 1995, Chapter 3; *Soils*, Chapter 10.
3. *Methods/Discussion:* Recognizing field evidence of bioturbation, simple models of bioturbation, and/or discussion of luminescence dating and whether it can detect bioturbation. *Readings:* Heimsath et al., 2002

2/12, 2/19.

4. Water flow in soils as a key driver of pedogenesis. *Readings: Soils,* Chapter 5 (up to the start of "Soil Temperature" on page 87).
5. Cation cycling by vegetation, acidification of soil profiles.
6. Chemical weathering. Weathering profiles and their relationship to bedrock lithology and climate. Products of weathering, especially clay minerals. Role of weathering in landscape evolution. Mass balance analysis. *Readings:* Chadwick et al., 1990; Egli et al., 2003; Schaller et al., 2010 [you may want to wait until I discuss some technical details of this study in lecture before reading the paper]; *Soils*, Chapter 9; Chapter 8 (*up to page 189 only*); also read Chapter 4 if you need more background on minerals.
7. *Methods:* Relating pH and exchangeable acidity, using lab measurements or existing data, calculating mass balance (also, field water content measurements will be made later on the field trip). **Homework Assignment 2** handed out.

2/26, 3/5.

1. Transfer of material between soil horizons in acidic and neutral soils. Clay illuviation. Lamellae. Non-illuvial Bt horizons. *Readings: Soils,* pages 361-373 (starting with "Lessivage" and ending with "Fragipans"), pages 440-453 (starting with "Podzolization" and ending with "Sulfidization...".
2. Formation of secondary carbonate, gypsum, salt and silica features. Evidence from chronosequences. Podzolization. *Readings:* Machette, 1985; Reheis, 1987, Gile, 1966; *Soils*, pages 402-433 (starting with "Calcification," ending with "Near-surface processes...").
3. *Methods:* Interpreting soil thin sections, especially evidence of clay illuviation.

3/5. Exam 1 handed out (take-home exam)

3/12. Exam 1 due.

3/12.

1. Conceptual models of soil development. *Readings:* Darwin, 1837; Dokuchaev, 1884, p. 333-341; Shantz and Marbut, 1923, Chapt. 5; Jenny, 1980, Chapt. 8; Simonson, 1959; *Soils*, pages 295-336.
2. The problem of defining "t_0" and soil age. Concept of soil residence time. *Readings: Soils*, pages 169-170 on "The mutability of $time_{zero}$"
3. *Discussion:* How can geomorphology be integrated more effectively into conceptual models of soil development? Which models are best suited for this purpose?

An additional reading list covering topics from this point on will be handed out later.

3/19, 4/2 (first part of lecture)

1. Case studies of soils on hillslopes: Interaction of pedogenesis, bioturbation, and erosion/deposition. Catenas in tropical and temperate regions. Stonelines and stone pavements. Do tropical and subtropical catenas record long-term changes in climate and vegetation?

2. *Methods:* Application of cosmogenic isotopes and luminescence dating to studies of hillslope processes and pedogenesis. Interpreting data from catena studies in the tropics and/or temperate regions. **Homework 3 handed out.**

4/2 (second part of lecture)**, 4/9.**

1. Case studies in aeolian systems. Soils in episodically active dunefields. Feedbacks of soil genesis on dune vegetation. Dust sources and sinks, and formation of major loess deposits. Erosion, "upbuilding", and burial of soils in dune fields and loess-mantled landscapes. Inference of past vegetation or climate from soils in loess and dune sand. Loess-paleosol sequences.
2. *Methods:* Interpreting soil geomorphic patterns in dunefields and loess landscapes, using soil survey data.

4/16; 4/23.

1. Case studies in fluvial systems. Competition between sedimentation and soil formation on active floodplains. Alluvial paleosols, Quaternary and pre-Quaternary, their paleoenvironmental interpretation, and importance for paleontology and paleoecology. Soils on fluvial and coastal terraces and old fan or pediment surfaces. Aeolian processes on old fluvial surfaces. Chronosequences on terraces/fans/pediments in arid and humid regions. Desert pavement, desert varnish, and Av horizons.
2. *Discussion:* Sampling schemes and local variability in terrace chronosequences.

4/23. Exam 2 handed out (take-home exam)

4/30, 5/7.

1. Case studies in glaciated landscapes. Distinctive characteristics of catenas on moraines and other glacial landforms. Soils on alpine glacial moraines in semiarid to humid settings. Soil patterns across the forest-grassland boundary in the glaciated mid-latitudes. Can soils be used to reconstruct past shifts in this boundary? Role of soils and paleosols in continental and alpine glacial stratigraphy. Paleopedologic record of past interglacials in North America and Europe.

5/10. Exam 2 due.

5/15. Paper due.

Geography 525. Soil Geomorphology. Reference List.

This list includes the assigned readings for the first part of the semester, and most of those for the second part, along with many other papers that aren't assigned but may provide useful additional background on specific topics. The list will be updated as needed when I assign readings for later in the semester.

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Harden, J.W., 1982. Quantitative index of soil development from field descriptions. Geoderma 28: 1-28.

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