

Soil Geomorphology (Geog 525). Fall, 2007.

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Office hours: Tuesday, 11-12AM; Wednesday, 2:30-3:30 PM, or by appointment.

Overview of the Course. Soils cannot be separated from the landscapes in which they form; as landscapes evolve, soils on those landscapes develop through the interaction of pedogenic and geomorphic processes. To some extent, soils reflect their present environment (climate, vegetation, and currently active geomorphic and hydrologic processes). However, most soils are not in equilibrium with their present environment, but instead preserve evidence of their earlier history, and the history of the landscape in which they have formed. Therefore, soils can provide key evidence in reconstructing long-term landscape evolution and paleoenvironmental change. Furthermore, long-term soil development can have major implications for the ecosystem as a whole, primarily through changes in nutrient or water availability, and for biogeochemical cycles. This course will consider the concepts and research methods needed to understand the closely linked evolution of soils and landscapes.

The course will begin with a review of basic concepts in pedology and soil-forming processes. It is assumed that students will already be somewhat familiar with this material, but can benefit from a fresh, geomorphic perspective. We will emphasize processes that are important both in soil formation and in landscape evolution. This discussion provides essential background for the final section of the course, which deals with soils in specific geomorphic systems. For each system, we will discuss the interaction of pedogenic and geomorphic processes, the relations between soil morphology and land surface age in specific geomorphic settings, and the role of soils in reconstructing paleoenvironments and landscape evolution..

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

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

Textbook and readings. Readings form an essential part of this course. Both the textbook and numerous scientific papers are integrated into the lectures, and you will need to use them in completing the take-home essay exams. For the more difficult papers, it might be a good idea to take an initial look at them before they're covered in lecture, and then go through them more carefully while referring to your lecture notes.

The course textbook is *Soils: Genesis and Geomorphology*, by R. Schaetzl and S. Anderson (2005). Unlike most textbooks today, this one is well worth the price and is an excellent book to keep as a reference if you are thinking of going into any field remotely related to soil genesis and geomorphology.

In addition, I am assigning excerpts from another book, *Understanding Soil Change*, by D.D. Richter and D. Markewitz (2001). This is essentially a case study of deeply weathered soils on the South Carolina piedmont, describing how they developed over millennia and how they have been affected by human land use in recent centuries. The assigned readings are from the part of the book describing long-term development of these soils, placing them in the context of the forest ecosystem under which they formed. The book is written for a broad audience and reviews a lot of basic concepts, but even if you already have a strong background in pedology, there are some thought-provoking concepts here that are presented very well. The rest of the

book is worth reading as well, if you have the time and interest. The excerpts from Richter and Markewitz and the scientific papers will be made available in electronic form *on the password-protected Learn@UW site for this course.*

Grading. The course grade will be based on two exams (40% of semester grade), three homework exercises (30% of semester grade), and a paper (30% of semester grade). In the exams, the homework assignment, and the paper, the emphasis will be on evaluating students' ability to critically examine concepts covered in class, and to apply those concepts to new research problems.

Both exams will be in take-home, essay format. The homework assignments will include 1) running a soil organic carbon model and interpreting the results in terms of radiocarbon dating, 2) doing spreadsheet calculations of chemical mass balance during soil development, and 3) an interpretation of lab data from a soil geomorphology study, to be described in more detail later. The paper will be written on a topic agreed upon between the student and myself. After the topic is decided, I will 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 PM, 12/17.**

Although the overall grading scheme is the same for undergraduate and graduate students, graduate students will generally be held to a higher standard of work, especially on the paper.

Course Topics and Reading Assignments (*Soils* is the course textbook). Complete references for the readings are listed at the end of the syllabus. *Note: Reading assignments may be revised over the course of the semester.*

9/6. Introduction to the course. Objectives of soil geomorphic research, and relevance to ecology, archaeology, and paleoclimatology. Definitions of "soil." Review of soil horizons and soil profiles. Soil horizons vs. sedimentary strata. Paleosols and welded or composite soils. Review of Jenny's state factor model of soils and ecosystems, including its historical background. *Readings: Soils*, Chapters 1 and 2 (should be mostly review if you've had a pedology course such as Soil Sci 325 recently; otherwise read these chapters carefully), *Soils*, pages 295-320. On reserve: Jenny, 1961; Richter and Markewitz, 2001, p. 69-89. For more background: Bockheim, 1980, Bockheim et al., 2005.

9/13 (first part of lecture). Alternatives to the Jenny model. *Soils*, pages 320-336. On reserve: Simonson, 1959; Runge, 1973; Johnson et al., 1990.

9/13 (second part of lecture), **9/20.** The problem of defining "t₀" and soil age. Concept of soil residence time. Relative age relationships of sediments, geomorphic surfaces, and soils. Geochronological techniques applicable to soils and paleosols (luminescence, cosmogenic isotopes, radiocarbon dating). Organic matter accumulation and turnover, and implications for radiocarbon dating of soil organic matter. *Readings: Soils*, pages 169-170 on "The mutability of time_{zero}"; pages 547-550; and page 600-618. On reserve: Morrison, 1967, pages 1-30; Wang et al., 1996. **Homework Assignment 1 handed out on 9/20.**

9/27, 10/4. Chemical weathering as a pedogenic and geomorphic process. Weathering profiles and their relationship to bedrock lithology and climate. Products of weathering, especially clay minerals. Role of weathering in landscape evolution and sediment supply to geomorphic systems. Mass balance analysis. *Readings: Soils*, Chapter 9; Chapter 8 (*up to page 189 only*); also read Chapter 4 if you need more background on minerals. On reserve: Richter and

Markewitz, 2001, p. 90-104 (*read this first!*), Chadwick et al., 1990; Egli et al., 2003; Anderson et al., 2002 (this can be a difficult paper to get through—wait and get the overview in lecture first before trying to work through it in detail)

10/4. Homework Assignment 1 due. Exam 1 handed out (take-home exam)

10/11. Exam 1 due, Homework Assignment 2 handed out.

10/11 (first part of lecture). Pedoturbation, A horizon/biomantle development, and relationship to hillslope processes. Downslope movement of soil by pedoturbation. Applications of cosmogenic nuclides and luminescence dating to detect and quantify pedoturbation. *Readings: Soils*, Chapter 10; also pages 354-357, starting with “Process Bundles” and ending at “Acidification and base cycling.” On reserve: Hole, 1961; Paton et al., 1995, Chapter 3; Heimsath et al., 2002.

10/11 (second part of lecture), **10/18**. Processes of horizon differentiation, and their use as indicators of land surface age or stability. Overview of water retention and flow in soils, and the importance of textural discontinuities. Clay illuviation. Lamellae. Non-illuvial Bt horizons. Formation of secondary carbonate, gypsum, salt and silica features. Podzolization. *Readings: Soils*, Chapter 5 (up to the start of “Soil Temperature” on page 87); pages 361-373 (starting with “Lessivage” and ending with “Fragipans”); pages 402-433 (starting with “Calcification,” ending with “Near-surface processes...”), and pages 440-453 (starting with “Podzolization” and ending with “Sulfidization...”). On reserve: Machette, 1985; Reheis, 1987, Gile, 1966.

10/25 (first part of lecture). Surface exposure dating (or geomorphic surface dating) based on pedogenic processes and soil morphology. Chronosequences. *Readings: Soils*, Chapter 14 (up to page 596, start of “Numerical dating techniques...”) On Reserve: Harden, 1982. **Homework Assignment 2 due. Homework Assignment 3 handed out.**

10/25 (second part of lecture), **11/1**. Soils on hillslopes: Interaction of hillslope hydrology, erosion/deposition and pedogenesis. Catenas. Horizon formation through hillslope erosion and sedimentation. Competing models of stoneline/stone pavement formation. Application of cosmogenic isotopes to studies of hillslope processes and pedogenesis. *Readings: Soils*, Chapter 13. On reserve: Milne, 1936; Paton et al., 1995, Chapter 3; Braucher et al., 2000; Sommer and Schlichting, 1997. More Background: Johnson, 2002; Anderson et al., 2002 (also assigned above).

11/8. Homework Assignment 3 due.

11/8, 11/15. Dust deposition and soil development. Aeolian processes and soil genesis: Erosion, “upbuilding”, and burial of soils in dune fields and loess-mantled landscapes. Inference of past vegetation or climate from loess-derived soils. Chronosequences of soils in aeolian sand. Loess-paleosol sequences in arid, semi-arid, and humid regions. *Readings: Soils*, pages 195-207 (on wind-transported parent materials). On reserve: Chadwick and Davis, 1990; Mason and Jacobs, 1998; McDonald and Busacca, 1990; Jacobs and Mason, 2007; Kemp and Derbyshire, 1998. For more background: *Soils*, Chapter 15.

11/29; 12/6 Soils on active floodplains. Alluvial paleosols, Quaternary and pre-Quaternary, and their paleoenvironmental interpretation. Soils on terraces and old fan or pediment surfaces: Effect of fluvial incision on pedogenic processes, post-incision modification of the terrace surface. Chronosequences on terraces/fans/pediments in arid and humid regions. Desert

pavement, desert varnish, and Av horizons. *Readings: Soils*, pages 191-195 and pages 433-440 (starting with "Near-surface processes in desert soils"). On reserve: Aslan and Autin, 1998; Daniels, 2003; Retallack, 1986; Reheis, 1990; Howard et al., 1993; McFadden et al., 1987.

12/13. Soils in glacial deposits: Soils on alpine glacial moraines in semiarid to humid settings. Role of paleosols in continental glacial stratigraphy. Paleopedologic record of past interglacials in North America and Europe. *Readings: Soils*, pages 516-529 (section on Ruhe's work in Iowa); Chapter 15 (assigned earlier; some parts apply here as well). On reserve: Berry, 1994; Dahms, 1994; Hall, 1998; Follmer, 1982; Jacobs, 1998.

Geography 525. Soil Geomorphology. Reference List for Fall, 2007.

Many, though not all, of the following papers are assigned readings this semester. Others are not required readings but I may want to point them out to you over the course of the semester. Additional papers may be added to this list during the semester.

- Allan, R. J., and Hole, F. D., 1968. Clay accumulation in some Hapludalfs as related to calcareous till and incorporated loess on drumlins in Wisconsin. *Proceedings - Soil Science Society of America* 32, 403-408.
- Anderson, S.P., Dietrich, W.E., Brimhall, G.H., Jr. 2002. Weathering profiles, mass-balance analysis, and rates of solute loss. *Geological Society of America Bulletin* 114:1143-1158.
- Aslan, A., and Autin, W.J., 1998. Holocene flood-plain soil formation in the southern lower Mississippi Valley: Implications for interpreting alluvial paleosols. *Geological Society of America Bulletin* 110: 433-449.
- Berry, M.E., 1994. Soil-geomorphic analysis of Late-Pleistocene glacial sequences in the McGee, Pine, and Bishop Creek drainages, east-central Sierra Nevada, California. *Quaternary Research* 41: 160-175.
- Bettis, E. A., III, Muhs, D. R., Roberts, H. M., and Wintle, A. G., 2003. Last glacial loess in the conterminous USA. *Quaternary Science Reviews* 22, 1907-1946.
- Bockheim, J. G., 1980. Solution and Use of Chronofunctions in Studying Soil Development. *Geoderma* 24, 71-85.
- Bockheim, J. G., Gennadiyev, A. N., Hammer, R. D., and Tandarich, J. P., 2005. Historical development of key concepts in pedology. *Geoderma* 124, 23-36.
- Braucher, R., Bourlès, D.L., Brown, E.T., Colin, F, Muller, J.-P., Braun, J.-J., Delaune, M., Edou Minko, A., Lescouet, C., Raisbeck, G.M., Yiou, F., 2000. Application of in situ-produced cosmogenic ¹⁰Be and ²⁶Al to the study of lateritic soil development in tropical forest: theory and examples from Cameroon and Gabon. *Chemical Geology* 170: 95-111.
- Butler, B. E. 1959. Periodic phenomena in landscapes as a basis for soil studies. CSIRO Soil Publication 14, Melbourne, Australia.
- Dahms, D.E., 1994. Mid-Holocene erosion of soil catenas on moraines near the type Pinedale till, Wind River Range, Wyoming. *Quaternary Research* 42: 41-48.
- Daniels, J.M., 2003. Floodplain aggradation and pedogenesis in a semiarid environment. *Geomorphology* 56: 225-242.
- Egli, M., Mirabella, A., Sartori, G., and Fitze, P. 2003. Weathering rates as a function of climate: results from a climosequence of the Val Genova (Trentino, Italian Alps). *Geoderma* 111: 99-121.
- Fehrenbacher, J. B., Olsen, K., and Jansen, I., 1986. Loess thickness in Illinois. *Soil Science* 141, 423-431.
- Follmer, L.R., 1982. The geomorphology of the Sangamon surface: its spatial and temporal attributes. p. 117-146 in C.E. Thorn (Ed.) *Space and time in geomorphology*. Allen and Unwin, London.

- Gile, L.H., Peterson, F.F., and Grossman, R.B., 1966. Morphological and genetic sequences of carbonate accumulation in desert soils. *Soil Science* 101: 347-360.
- Hall, R.D., 1999. Effects of climate change on soils in glacial deposits, Wind River Basin, Wyoming. *Quaternary Research* 51: 248-261.
- Harden, J.W., 1982. Quantitative index of soil development from field descriptions. *Geoderma* 28: 1-28.
- Heimsath, A., Chappell, J., Dietrich, W., Nishiizumi, K. and Finkel, R., 2000. Soil production on a retreating escarpment in southeastern Australia. *Geology*, 28(787-790).
- Heimsath, A. M., Chappell, J., Spooner, N.A., and Questiaux, D.G. 2002. Creeping soil. *Geology* 30:111-114.
- Hole, F. D., 1981. Effects of animals on soil. *Geoderma* 25, 75-112.
- Howard, J.L., Amos, D.F., and Daniels, W.L., 1993. Alluvial soil chronosequence in the Inner Coastal Plain, central Virginia. *Quaternary Research* 39: 201-213.
- Jacobs, P.M., 1998. Morphology and weathering trends of the Sangamon Soil Complex in south-central Indiana in relation to paleodrainage. *Quaternary Research* 50: 221-229.
- Jacobs, P.M. and Mason, J.A., 2007. Late Quaternary climate change, loess sedimentation, and soil development in the central Great Plains: A pedosedimentary model. *Geological Society of America Bulletin*, 119: 462-475.
- Jenny, H. 1941. Factors of soil formation. McGraw-Hill, New York. *Chapter 1*
- Jenny, H., 1961. Derivation of state factor equations of soils and ecosystems. *Soil Science Society of America Proceedings* 25, 385-388.
- Jenny, H., 1961. Derivation of state factor equations of soils and ecosystems. *Soil Science Society of America Proceedings* 25, 385-388.
- Johnson, D. L., Domier, J. E. J., and Johnson, D. N., 2005. Reflections on the nature of soil and its biomantle. *Annals of the Association of American Geographers* 95, 11-31.
- Johnson, D. L., Keller, E. A., and Rockwell, T. K., 1990. Dynamic Pedogenesis - New Views on Some Key Soil Concepts, and a Model for Interpreting Quaternary Soils. *Quaternary Research* 33, 306-319.
- Johnson, D.L., 2002. Darwin would be proud: Bioturbation, dynamic denudation, and the power of theory in science. *Geoarchaeology*, 17(6): 7-40.
- Kemp, R. A., 2001. Pedogenic modification of loess; significance for palaeoclimatic reconstructions. *Earth Science Reviews* 54, 145-156.
- Kemp, R. A., and E. Derbyshire. 1998. The loess soils of China as records of climatic change. *European Journal of Soil Science* 49: 525-539.
- Machette, M. 1985. Calcic soils of the southwestern United States. p. 1-21 in D.L. Weide (Ed.) *Soils and Quaternary geology of the southwestern United States*. Geological Society of America Special Paper 203, Boulder, Colorado.
- Mason, J. A., and Jacobs, P. M., 1998. Chemical and particle-size evidence for addition of fine dust to soils of the Midwestern United States. *Geology* 26, 1135-1138.
- McDonald, E. V., and A. J. Busacca. 1990. Interaction between aggrading geomorphic surfaces and the formation of a Late Pleistocene paleosol in the Palouse loess of eastern Washington state. *Geomorphology* 3: 449-470.
- McFadden, L.D., Wells, S.G., and Jercinoich, M.J., 1987. Influences of eolian and pedogenic processes on the origin and evolution of desert pavements. *Geology* 15: 504-508.
- Milne, 1936. Normal erosion as a factor in soil profile development. *Nature* 138, 548-549.
- Morrison, R.B. 1967. Principles of Quaternary soil stratigraphy. p. 1-69 in R.B. Morrison and H.E. Wright, Jr. (Eds.) *Quaternary Soils*. Desert Research Institute, University of Nevada.
- Paton, T., Humphreys, G. and Mitchell, P.B., 1995. *Soils: A New Global View*. Yale University Press, New Haven.

- Phillips, J. D., 1993a. Progressive and regressive pedogenesis and complex soil evolution. *Quaternary Research* 40, 169-176.
- Phillips, J. D., 1993b. Stability implications of the state factor model of soils as a nonlinear dynamical system. *Geoderma* 58, 1-15.
- Reheis, M.C., 1987. Climatic implications of alternating clay and carbonate formation in semiarid soils of south-central Montana. *Quaternary Research* 27: 270-282.
- Reheis, M.C., 1990. Influence of climate and eolian dust on the major-element chemistry and clay mineralogy of soils in the northern Bighorn Basin, U.S.A. *Catena* 17: 219-248.
- Retallack, G.J., 1986. Fossil soils as grounds for interpreting long-term controls of ancient rivers. *Journal of Sedimentary Petrology* 56: 1-18.
- Richardson, J. L., and Hole, F. D., 1979. Mottling and Iron Distribution in a Glossoboralf-Haplaquoll Hydrosequence on a Glacial Moraine in Northwestern Wisconsin. *Soil Science Society of America Journal* 43, 552-558.
- Richter, D.D., and Markewitz, D., 2001. *Understanding soil change: Soil sustainability over millennia, centuries, and decades.* Cambridge University Press, Cambridge, England.
- Rostad, H. P. W., Smeck, N. E., and Wilding, L. P., 1976. Genesis of Argillic Horizons in Soils Derived from Coarse-Textured Calcareous Gravels. *Soil Science Society of America Journal* 40, 739-744.
- Ruhe, R. V., 1956. Geomorphic surfaces and the nature of soils. *Soil Science* 82, 441-455.
- Ruhe, R. V., and Walker, P. H., 1968. Hillslope models and soil formation; I, Open systems.
- Runge, E. C. A., 1973. Soil Development Sequences and Energy Models. *Soil Science* 115, 183-193.
- Schaetzl, R., and Anderson, S. 2005. *Soils. Genesis and Geomorphology.* Cambridge University Press, Cambridge. *Chapters 1-4, 6, 9-13.*
- Simonson, R. W., 1959. Outline of a generalized theory of soil genesis. *Soil Science Society of America Proceedings* 23, 152-156.
- Smeck, N. E., 1985. Phosphorus Dynamics in Soils and Landscapes. *Geoderma* 36, 185-199.
- Sommer, M., and Schlichting, 1997. Archetypes of catenas in respect to matter--a concept for structuring and grouping catenas. *Geoderma* 76, 1-33.
- Walker, D. A., Bockheim, J. G., Chapin, F. S., Eugster, W., Nelson, F. E., and Ping, C. L., 2001. Calcium-rich tundra, wildlife, and the "Mammoth Steppe". *Quaternary Science Reviews* 20, 149-163.
- Walker, P. H., and Ruhe, R. V., 1968. Hillslope models and soil formation. II. Closed systems. *Ninth International Congress of Soil Science Transactions* 58, 561-568.
- Wang, Y., and Amundson, R. 1996. Radiocarbon dating of soil organic matter. *Quaternary Research* 45: 282-288.
- Wells, S.G., Dohrenwend, J.C.,
- Willis, K. J., Braun, M., Sumegi, P., and Toth, A., 1997. Does soil change cause vegetation change or vice versa? A temporal perspective from Hungary. *Ecology* 78, 740-750.