Weathering System
PLSC 467/667 & GEOL 467/667 Section 011
Fall 2009

Course Information: Weathering System is a course designed for graduate students and advanced undergraduate students. The course is offered in the fall of odd numbered years. Whereas the course does not have pre-requisites, students with backgrounds in soil science or geology will find themselves better prepared for the course. The course is designed to encourage students' participation and the interactions among students and the instructor. In tandem with instructor's lectures, every student will make presentations, lead discussions, and write critiques of other students' works.

Course Hours, Location and Instructor: Class will meet from 11:00 AM-12:30 PM Tuesday and Thursday at 102 Fisher Greenhouse. My office hours will be from 1:30 pm to 2:30 pm on Tuesday and Thursday. However, as long as you let me know beforehand and I don't have pressing issues, I will be happy to talk to you outside of regular office hours. Here is my contact info.

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Readings: There is no text book for this course. Instead, a number of peer-reviewed research papers and several book chapters will be used throughout the semester. At the beginning of each class that is led by students, you will have a five minute quiz on the reading materials required for the preceding two classes led by the instructor. From the suggested papers, you may choose papers of your interest for your presentations. You are welcome to work with papers not listed in the suggested reading as long as they are closely related to the subject and approved by the instructor. A tentative list of readings can be found at the end of this syllabus. As the class evolves during this semester, a few changes are likely to be made to the list.

In addition to the research papers, I will often incorporate the materials from the following books into my lectures to cover basic knowledge required for understanding the paper contents. Those books are on reserve at Agricultural Library (Rm. 025) in Townsend Hall.

- Soil Genesis and Classification (Fifth Ed.), S.W. Buol, R.J. Southard, R.C. Graham, P.A. McDaniel, Ames Iowa, 2003, p.494. Iowa State Press
- Principles and Applications of Geochemistry (Second Ed.), Gunter Faure, Prentice Hall, 1007, 665p.
- Isotopes: Principles and Applications (Third Ed.), Gunter Faure, Teresa M. Mensing, 2005, p.897. Wiley John Wiley & Sons, Inc.
- Schlesinger W. H. (1997). Biogeochemistry: an analysis of global change, Academic Press.

- Cox, P. A. (1995). The elements on earth: inorganic chemistry in the environment. Oxford, Oxford University Press.

Course Description:

The course follows physical and chemical weathering processes that combine to lead to the disintegration of rocks, formation of soils and generation of sediments and solutes. We focus on weathering as a process that shapes morphology of soils and landscapes, soils' geochemical profiles, and inorganic and organic biogeochemical cycles in terrestrial ecosystems. From published papers and ongoing research, we will also make efforts to learn how scientists identify knowledge gaps, formulate new questions, and develop field, laboratory, and modeling techniques to advance our knowledge of weathering. By focusing on the published papers, we will also learn how scientists communicate their finding to the larger scientific communities.

The course materials will suit students from diverse backgrounds and interests. Students in soil science programs will appreciate how soil chemistry, physics, and microbiology contribute to the elemental and mineralogical mass balance of a soil system. Students with geology or geography backgrounds will learn how the evolution of landscapes and global climates are coupled to mass conversions of rocks to soils to sediments or solutes. Students with interests in conservation and environmental science will be exposed to how terrestrial nutrient cycles operate and how sensitive the cycles are to environmental forcings such as climate and land use changes.

Course Assignments and Grading:

Students will be graded upon the following class assignments:
Quiz on required reading: 30 %
Presentations: 40 %
Critiques: 30 %

Quiz: At the beginning of each class that is led by students, students will answer 2-3 questions regarding the materials covered in the most recent two or three classes led by the instructor.

Presentations: Each student will give two 40 min power point presentations (followed by 15 min discussion) regarding the paper(s) of his/her interest which could be selected from the suggested reading list OR the research he/she is conducting (must be related to weathering). At least two weeks before the presentation, students should discuss the presentation plan with the instructor. It is expected that the student treat the paper(s) as his/her own research and defend them (including acknowledging weaknesses) when criticized. The presentation schedule will be made by the end of the second week of class.

Critiques: For each student's presentation, students will criticize, question, and comment on the presentation. A student will introduce the speaker, enforce the time limit, and lead the follow-up discussion. Everyone is required to read the paper(s) presented. Equally importantly, students should write 1 page (11 fonts, 1.5 line spacing, and 1 inch margin) comments (including constructive criticisms) regarding the research summary of the presentation and presentation skill and hand in the comments to the instructor in the next class. Qualities of written comments determine the grade.

Presentation Tips:

Your presentations will be more exciting and informative by following the guidelines listed below. Your presentation should include introduction (eg., intellectual context, research justification, and hypotheses of goals of the research), methods (eg., field settings, laboratory techniques, and mathematical treatments), results and discussion, and conclusion (eg., impacts on the discipline and future works required to extend the findings). In additions;

- Connect your presentation to the preceding lecture materials. Do not make your talk a simple summary of the paper(s) you select.
- Emphasize the most important message(s). Do not sacrifice the key points for discussing details.
- Make efforts to make your presentation understood by the other students whose backgrounds could be very different from yours. Prepare background knowledge and incorporate them into your presentation.
- Use your slides efficiently. Do not flood your slides with texts or irrelevant figures.
- Talk to your audiences. Do not read your power point slides.
- Use your allocated time wisely. The discussion leader will stop you when you continue after the allotted time.
- Prepare your talk well in advance. Do not put off your preparation to the last minute.
- Talk enthusiastically. As noted earlier, consider the paper(s) you select as your own work. You will be expected to defend the work and positively acknowledge the weaknesses when critique.

Academic Dishonesty:

Academic dishonesty in any form will not be tolerated and will be subject to University's Policy on Academic Honesty as described in the Student Guide to Policies (http://www.udel.edu/stuguide/09-10/code.html#honesty).

Course Schedule

Date	*Day*	*Instructor Lecture #*	*Student Lecture # Quiz #*	*Contents*
1-Sep	Tue	1		**Course overview**
3-Sep	Th	2		**Cosmogenic radionuclides**
8-Sep	Tue		1	Student presentation and discussion (all students)
10-Sep	Th	3		**Concept of soil profile and Soil Production**
15-Sep	Tue		2	Student presentation and discussion
17 Sep	Th			No Class
22 Sep	Tue			No Class
24-Sep	Th	4		**Weathering of primary minerals_1**
29-Sep	Tue	5		**Weathering of primary minerals_2**
1-Oct	Th		3	Student presentation and discussion
6-Oct	Tue			No Class
8-Oct	Th	6		**Short-term vs. long-term chemical weathering rate**
13-Oct	Tue		4	Student presentation and discussion
15-Oct	Th	7		**Soil chronosequence**
20-Oct	Tue	8		**Mineral weathering vs. Time (lab vs. field)**
22-Oct	Th		5	Student presentation and discussion
27-Oct	Tue	9		**Interaction between physical and chemical weathering processes_1**
29-Oct	Th	10		**Interaction between physical and chemical weathering processes_2**
3-Nov	Tue		6	Student presentation and discussion
5-Nov	Th	11		**Geochemical soil catena or toposequence**
10-Nov	Tue	12		**Geomorphic processes on soil covered hillslopes**
12-Nov	Th		7	Student presentation and discussion
17-Nov	Tue	13		**Coupled processes of chemical weathering, sediment transport, and soil production**
19-Nov	Th	14		**Weathering and carbon cycle**
24-Nov	Tue		8	Student presentation and discussion
26-Nov	Th			*Thanksgiving-No class*
1-Dec	Tue	15		**Weathering and inorganic nutrient cycles**
3-Dec	Th	16		**Weathering in Anthropocene and Fundamental Questions**
8-Dec	Tue		9	Student presentation and discussion (all students) / course evaluation

Tentative Reading Schedule

Most of the papers listed below can be obtained through the links on the course website.

(H) Handout from instructor
(D) Students download pdf files through university library website.

1-Sept Tue, Course overview-Contents, Structure, and Grading

- Stallard, R.F., 2000, Tectonic processes and erosion, *in* Jacobson, M.C., Charlson, R.J., Rodhe, H., and Orians, G.H., eds., Earth system science: from biogeochemical cycles to global change, Volume V.72: International Geophysical Series: Amsterdam, Elsevier, p. 195-229. (H)

3-Sept Th, Application of cosmogenic radionuclides in weathering science

- Bierman, P.R., and Nichols, K.K., 2004, Rock to sediment-slope to sea with ^{10}Be-rates of landscape change: Annual review of earth and planetary sciences, v. 32, p. 215-255. (D)

8-Sep Tue, Student presentation and discussion

Each student gives 10 minute (will be adjusted depending on the number of students enrolled) power point presentation. Students are expected to frame this presentation around four themes: (1) what their (research) interests are including brief introduction of themselves, (2) what they know about weathering, (3) how they think weathering is related to their interest or current research, and (4) what they expect from this class.

10-Sep Th, Soil profile concepts and Soil production

- Buol, S.W., R, J., Southard, Graham, R.C., and McDaniel, P.A., 1997, Soil genesis and classification: Ames, Iowa, Iowa state press, 494 p. Chapter 1 and 2 (H)
- Johnson, D.L., 1990, Biomantle evolution and the redistribution of earth materials and artifacts: Soil Science, v. 149, p. 84-102. (H)
- Humphreys, G. S. and M. T. Wilkinson (2007). "The soil production function: a brief history and its rediscovery." Geoderma **139**: 73-78. (D)
- Heimsath, A.M., Dietrich, W.E., Nishiizumi, K., and Finkel, R.C., 1997, The soil production function and landscape equilibrium: Nature, v. 388, p. 358-361. (D)

15-Sep Tue, Student presentation and discussion
Suggested papers for presentation:

- Bockheim, J. G., A. N. Gennadiyev, R. D. Hammer and J. P. Tandarich (2005). "Historical development of key concepts in pedology." Geoderma **124**: 23-36. (D)
- Tandarich, J. P., r. G. Darmody, L. R. Follmer and D. L. Johnson (2002). "Historical development of soil and weathering profile concepts from Europe to the United States of America." Soil Science Society of America **66**(No.2): 335-343. (D)
- Ahnert, F., 1977, Some comments on the quantitative formulation of geomorphological processes in a theoretical model: Earth Surface Processes and Landforms, v. 2, p. 191-201. (H)
- Cox, N.J., 1980, On the relationship between bedrock lowering and regolith thickness: Earth surface processes and landforms, v. 5, p. 271-274. (H)
- McKean, J.A., Dietrich, W.E., Finkel, R.C., Southon, J.R., and Caffee, M.W., 1993, Quantification of soil production and downslope creep rates from cosmogenic ^{10}Be accumulations on a hillslope profile: Geology, v. 21, p. 343-346. (H)

- Small, E.E., Anderson, R.S., and Hancock, G.S., 1999, Estimates of the rate of regolith production using ^{10}Be and ^{26}Al from an alpine hillslope: Geomorphology, v. 27, p. 131-150. (D)

24-Sep Th, Weathering of silicate minerals: geochemical background

- Faure, G. (1998). Principles and applications of geochemistry. Upper Saddle River, New Jersey, Prentice Hall.: selections from Part III (p.110-273) (H)

29-Sep Tue, Weathering of silicate minerals_2

- White, A. F. 2003, Natural Weathering Rates of Silicate Minerals, Treatise on Geochemistry, Volume 5. Editor: James I. Drever. Executive Editors: Heinrich D. Holland and Karl K. Turekian. pp. 605. ISBN 0-08-043751-6. Elsevier, 2003., p.133-168 (H)

1-Oct Th, Student presentation and discussion

Suggested papers for presentation:

- White, A. F. (2002). "Determining mineral weathering rates based on solid and solute weathering gradients and velocities: application to biotite weathering in saprolites." Chemical Geology **190**: 69-89. (D)
- White, A. F., T. D. Bullen, M. S. Schulz, A. E. Blum, T. G. Huntington and N. E. Peters (2001). "Differential rates of feldspar weathering in granitic regoliths." Geochemica et Cosmochimica Acta **65**(No.6): 847-869.(D)

8-Oct Th, Short-term and long-term chemical weathering

- Stonestrom, D. A., A. F. White and K. C. Akstin (1998). "Determining rates of chemical weathering in soils-solute transport versus profile evolution." Journal of Hydrology **209**: 331-345. (D)
- White, A. F. and A. E. Blum (1995). "Effects of climate on chemical weathering in watersheds." Geochemica et Cosmochimica Acta **59**: 1729-1747. (H)
- Brimhall, G.H., and Dietrich, W.E., 1987, Constitutive mass balance relations between chemical composition, volume, density, porosity, and strain in metasomatic hydrochemical systems: Results on weathering and pedogenesis: Geochimica et Cosmochimica Acta, v. 51, p. 567-587. (H)

13-Oct Tue, Student presentation and discussion

Suggested papers for presentation:

- White AF, Schulz MS, Vivit DV, et al. Chemical weathering rates of a soil chronosequence on granitic alluvium: III. Hydrochemical evolution and contemporary solute fluxes and rates Geochimica et Cosmochimica Acta 69 (8): 1975-1996 APR 15 2005 (D)
- Oh, N.-H. and D. D. Richter (2005). "Elemental translocation and loss from three highly weathered soil-bedrock profiles in the southeastern United States." Geoderma **126**: 5-25. (D)

15-Oct Th, Soil chronosequence

- Merritts, D. J., O. A. Chadwick, D. M. Hendricks, G. H. Brimhall and C. J. Lewis (1992). "The mass balance of soil evolution on late Quaternary marine terraces, northern California." Geological Society of America Bulletin **104**(November): 1456-1470. (H)

- White, A. F., A. E. Blum, M. S. Schulz, T. D. Bullen, J. W. Harden and M. L. Peterson (1996). "Chemical weathering rates of a soil chronosequence on granitic alluvium: I. Quantification of mineralogical and surface area changes and calculation of primary silicate reaction rates." Geochimica et Cosmochimica Acta **60**(No.14): 2533-2550. (H)

20-Oct Tue, Mineral weathering vs. Time

- Yoo K. and S.M. Mudd, in press, 2007, "The Discrepancy between Mineral Residence Time and Soil Age: Implications for the Interpretation of Chemical Weathering Rates", Geology (H)
- White, A., and Brantley, S., 2003, The effect of time on the weathering of silicate minerals: why do weathering rates differ in the laboratory and field?: Chemical Geology, v. 202, p. 479-506. (D)

22-Oct Thu, Student presentation and discussion
Suggested papers for presentation:

- Chadwick, O. A., G. H. Brimhall and D. M. Hendricks (1990). "From a black to a gray box - a mass balance interpretation of pedogenesis." Geomorphology **3**: 369-390. (H)
- Merritts, D. J., O. A. Chadwick and D. M. Hendricks (1991). "Rates and processes of soil evolution on uplifted marine terrances, northern California." Geoderma **51**: 241-275. (H)
- Hodson, M. E. and S. J. Langan (1999). "The influence of soil age on calculated mineral weathering rates." Applied Geochemistry **14**: 387-394.(D)

27-Oct Tue, Interaction between physical and chemical weathering processes_1

- West, A. J., A. Galy and M. Bickle (2005). "Tectonic and climatic controls on silicate weathering." Earth and Planetary Science Letters. (D)
- Anderson, S.P., von Blanckenburg, F.; White, A.F., 2007. Physical and chemical controls on the critical zone. Elements, 3, 315-319.

29-Oct Th, Interaction between physical and chemical weathering processes_2

- Riebe et al., 2004, Erosional and climatic effects on long-term chemical weathering rates in granitic landscapes spanning diverse climate regimes: Earth and Planetary Science Letters. (D)

3-Nov Tue, Student presentation and discussion
Suggested papers for presentation:

- Lyons, W. B., A. E. Carey, D. M. Hicks and C. A. Nezat (2005). "Chemical weathering in high-sediment-yielding watersheds, New Zealand." Journal of Geophysical Research **110**(F01008): doi:10.1029/2003JF000088. (D)
- Gaillardet, J., B. Dupre and C. J. Allegre (1999). "Geochemistry of large river suspended sediments: siliate weathering or recyling tracer?" Geochimica et Cosmochimica Acta **63**(No. 23/24): 4037-4051. (D)
- Riebe, C.S., Kirchner, J.W., and Finkel, R.C., 2003a, Long-term rates of chemical weathering and physical erosion from cosmogenic nuclides and geochemical mass balance: Geochemica et Cosmochimica Acta, v. 67, p. 4411-4427. (D)
- —, 2003b, Sharp decrease in long-term chemical weathering rates along an altitudinal transect: Earth and Planetary Science Letters, v. 218, p. 421-434. (D)

5-Nov Th, Geochemical soil catena or soil toposequence

- Sommer, M., and Schlichting, E., 1997, Archetypes of catenas in respect to matter-a concept for structuring and grouping catenas: Geoderma, v. 76, p. 1-33. (D)
- Huggett, R., 1975, Soil and landscape systems-Model of soil genesis: Geoderma, v. 13, p. 1-22. (H)

10-Nov Tue, Geomorphic processes on soil covered hillslopes

- Gilbert, G.K., 1909, The convexity of hilltops: Journal of Geology, v. 17, p. 344-350. (H)
- Dietrich, W.E., Reiss, R., Hsu, M.L., and Montgomery, D.R., 1995, A Process-Based Model for Colluvial Soil Depth and Shallow Landsliding Using Digital Elevation Data: Hydrological Processes, v. 9, p. 383-400. (H)

12-Nov Th, Student presentation and discussion
Suggested papers for presentation:

- Sommer, M., D. Halm, C. Geisinger, I. Andruschkewitsch, M. Zarei and K. Stahr (2001). "Lateral podzolization in a sandstone catchment." Geoderma **103**: 231-247. (D)
- Roering, J. J. and M. Gerber (2005). "Fire and the evolution of steep, soil-mantled landscapes." Geology **33**(5): 349-352. (D)
- Heimsath, A.M., Chappell, J., Spooner, N.A., and Questiaux, D.G., 2002, Creeping soil: Geology, v. 30, p. 111-114. (D)

17-Nov Tue, Coupled processes of chemical weathering, sediment transport, and soil production

- Yoo, K., R. Amundson, A. M. Heimsath, W. E. Dietrich, and G. H. Brimhall (2007), Integration of geochemical mass balance with sediment transport to calculate rates of soil chemical weathering and transport on hillslopes, Journal of Geophysical Research, 112, F02013, doi:10.1029/2005JF000402. (D)
- Yoo, K. S.M. Mudd, J. Sanderman, R. Amundson, A. Blum, *pending revision*, Spatial patterns and controls of soil chemical weathering rates along a transient hillslope, *Earth and Plantetary Science Letters*. (H)
- Anderson, S.P., von Blanckenburg, F.; White, A.F., 2007. Physical and chemical controls on the critical zone. Elements, 3, 315-319.

19-Nov Thu, Weathering and carbon cycle

- Kennedy, M., Droser, M., Mayer, L.M., Pevear, D., and Mrofka, D., 2006, Late Precambrian oxygenation; Inception of the clay mineral factory: Science, v. 311, p. 1446-1449. (D)
- Berner, R. A., A. C. Lasaga, et al. (1983). "The Carbonate-Silicate Geochemical Cycle and Its Effect on Atmospheric Carbon-Dioxide over the Past 100 Million Years." American Journal of Science 283(7): 641-683. (H)
- Raymo, M. E. and W. F. Ruddiman (1992). "Tectonic Forcing of Late Cenozoic Climate." Nature 359(6391): 117-122. (H)

24-Nov Tue, Student presentation and discussion
Suggested papers for presentation:

- Green, E. G., W. E. Dietrich and J. F. Banfield (2006). "Quantification of chemical weathering rates across an actively eroding hillslope." Earth and Planetary Science Letters **242**: 159-169. (D)
- Nezat, C. A., J. D. Blum, A. Klaue, C. E. Johnson and T. G. Siccama (2004). "Influence of landscape positions and vegetation on long-term weathering rates at the Hubbard Brook Experimental Forest, New Hampshire, USA." Geochemica et Cosmochimica Acta **68**(No. 14): 3065-3078. (D)
- Masiello, C.A., Chadwick, O.A., Southon, J., Torn, M.S., and Harden, J.W., 2004, Weathering controls on mechanisms of carbon storage in grassland soils: Global Biogeochemical Cycles, v. 18, p. doi:10.1029/2004GB002219. (D)
- Torn, M. S., S. E. Trumbore, O. A. Chadwick, P. M. Vitousek and D. M. Hendricks (1997). "Mineral control of soil organic carbon storage and turnover." Nature **389**(11 September): 170-173. (D)

1-Dec Tue, Weathering and inorganic nutrient cycles

- Porder, S., Clark, D.A., and Vitousek, P.M., 2006, Persistence of rock-derived nutrients in the wet tropical forests of La Selva, Costa Rica: Ecology, v. 87, p. 594-602. (D)

3-Dec Th, Weathering in Anthropocene/ Fundamental questions in weathering science

- Wilkinson, B.H., 2005, Humans as geologic agents: A deep-time perspective: Geology, v. 33, p. 161-164. (D)
- Anderson, S.P., Blum, J., Brantley, S.L., Chadwick, O., Chorover, J., Derry, L.A., Drever, J.I., Hering, J.G., Kirchner, J.W., Kump, L.R., Richter, D., and White, A.F., 2004, Proposed initiative would study earth's weathering engine: EOS, v. 85, p. 265, 269.
  (D) http://www.czen.org/db/publications
- Brantley, S.L., White, T. S., White, A. F., Sparks, D., Richter, D., Pregitzer, K., Derry, L., Chorover, J., Chadwick, O., April, R., Anderson, S., Amundson, R., 2006, Frontiers in Exploration of the Critical Zone: Report of a workshop sponsored by the National Science Foundation (NSF), October 24-26, 2005, Newark, DE, 30p.
  (D) http://www.czen.org/db/publications

8-Dec. Tue., Student presentation and discussion / Course evaluation
Suggested papers for presentation:

- Vitousek, P., Chadwick, O.A., Matson, P., Allison, S., Derry, L., Kettley, L., Luers, A., Mecking, E., Monastra, V., and Porder, S., 2003, Erosion and the rejuvenation of weathering-derived nutrient supply in an old tropical landscape: Ecosystems, v. 6, p. 762-772. (D)
- Porder, S., P. M. Vitousek, O. A. Chadwick, G. P. Chamberlain and G. E. Hilley (2007). "Uplift, erosion, and phosphorous limitation in terrestrial ecosystems." Ecosystems **10**: 158-170. (D)
- Porder, S., Paytan, A., and Vitousek, P.M., 2005, Erosion and landscape development affect plant nutrient status in the Hawaiian Islands: Oecologia, v. 142, p. 440-449. (D)
- Likens, G.E., Driscoll, C.T., and Buso, D.C., 1996, Long-term effects of acid rain: Response and recovery of a forest ecosystem: Science, v. 272, p. 244-246. (H)
- Trimble, S. W. (1999). "Decreased rates of alluvial sediment storage in the Coon Creek Basin, Wisconsin, 1975-93." Science **285**(20 August): 244-246. (D)