



GEOL305/545: Earth Surface Processes

Course Syllabus - Spring 2008

Class meetings: Mon and Wed, 2:00-3:30pm, DRLB 3C4

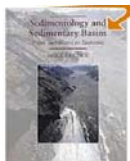
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Course Description

Patterns on the Earth's surface arise due to the transport of sediment by water and wind, with energy that is supplied by climate and tectonic deformation of the solid Earth. This course presents a treatment of the processes of erosion and deposition that shape landscapes. Emphasis will be placed on using simple physical principles as a tool for (a) understanding landscape patterns including drainage networks, river channels and deltas, desert dunes, and submarine channels, (b) reconstructing past environmental conditions using the sedimentary record, and (c) the management of rivers and landscapes under present and future climate scenarios. The course will conclude with a critical assessment of landscape evolution on other planets, including Mars. Includes two required field trips and a hands-on laboratory component.

Texts and Resources



Leeder, M. Sedimentology and Sedimentary Basins. Oxford: Blackwell Science Ltd., 1999, 592 pp. ISBN: 0632049766.

REQUIRED



Ritter, D.F., Kochel, R.C., and Miller, J.R. Process Geomorphology. New York: McGraw-Hill, 2002, 560 pp. ISBN: 1577664612.

Supplemental – I will supply relevant chapters to students.



Gary Parker's freely available E-book: **Supplemental** – download at:
http://cee.uiuc.edu/people/parkerg/morphodynamics_e-book.htm

Course Structure

The course is structured into two (2) 80-minute lectures per week. The first ten minutes of each lecture will be dedicated to discussion regarding earth-surface processes in current events, where each discussion will be led by a different student. In addition to these lectures there will be three laboratory experiments that will take place in Hayden 56, at times convenient to students. There will also be two field trips, on Saturdays chosen by the class, to sites relevant to river dynamics.

Grading

Distribution of Marks

Class participation	10%
Assignments (10@ 4% each)	40%
Mid-term exam	20%
Final Project	<u>30%</u>
	100%

Assignments and Grading Policies

- Participation is judged by your ability to lead and participate in class discussions related to current events and problems/questions with assignments. Participation in laboratory and field trips is required.
- On the mid-term exam, you will be tested on your ability to apply the principles you have learned to problems that may be directly related to topics covered in class, or may be new topics that can be addressed using physical reasoning developed in class.
- Assignments will require the use of some (fairly simple) mathematics, and application of spread-sheet based numerical models. Some assignments will use data collected in the lab or field. These homeworks may be worked on in groups, however **it is required that participants in homework groups list all group members.** Working together is different from copying, and I will look for original contributions from each student.
- This class has no final exam, but rather a final project report. This report will use concepts developed in class to frame a problem, of the students' interest, that may be addressed using methods covered in the course. The report may be considered as a literature review, however development of testable hypotheses using mathematical expressions is required in addition to reading and citing primary sources.
- The graduate section (545) will require additional quantitative project work.
- I will deduct 20 percentage points for each 24 hours that a graded homework assignment is late. Notify me as soon as any problems arise regarding homeworks (questions, computer problems, etc.), or else points will be deducted for late assignments.

Lecture Topics (Mondays & Wednesdays)

1. Wed., Jan. 16 Introduction to Landscapes: the sediment-fluid interface
Introduction to the three fundamental variables in earth-surface processes: fluid stress, sediment transport rate, and elevation. Introduction to the fundamental equation in earth-surface dynamics: conservation of mass. Discussion of convergent and divergent topography and its relation to zones of erosion and deposition.
Reading: Ritter, Chapter 1; Parker E-book, Chapters 1 and 4.
2. Wed., Jan. 23 Global and regional drivers: climate and tectonics
Global view of locations of mountains and basins. Introduction to tectonic uplift and subsidence, and geomorphic “equilibrium”. Influence of climate on erosion rates, and feedbacks between climate and tectonics.
Reading: Leeder, Chapter 13.
3. Mon., Jan. 28 Fluid mechanics 1: Viscosity, drag and particle settling
Shear stress and viscosity in Newtonian fluids. Molecular diffusion of momentum. Drag on a sphere and derivation of the Reynolds number. Relationship between drag and Reynolds number. Dimensional analysis applied to settling of a sphere, and derivation of the settling velocity of grains. Introduction of the Froude number.
Reading: Leeder, Chapters 4 and 6.
4. Wed., Jan. 30 Fluid mechanics 2: Boundary shear stress and turbulence
Flow on an inclined plane and derivation of boundary shear stress. Introduction to turbulence and its importance. Velocity gradients, “turbulent diffusion” of momentum and derivation of the “law of the wall” velocity profile in a turbulent boundary layer. Scaling of velocity fluctuations with shear velocity. Local bed shear stress and comparison to the depth-slope product.
Reading: Leeder, Chapter 5. Parker E-book, Chapter 5.
5. Mon., Feb. 4 Initiation of motion of grains in a shearing fluid
Theoretical assessment of the force required to initiate grain motion, and empirical treatments commonly used. Dimensional analysis and Shields stress. Initiation of motion for mixed grain sizes. Application to sediment movement during floods in rivers.
Reading: Leeder, Chapter 6; Parker E-book, Chapter 6.
6. Wed., Feb. 6 Modes of transport 1: saltation and bed load
Definition of saltation and bed load transport. Estimation of particle trajectories and their relationship to fluid flow. Derivation of the relationship between bed load transport and applied fluid shear stress. Application to estimating sediment transport in a river.
Reading: Leeder, Chapter 6; Parker E-book, Chapters 6-7.
7. Mon., Feb. 11 Modes of transport 2: Suspended sediment and “wash load”
Introduction to the Rouse number and its empirical relation to transport mode. Use of the Rouse number to compute suspended sediment concentration profiles in rivers and eolian environments. Definition of “wash load” and the transport of very fine sediments in rivers.
Reading: Leeder, Chapter 6; Parker E-book, Chapters 6-7.
8. Wed., Feb. 13 Collision of grains and transport by wind
The Stokes number, and its relation to transport mode. Introduction to eolian (wind-

blown) sediment transport, and its similarities and differences compared to fluvial transport. Application of grain collision and viscous dissipation concepts to erosion of landforms in air and water by “sand blasting”.

Reading: Leeder, Chapter 8.

9-10. Mon., Feb. 18 and Wed., Feb 20 Putting it all together: Dimensionless variables and transport relations

Review of all the dimensionless numbers covered so far. Use of these numbers in sediment transport equations, and application to estimating the total sediment load carried by a river. Application of dimensionless numbers to constraining past flow conditions from sediments preserved in rock.

Reading: Leeder, Chapters 6-7; Parker E-book, Chapters 7, 11 and 12.

11. Mon., Feb. 25 Profile of a river from source to sink – channel types and processes

Zones of erosion and deposition in a river system, and their relationships to plate tectonics. Geomorphic cross section of the Eastern seaboard from Appalachian Mountains to the coast. Overview of dominant processes in different regions of the profile – hillslope, mountain river, alluvial river and floodplain, and estuary/delta.

Reading: Ritter, Chapters 5-7.

12. Wed., Feb. 27 Hillslope processes: Soil erosion, rill formation and channel initiation

Slope hydrology - infiltration and runoff generation. Tractive stress and the formation of rills through positive feedback. Relation between contributing drainage area and discharge. Base flow in rivers due to groundwater flow and Darcy's law. Hillslope creep and landsliding.

Reading: Ritter, Chapters 4-5.

13. Mon., Mar. 3 Drainage network characteristics and hydrographs – LAB

Statistics of drainage basin networks and channel hydraulic geometry. Stream order, Hack's Law and other scaling relations. Relation between basin geometry and flood hydrograph. Drainage basin networks as random walks on sloping surfaces. The concept of geomorphic 'work' using flood frequency statistics.

Reading: Ritter, Chapters 5-6.

14. Wed., Mar. 5 MID-TERM EXAM

Mon., Mar. 10 – **Spring Break**

Wed., Mar. 12 – **Spring Break**

15. Mon., Mar. 17 Alluvial rivers – introduction and large-scale patterns

Overview of alluvial channel patterns – meandering, braiding and anabranching. Important variables regarding channel dimensions, flow and sediment transport. Conservation of fluid mass, and hydraulic geometry scaling relationships for gravel and sand rivers. Flow resistance equation from dimensional analysis.

Reading: Leeder, Chapter 17; Parker E-book, Chapter 9.

16. Wed., Mar. 19 Development of bed forms in alluvial rivers – LAB

Initiation and growth of ripples and dunes (bed forms). Relationships between bed configuration, fluid flow (Rouse, Shields and Froude numbers), and flow resistance. Bed

load transport through bed forms.

Reading: Leeder, Chapter 7; Parker E-book, Chapter 8.

17. Mon., Mar. 24 Development of bars and meandering/braiding in alluvial rivers

Definition of migrating and point bars. Quantitative description of alternate bar development. Fluid/sediment dynamics leading to meander development. The conditions leading to braiding. Influence of vegetation on channel pattern.

Reading: Ritter, Chapter 6.

18. Wed., Mar. 26 Sedimentary structures of bed/bar forms

Outline sedimentary structures preserved from migrating bed and bar forms. Use of dimensionless numbers and physical reasoning to estimate paleo-flow conditions using sedimentary features and grain size.

Reading: Leeder, Chapter 7, 18.

19. Mon., Mar. 31 Hydraulic geometry of alluvial rivers

Review observed hydraulic geometry scaling in rivers. Delineation of gravel and sand rivers through Shields stress. Introduction to the threshold river concept, and development of a complete model for predicting “equilibrium” hydraulic geometry of alluvial rivers.

Reading: Leeder, Chapter 18; Ritter, Chapter 6; Parker E-book, Chapters 3, 24.

20. Wed., Apr. 2 Anthropogenic effects on alluvial rivers

Changes in sediment and water supply, bank erodibility, and channel geometry, and their observed effects in real rivers. Examples from dam construction and removal, urbanization of streams, farming and logging, and invasive species. Modeling the impact of these changes using flow and transport equations.

Reading: Parker E-book, Chapters 13, 14, 21, 31

21. Mon., Apr. 7 River deltas and alluvial fans

Conditions leading to formation of depositional fans. Quantitative descriptions of the avulsion process, lateral bank erosion and branching. Modeling the average evolution of fans, and the formation of channel networks. Discussion of Holocene delta evolution.

Reading: Leeder, Chapter 19; Ritter, Chapter 7; Parker E-book, Chapter 32.

22. Wed., Apr. 9 Coastal processes

Near-shore transport by waves and longshore currents. Formation of bed forms and their relation to wave conditions. Large-scale effects of waves on sandy coastlines and deltas. The formation and significance of spits, cusps and barrier islands.

Reading: Leeder, Chapter 9; Ritter, Chapter 13.

23. Mon., Apr. 14 Characteristic timescales of transport and environmental disturbance

Using dimensional analysis to derive relevant transport, morphodynamic and environmental timescales. Application of timescales to designing laboratory experiments, and predicting response to environmental disturbance. Critical assessment of the equilibrium concept in landscape evolution.

Reading: Supplementary handouts.

24. Wed., Apr. 16 Gravity currents: introduction - LAB
Description of gravity currents in their various forms, and the fundamental parameters of buoyancy and fluid entrainment. Derivation and application of dimensionless parameters: densimetric Froude number, Richardson number. Sediment deposition and entrainment/erosion in subaqueous gravity currents (turbidity currents).
Reading: Leeder, Chapter 11.

25. Mon., Apr. 21 Evolution of submarine landscapes
Introduction to submarine landforms. Survey of submarine channel networks, and their differences and similarities compared to terrestrial systems. Transport and evolution of submarine channels by turbidity currents. Characterization and analysis of turbidity current deposits at small and large scales. Importance of submarine channel networks as oil reservoirs.
Reading: Leeder, Chapter 11.

26. Wed., Apr. 23 Wind processes and landforms
Survey of eolian landforms, and their relationship to desert environments. Qualitative and quantitative models for ripple formation. Grain size sorting by kinetic sieving, size selective transport and avalanching. Dimensional analysis to derive characteristic scales of desert dunes.
Reading: Leeder, Chapter 8; Ritter, Chapter 8.

27. Mon. Apr. 28 Outlook – landscape response to global climate change
Historical data of climate change and landscape response in the geologic record. Rising sea level and the its effects on coastal environments. Melting glaciers and permafrost, and their influence on Arctic river channel change. The Mississippi Delta as a case study of the “perfect storm” of human impacts.
Reading: Leeder, Chapters 14-15; Parker E-book, Chapter 25.

28. Wed., Apr. 30 Planetary surfaces – interpreting surface processes on Mars and other bodies
Overview of geomorphology on Mars and Titan. Discussion of the debate on early Martian climate. Using surface deposits and sediment transport models to deduce water and wind transport in the ancient past on planetary surfaces. Use of dimensional analysis to account for effects of different density, viscosity and gravity on Mars.
Reading: Supplementary handouts.

29. Mon., May 5 – **Final Report Presentation**