

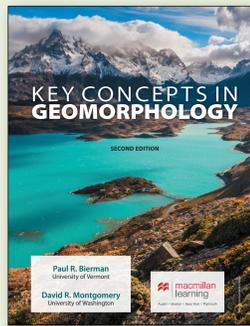
Key Concepts in Geomorphology – Edition 2 of a community-based textbook

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Abstract

It's time for a new edition! In 2019, we extensively revised Key Concepts in Geomorphology, the 2013 Geomorphology textbook supported by the US National Science Foundation to serve as a model for extensive community involvement and vetting at all stages from initial outlining through chapter development and revision to final review. Our revision was based in large part of nearly 60 pages of comments submitted to our public revision blog by students and faculty around the world. Comments from the community identified organizational improvements, recent advances that should be included, and images and figures that could be clarified, added, or omitted.

The new, second edition differs from the initial edition in several important ways. The textbook now has 16 chapters organized into four sections. Each chapter still includes 8 to 16 revised full-color figures designed specifically for novice learners. The previous section on the history of geomorphology has been expanded into a stand-alone chapter, and the previous chapter on soils and weathering has been expanded and split into a chapter on each. We have swapped out many of the 20 to 30 color photographs that illustrate each of the chapters and added more callouts to guide novice readers. We have added a Case Study to each chapter which applies geomorphology skills and techniques to a current-day problem important to society. At the start of each chapter, we articulate Learning Objectives and have organized the end-of-chapter questions in the order in which material is presented and in line with the Learning Objectives. The text is updated with new, important changes to the field of Geomorphology including such revolutionary data collection techniques as LIDAR. At the end of each chapter, revised Digging Deeper sections continue to present an in-depth look at the development of scientific thought on a problem relevant to the chapter. Come by the poster and have a look at proofs of the new edition.

Key Concepts in Geomorphology is designed to serve undergraduate students in their first course about Earth Surface Processes, Geomorphology, Physical Geography, and Quaternary Geology. It is also designed to be useful for students in related fields such as forestry, agriculture, and civil engineering.

16 Chapters each begin with Learning Objectives.

Geomorphologist's Tool Kit

LEARNING OBJECTIVES

- Characterizing Earth's Surface: Understand how a variety of different techniques are used to characterize the form and behavior of Earth's surface over time and space.
- Relative Dating Methods: Identify methods that can be used to understand the relative age of Earth's surface and how these methods work.
- Numerical Dating Methods: Understand a variety of techniques used to make numerical age estimates for geomorphic features.
- Measuring Rates of Geomorphic Processes: Compare and contrast the study of rates of geomorphic processes with the rates of processes active on and near Earth's surface.
- Experiments: Appreciate the power of laboratory and field experiments in understanding surface processes.
- Proxy Records: Explain how records of Earth's past geomorphic behavior can be used to understand geomorphic change over geologic time.
- Digging Deeper: How Does a Dating Method Develop? Understand how the most widely applied dating methods in geomorphology, carbon 14, were developed and tested.
- Case Study: Surface Indications of a Volcanic Contraction: How did geomorphological mapping of Earth's surface revolutionize our understanding of a volcanic society?

1. Earth's Dynamic Surface **Part 1**
2. Brief History of Geomorphology
3. Geomorphologist's Tool Kit
4. Geomorphic Hydrology
5. Weathering and Geomorphology
6. Soils and Geomorphology **Part 2**
7. Slopes
8. Channels
9. Drainage Basins
10. Coastal and Submarine Geomorphology
11. Wind as a Geomorphic Agent **Part 3**
12. Volcanic Geomorphology
13. Glacial and Periglacial Geomorphology
14. Geomorphology and Climate
15. Tectonic Geomorphology **Part 4**
16. Landscape Evolution

Full color art, 10 to 14 figures per chapter, uses explanatory text boxes and images to make learning new concepts easier for students.

FIGURE 1.10 Drainage Basins: Source-to-Sink. It is useful to understand Earth's surface from the perspective of drainage basins—units of the landscape in which mass can be accounted and conserved. In general, sediment is sourced in the eroding headwaters of a drainage basin, and is transported and stored in lowland sinks, although it may be stored temporarily in floodplains along the way to long-term storage in marine environments.

FIGURE 5.3 Winnowing Erosion in Action. At Twin Harms Dome, a granite outcrop in northern California, exfoliation occurred high along the cliff face. The photograph shows the weathered surface of the dome. The left image shows the weathered surface of the dome. The right image shows a sheet detaching in a dramatic, loud, and dusty fashion captured on video. The left image is the result of such exfoliation, a pop-up where the 30-cm-thick granite sheet now stands above the dome surface.

FIGURE 5.4 Winnowing Erosion in Action. At Twin Harms Dome, a granite outcrop in northern California, exfoliation occurred high along the cliff face. The photograph shows the weathered surface of the dome. The left image shows the weathered surface of the dome. The right image shows a sheet detaching in a dramatic, loud, and dusty fashion captured on video. The left image is the result of such exfoliation, a pop-up where the 30-cm-thick granite sheet now stands above the dome surface.

Community involvement and extensive peer review determined content and ensured accuracy. 60 pages of public blog comments guided our revision

We thank Editorial experts Ari Matmon, Arjun Heimsath, Beverley Wemple, Cam Wobus, Chuck Nittrouer, David Dethier, Derek Booth, Dorothy Merritts, Doug Clark, Ellen Wohl, Eric Leonard, Eric Steig, Frank Magilligan, Frank Pazzaglia, Gordon Grant, Grant Meyer, Kathy Cashman, Leslie McFadden, Lisa Ely, Milan Pavich, Missy Eppes, Nick Lancaster, Paul Bishop, Ray Torres, Sara Mitchell, Scott Burns, and Scott Linneman.

Case Studies at the end of each chapter provide contemporary, real-life Geomorphic applications.

Superstorm Sandy

The disastrous impacts of Superstorm Sandy on New York and the New Jersey coast in 2012 are discussed with unusual circumstances that amplified the storm's impact and so long-term development in the region.

Sandy formed in the southeastern Caribbean Sea on October 23, 2012. Originally a tropical storm fueled by warm ocean water, it soon intensified into a compact but powerful hurricane with winds exceeding 74 mph. As it moved air rises in the core of these low-pressure weather systems is cooled, causing water vapor to condense and produce copious amounts of rain. Over the next several days, the storm marched north through Jamaica, Cuba, and Puerto Rico with winds over 100 mph. On October 26, the storm began to weaken and shifted its northward advance, with winds slowing to about 80 mph. The following day, the storm dropped below hurricane strength and reverted to tropical storm status. But a large core of high pressure over the Great Lakes basin's surface and behind the storm weakened and then shifted just in time for high spring tides associated with a full moon. The storm's height to the tropical characteristics, such as a well-defined eye, and transitioned into an even more powerful extratropical storm.

On October 28, a day before the storm moved ashore, storm surge warnings of 1 to 1.8 m were issued for New York harbor. When the storm hit, parts of New Jersey received almost a foot of rain. The combination of heavy precipitation and high storm surge proved disastrous. More than 7 million homes and businesses were left without power during the storm's peak. The storm then moved west and weakened as a storm inland. By October 31, the storm was over—and the cleanup began.

Superstorm Sandy was the second most expensive natural disaster in U.S. history after Hurricane Katrina, with an estimated cost of over \$150 billion dollars. The deaths of nearly 100 people have been blamed on the storm, almost two dozen of them in New York City. The storm affected 1.8 million square miles, but the heaviest damage was done to coastal flooding. Most of the flooding was due to storm surge, with damage concentrated along the coast of southern New Jersey and around New York City. The storm's surge was the highest ever recorded for a tropical storm, with waves reaching 18 meters (60 feet) in some places. The surge was caused by the storm's low pressure and high winds, which pushed water toward the shore. The surge was also caused by the storm's low pressure and high winds, which pushed water toward the shore. The surge was also caused by the storm's low pressure and high winds, which pushed water toward the shore.

Worked problems at the end of each chapter provide written and numeric examples to aid student learning - some are quantitative, some qualitative.

WORKED PROBLEM

QUESTION: Using the infinite-slope model, what is the maximum stable angle for both dry and saturated sand with no cohesion and a friction angle of 37 degrees? How does this stable angle compare to that of more cohesive material such as till or clay?

ANSWER: For dry cohesionless materials, the maximum stable angle is the friction angle, ϕ , in this case, 37 degrees. For the failure of a fully saturated, cohesionless soil like coarse sand ($\gamma = 1.0, C = 0$, and $m = 1.0$, eq. 7.8 reduces to $\tan \theta = \frac{1}{2}(\phi + \phi) = \phi$, which may be approximated by $\tan \theta = \frac{1}{2}(\phi + \phi)$ (since for most soils, $\phi = 2\alpha_c$). This indicates that sandy slopes steeper than about half the friction angle tend to fail if saturated. Thus, when saturated, cohesionless sand with a friction angle of 37 degrees will fail when the slope is about 23.5 degrees. At higher slopes where $\theta > 2\alpha_c$, cohesionless soils tend to slide even when dry; the soil mantle rarely stays on such steep slopes unless there is significant root reinforcement. Soils with even modest amounts of cohesion can stand at much steeper angles over lengths shorter than typical hillside lengths. For example, excavations in clay (and other cohesive materials like glacial till) can hold vertical faces of up to several meters in height, as can riverbanks, especially if reinforced by roots that provide apparent cohesion.

New high quality color photographs, illustrate key concepts, techniques, and landforms. Many are taken by geoscientists. Annotations aid recognition of landforms.

PHOTOGRAPH 2.16 Tracking Sediment Movement.

Placing painted pebbles at General Patton's former Camp Iron Mountain in the Mojave Desert to trace sediment movement over time.

PHOTOGRAPH 2.1 Glacial Lake Sediment and Till.

When a glacial lake formed next to a retreating ice margin in eastern New York State, rhythmically bedded fine-grain couplets of sand and silt were deposited over till. The underlying till is older than the overlying lake sediments. The fieldbook is about 20 cm long.

PHOTOGRAPH 3.5 Felsenmeer.

Felsenmeer, frost-shattered rock and sheeted tors of bedrock on the summit of Mount Darling, Marie Byrd Land, Antarctica. The geologist in the image is between two much less weathered glacial erratics deposited on the surface by glacial ice frozen to its weathered bed.

Digging Deeper sections end each chapter and provide an in-depth, referenced narrative detailing the development of thinking on important geomorphic problems.

DIGGING DEEPER

How Do Geomorphologists Determine Chemical Weathering Rates?

Without chemical weathering, Earth would be a very different place—life might not exist and the rock cycle would operate far more slowly. The alteration and dissolution of minerals releases elements to the environment, where they are taken up and used by a variety of different organisms including bacteria, plants, and animals. Rivers and groundwater move elements dissolved in water, transferring mass from the continents to the oceans. Chemical weathering isn't something geomorphologists measure with a meterstick; rather, they employ a series of different microscopic, physical, geochemical, and isotopic techniques to understand when, where, and how fast earth materials weather. Such approaches employ laboratory benchtop experiments, field experiments at scales from hillsides to drainage basins, and analysis of river water to understand how the planet as a whole has weathered.

At the smallest scale, high-tech microscopes are used to examine mineral grains for telltale signs of weathering (Hockaday and Barfield, 1995). Such microscopes include those that use electrons rather than light to image surfaces—where microscopes can peer directly through very thin slices of minerals (transmission electron microscopy) or image mineral surfaces using electrons that either backscatter off a surface or cause the emission of other electrons (scanning electron microscopy). Such imaging clearly shows chemical weathering at the microscopic. In fieldplots with differing compositions, the sediment-rich feldspar albite weathers more first, consistent with its greater solubility in soil-water solutions (PROFESSOR DODD, A). Conversely, the small pits produced by this weathering are about the same size as soil bacteria (Photograph 10.5); this observation led Parsons, Lee, and Smith (1978) to suggest that perhaps such weathering pits provided shelter and nutrients critical to the evolution of bacteria billions of years ago!

Rates of chemical weathering can be determined at various scales using various means. A paired experiment by Yokoyama and Matsuzaki (2016) illustrates two contrasting approaches (DODD, B). First, they

Knowledge assessments provide study guides for students and reflect the important content of each chapter organized by Learning Objectives.

KNOWLEDGE ASSESSMENT Chapter 16

Factors of Landscape Evolution: Understand the factors controlling landscape evolution over time and space.

1. List the factors governing landscape evolution.
2. Explain the importance of time scales in considering the factors responsible for landscape evolution.
3. Give an example of how tectonic forces may be an independent variable over short timescales, but dependent variables over long timescales.
4. Define "base level" and explain how it is a fundamental control on landscape evolution.
5. Explain how climate affects the processes and tempo of landscape evolution.
6. Explain the importance of the distribution and erosion of the Tibetan Plateau and the Alpidians.
7. List the factors in which glacial cycles affect the evolution of landscapes.
8. Define relief and explain why it is important for the erosion evolution of topography.
9. List the factors influencing bedrock stability.
10. Explain why topography can be used to map the weathering, bedrock erosion and linkages in some cases and in others.
11. Predict how steep forested hillsides will respond if trees are removed.
12. Define a conceptual model and provide an example of a landscape model important to geomorphology.
13. Define and contrast steady-state and transient landscapes.
14. Provide examples of steady-state and transient landscapes.
15. Explain how landscapes in dynamic equilibrium behave.
16. How William Morris Davis and what did he call them (his landscape evolution).
17. Compare and contrast the three general models of slope profile evolution.
18. Explain the difference between landscape stability and landscape evolution.
19. Give an example of how physical models are used to study landscape evolution, and give one that does not use a model.
20. Explain how and why mathematical models are used in geomorphology.
21. Compare and contrast diffuse and advective sediment transport.
22. What are some of the strengths and weaknesses of numerical models of landscape process in evolution?
23. Explain how and why landscape evolution is a geomorphology.
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Digging Deeper in This Landscape in Steady State? Consider what factors in a landscape can be its steady state and the implications for interpreting its geomorphology.

Case Study: The Anthropocene: Understanding It. How are geomorphologists preparing a new geological epoch Earth's present surface?

