# 8

# CYCLES

*Cycles represent natural systems in which matter and energy are continuously transferred between different spheres of the environment. Their study involves a recognition of stores, fluxes, and residence times, with hydrological, geological, and biogeochemical cycles providing the global context for landform science. Whereas cycles can be repeated, portions of cycles, as cascades or trajectories, are uni-directional. Temporal cycles include those in Milanković theory, as well as short-term cycles that enable different orders of magnitude of change to be identified, as cycles, or portions of cycles, that are more specifically geomorphic. Spatial cycles, usually referred to as cascades, involve erosion and deposition aspects of denudation, and geomorphology is central to understanding the temporal phasing of environmental flows.*

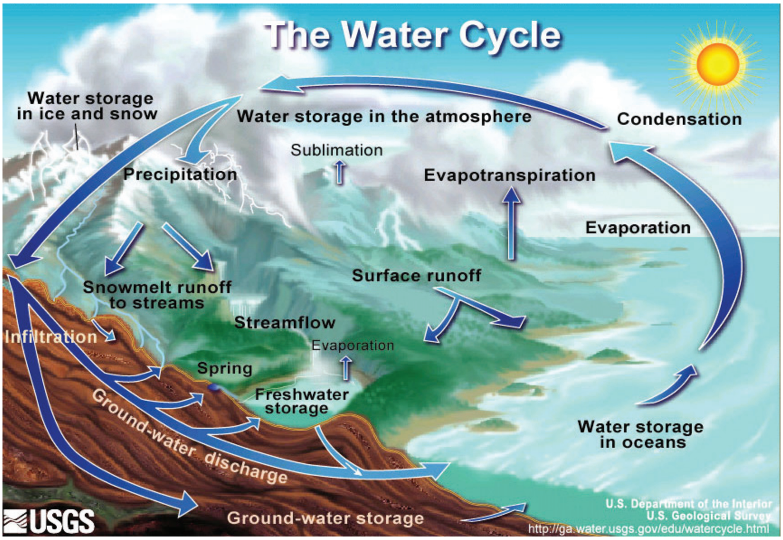


**Figure 8.1** The hydrological cycle (US Geological Survey)

A very good illustration of Milankovitch cycles is provided at http://www.globalwarmingart.com/wiki/File:Milankovitch_Variations_png

**Table 8.1** Global cycles (developed from Table 3.2 in Gregory, 2010)

| Cycle | Stores or Reservoirs | Aspects of Transfers or Flux and Budget |
|---|---|---|
| **Geological:** the creation and destruction of rocks, usually measured in hundreds of millions to billions of years | **Tectonic**: Involves the movement of large plates in the lithosphere, produces ocean basins, continents, and mountains | Driven by geothermal energy and can provide pressure and thermal conditions to metamorphose rocks |
| | **Rock:** Igneous, sedimentary and metamorphic rocks | Involves the processes that produce, change and weather rocks and soils, involving weathering, transport and deposition of sediment |
| **Hydrological** or water cycle, the continuous movement of water on, above and below the surface of the Earth | Oceans (c.94%), groundwater (>4%), in ice sheets and glaciers (c.2%), with smaller amounts in the atmosphere, on land – in lakes and seas and rivers and in the soil | Evaporation, precipitation, runoff<br>Solar energy, with about one third of that reaching the earth used in evaporating water and about 400,000 $km^3$ evaporated each year<br>The entire contents of the oceans would take about 1 million years to pass through the hydrological cycle |
| **Biogeochemical** cycling of elements, minerals and compounds | The whole or part of the atmosphere, ocean, sediments and living organisms | The 'big six' elements, carbon, nitrogen, phosphorous, hydrogen, oxygen and sulphur, are the building blocks of life<br>Variations in residence times – calcium can average less than 109 years in tropical soils but 10–100 in temperate environments |
| | **Carbon**: Over 99% in carbonate rocks and organic deposits | Photosynthesis fixes carbon dioxide from air and water; plants and animal respiration, decomposition |
| | **Nitrogen**: The nitrogen cycle is one of the most complicated material cycles in nature: the atmosphere (80% $N_2$) contains most of the nitrogen but there are also significant amounts in living organisms and in the soil | Nitrogen fixation is the process of converting $N_2$ to nitrate or ammonia which can then be used: major processes in the global nitrogen cycle include nitrogen fixation (by both biological and industrial processes), uptake and release by organisms, denitrification (the conversion of nitrate back to $N_2$), soil erosion, runoff, and flux in rivers, and burial in marine sediments |

*(Continued)*

**Table 8.1** (Continued)

| Cycle | Stores or Reservoirs | Aspects of Transfers or Flux and Budget |
|---|---|---|
| | | Eutrophication of lakes and rivers. Five main reactions in nitrogen cycling are: fixation, assimilation of nitrate to organic N, mineralization, nitrification oxidation process, and denitrification |
| | **Sulphur**: Mainly in lithosphere, also in hydrosphere and vital in proteins | Second to bicarbonate as the most abundant anion in rivers, major cause of acidity in natural and polluted rain water, a key ingredient in rock weathering, and the sulphur cycle is one of the most affected by human activity |
| | **Phosphorus** | Unlike many other biogeochemical cycles, does not include a gas phase so that the atmosphere does not play a significant part, and the largest reservoir of phosphorus is in sedimentary rock: involves the uptake of phosphorus by organisms. After the decomposition of biological waste, it can accumulate in large amounts in soils and sediments. Phosphorus is used by humans as a fertilizer in farmlands and in detergents. Overuse of phosphorus can lead to eutrophication |
| | **Hydrogen** | The transmission of hydrogen from water to carbohydrates etc. and back to water by living organisms. Differs from other biogeochemical cycles in that because of its low molecular weight hydrogen can leave Earth's atmosphere. It has been suggested that this occurred on a grand scale in the past and that this is why today the Earth is mostly irreversibly oxidised |
| | **Oxygen** | Three main reservoirs are the atmosphere, biosphere and the lithosphere in which silicate and oxide minerals are the main stores. Photosynthesis is the main driver producing sugars and free oxygen from carbon dioxide and water |

**Table 8.3** A channel classification framework compiled as a basis for river channel management (from Downs and Gregory, 2004, Table 3.3, page 58)

| | | | | |
|---|---|---|---|---|
| • **Drainage basin**/watershed/catchment | | | | |
| • **Zones:** | production<br>transfer<br>deposition | | *Schumm* 1977b | Boulder + floodway<br>Pastoral<br>Estuarine — *Palmer* 1976 |
| • valley **segments:** | bedrock<br>aliuvial<br>coiluvial | | *Montgomery and Buffington* 1993 | **valley floor**<br>**floodplain**<br>river **corridor** |
| • Stream **reaches:** | cascade<br>step-pool<br>plane-bed<br>pool-nffle<br>regime<br>braded | | *Bisson and Montgomery* 1996 | |
| • **channel unit:** habitats: (**section** of *Newson et al*. 1998) | fast water:<br><br>slow water: | turbulent<br>nonturbulent<br>scour pools<br>dammed pools | *Hawkins et al* 1993 | |
| • **within channel:** | aquatic hapitates<br>aquatic communicates<br>sedimentary assembiage | | | |
| • river **environment at a point** – incremental analysis | | | | |

BOX 8.1

**Burke, K. (2011)** Plate tectonics, the Wilson Cycle, and mantle plumes: geodynamics from the top**,** *Annual Review of Earth and Planetary Sciences,* 39: 1–29 (Volume publication date May 2011). First published online as a Review in Advance on January 3, 2011. DOI: 10.1146/annurev-earth-040809-152521.

By 1968, J. Tuzo Wilson had identified three basic elements of geodynamics: plate tectonics, mantle plumes of deep origin, and the Wilson Cycle of ocean opening and closing, which provides evidence of plate tectonic behaviour in times before quantifiable plate rotations.

The rock cycle according to the Geological Society at www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle.html and on YouTube at www.youtube.com/watch?v=dwLRITtCYQo

## RELEVANT ARTICLES IN *PROGRESS IN PHYSICAL GEOGRAPHY:*

Bryant, R.G. (2013) Recent advances in our understanding of dust source emission processes, *Progress in Physical Geography,* 37: 397–421.

Martin, Y.E. and Johnson, E.A. (2012) Biogeosciences survey: studying interactions of the biosphere with the lithosphere, hydrosphere and atmosphere, *Progress in Physical Geography,* 36: 833–52.

Nicholas, A.P., Ashworth, P.J., Kirkby, M.J., Macklin, M.G. and Murray, T. (1995) Sediment slugs: large-scale fluctuations in fluvial sediment transport rates and storage volumes, *Progress in Physical Geography,* 19: 500–19.

Parsons, A.J. (2012) How useful are catchment sediment budgets?, *Progress in Physical Geography,* 36: 60–71.

## UPDATES

Many papers can be cited to illustrate application of recent technique advances (see Table 1.4) but a particularly graphic demonstration of the use of the use of cosmogenic nuclides is given by:

Sarikaya, M.A., Çiner, A. and Zreda, M. (2015) Fairy chimney erosion rates on Cappadocia ignimbrites, Turkey: Insights from cosmogenic nuclides, *Geomorphology*, 234: 182–91.

This illustrates the discussion in Section 8.2 (p. 82) and shows how bedrock erosion rates were determined for three evolution stages of fairy chimneys (mushroom-like structures or hoodoos) in the Central Anatolian Plateau of Turkey.

Another paper using technical advances in survey to reveal spatial patterning in landforms to good effect is:

Spagnolo, M., Clark, C.D., Ely, J.C., Stokes, C.R., Anderson, J.B., Andreasson, K., Graham, A.G. and King, E.C. (2015) Size, shape and spatial arrangement of mega-scale glacial lineations from a large and diverse data set, *Earth Surface Processes and Landforms*, 39: 1432–48.

The theme of sediment connectivity within sediment cascades is taken further in:

Bracken, L.J., Turnbull, L, Waiwright, J. and Bogaart P. (2015) Sediment connectivity: a framework for understanding sediment transfer at multiple scales, *Earth Surface Processes and Landforms*, 40: 177–88.

In practice, sediment cascades (or fluxes) can be very complex. This is well illustrated in a special issue of *Geomorphology:*

Beylich, A.A., Gärtner-Roer, I.' Decaulne, A., and Morche, D. (eds) (2015) Sediment flux and sediment budget studies in cold environments: new approaches and techniques, *Geomorphology*, 218: 1–108.

A paper cited for 4 above is also pertinent to cycles in that the toposphere, encompassing Earth's landforms, is partly a biotic construct. Whereas the bio, litho-, atmo-, hydro-, topo-, and pedospheres coevolve at the global scale major biotic events have driven revolutions in the other spheres. The atmosphere and the global hydrological system are suggested to have been relatively steady-state at the global scale but the toposphere and pedosphere have not, perhaps indicating that landforms and soils provide the major mechanisms or degrees of freedom by which Earth responds to biological evolution: Phillips, J.D. (2016) Landforms as extended composite phenotypes, *Earth Surface Processes and Landforms*, 41: 16–26.