INTRODUCTION TO GEOLOGICAL PROCESS IN ILLINOIS

WATER CYCLE & WATER EROSION

INTRODUCTION

The processes that tear apart the rocks and shape the features we see on the Earth's surface usually involve the action of water both directly and indirectly.

> **Weathering** processes tear apart rock both physically and chemically. Running water abrades with sand and other sediments, freezing water wedges open cracks, and standing water dissolves rock and alters minerals.
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> **Erosional** processes remove the products of weathering (sediments).
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> Transportation by moving water takes the sediment to new locations.
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> **Deposition** from the water results in everything from sand bars to river deltas to beaches and even stalagmites in caves.

Geologists group all of the processes that shape the Earth's surface into the sub-discipline known as geomorphology. Geomorphologists' work includes examining streams, deserts, coasts, glaciers, and caves, characterizing the features present, and examining the processes that shape them.

Geomorphologists describe the surface features and processes in two ways.

> **Morphology** uses descriptive terminology to explain what is present. In science, terms used in written descriptions must be defined very precisely. This way when these terms are used in scientific discourse (such as in published papers and texts and in presentations) everyone knows what they mean. (Even colors are specifically defined using specific wavelengths of light or color chips in a book.)
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> **Morphometry** assigns numerical values to morphological features. Easy to explain, sometimes very difficult to carry out.

THE WATER CYCLE

The water cycle is the set of processes through which water moves from the earth's surface to the atmosphere and back again. The cycle is driven primarily by energy from the sun which provides energy for evaporation from surface water bodies such as oceans, lakes, and streams as well as transpiration from plants. The evaporation-precipitation process provides a constant supply of recharge for lakes, streams, and groundwater.

Globally, most of the Earth's water (over 97%) is found in the oceans, where its work shaping the land is confined primarily to the coasts. The remainder of the water (less than 3%) is found everywhere from lakes to glaciers to the atmosphere; the distribution is as follows:

LOCATION	PROPORTION
Ocean	97.2%
Glaciers	2.15%
Groundwater	0.62%
Lakes & inland seas	0.017%
Atmosphere	0.001%
Streams	0.0001%

Oddly enough, streams are currently the prime shapers of land and movers of sediment in most places.

STREAMS
To a geologist, a stream is any running water that is confined to a channel. Rivers, creeks, brooks and every size and shape in between is a stream.

More on streams: http://www.physicalgeography.net/fundamentals/10y.html

Sources of stream water
Streams are a part of the water cycle; thus, the water in a stream comes from other parts of the water cycle. When you look at a stream in Illinois, the water most likely comes from one of four sources.

> **Rain:** While this may seem obvious, most Illinois streams have water in them even when it has not rained for weeks. So, while rain is the ultimate source of the water, the immediate source is usually one of the next three.
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> **Overland flow:** Very little rain falls directly on a stream, and most of what falls on the land soaks into the ground. Only when the rate at which the rain is falling exceeds the capacity of the soil to soak it up does the rain flow over the ground and into a stream. While this can be very dramatic, causing filled ditches and flooded roads, it does not happen very often. Overland flow is responsible for soil erosion and can result in water entering a stream more rapidly than the stream can move the water downstream, resulting in over bank flooding.
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> **Ground water:** Most Illinois streams are effluent, meaning they gain water from the ground through their banks. Most of the rain that falls soaks into the ground and recharges the groundwater portion of the water cycle. The water moves slowly through the ground until it is discharged from a spring or to a stream or lake through its banks, this is why Illinois streams have water in them year round. Because groundwater flows very slowly, it buffers the effect of rain, preventing dramatic floods from occurring frequently.
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> **Tributaries, wetlands, & lakes:** All streams are part of a system, so they receive much of their water from whatever is upstream. A stream and its tributaries make up its drainage basin (or watershed). Two hundred years ago, most of Illinois was covered with small ponds and wetlands that released their water to streams and the ground slowly. Most of these small water bodies were drained and are now used for farming. New lakes have been created by humans for water storage and recreation and have taken the place of the small wetlands and ponds. Many of these new lakes are prominent features in Illinois State Parks.

Drainage basin (AKA watershed)
The drainage basin is the area drained by a stream. Most of the water in a stream is derived from rain that fell within the drainage basin. Each drainage basin is separated from adjacent basins by the drainage divide, which runs around the basin on a series of ridge crests. The drainage divide is most easily determined using topographic maps. The following web site will lead you through the process: http://www.ivcc.edu/phillips/geology/db_divide/step1.htm

Once a drainage divide has been drawn on a map, you can describe the morphology and morphometry of the drainage basin. Most maps do not show all of the streams within a basin; typically, the small tributaries must be identified using a topographic map or aerial photographs.

Morphology

> *Drainage patterns* describe the overall shape and orientation of a stream and its tributaries and can help reveal the nature of the underlying geology.

http://www.physicalgeography.net/fundamentals/10aa.html

Morphometry

Basin area is the area (in square miles, square meters, square feet, etc.) of the drainage basin. Many features can be divided by the basin area to account for differences in the sizes of basins when several are compared.

Total stream length is the total combined length of all the stream channels in the basin.

Relief is the difference between the highest and lowest points in the basin.

Drainage density is the total stream length divided by the basin area.

Relief ratio is the relief divided by the basin area.

More on stream morphometry: http://www.physicalgeography.net/fundamentals/10ab.html

These characteristics (and others) can tell a geomorphologist a lot about a drainage basin. For example, basins with a high drainage density usually convert rainfall into runoff much more rapidly than those with low drainage densities. Basins with a high relief ratio are also better at generating runoff rapidly. Thus basins with a high drainage density, a high relief ratio, or both will have a tendency toward flash flooding (a very rapid rise in water level. It is interesting to note that humans can artificially increase the drainage density by adding drainage tiles to farm fields or streets and storm sewers to towns; this results in neighboring streams producing larger and flashier floods.

Stream Channel

Water in a stream is confined to a channel which is comprised of the bed (bottom) and banks (sides). Channels can be examined for their morphometry as follows:

- Width
- Depth
- Gradient (slope of the channel)
- Roughness

The water can be measured for:

- Velocity (distance/time)
- Discharge (volume/time)
- Sediment capacity (total volume that can be carried)
- Sediment competence (largest size carried)
- Stage (depth of water in the channel)

Geologists look for relationships between these parameters. For example, as you move downstream, you will typically find that the width and depth increase, while the gradient decreases. As you might expect, the discharge and sediment capacity both increase downstream.

But what about the velocity and competence? When we think of mountain streams, we think of white-water rafting and big boulders; in contrast, a big river like the Mississippi, appears to move slowly and carry mostly mud. However, when velocities are measured and compared, the mighty Mississippi and its large counterparts around the world have high velocities and high competence! How can this be? The answer is in the roughness of the channel bed and banks. It turns out that in addition to width, depth, and slope, the velocity of a stream is also affected by roughness, the tricky part is that roughness is morphological. Roughness was added to a stream flow equation in 1889 by Robert Manning, and geologists (and hydrologists and engineers) have been trying to develop a good way to derive the number ever since. Converting an observable characteristic to a number is not always simple!

Flooding

When a stream leaves its banks and spreads onto the adjacent land, it is called a flood. The flat area adjacent to a stream that is covered during a flood is the flood plain. Floods vary in size and duration, but all are related to the characteristics of the drainage basin and stream channel. Think of the drainage basin as a rainwater collection system and the streams within the basin as plumbing. The more rain that falls and the faster the water moves into the streams, the bigger the flood will be. The morphometry of the basin and its channels can be put into a computer model that, when combined with rainfall information, will generate a flood forecast.

Stream Erosion

Stream erosion is caused by the hydraulic pressure of the water as well as by the impact of sediments already carried by the stream. By itself, the water can entrain loose materials, but the process is much more effective when the loose particles are used to “sand-blast” the banks of the channel. Rivers can also dissolve some minerals and, thus, slowly break apart rock into small pieces the moving water can pick up.

The velocity of the water is the primary characteristic that determines when and where erosion will occur. The faster the water, the greater the hydraulic pressure and the greater the force of impact the sediments contained in the water will have. The fastest water in a stream is typically near the center of the channel, just below the surface, where it cannot cause any erosion. In this situation, the banks and bottom may slowly erode as the water runs over them.

When there is an obstruction or irregularity in the channel, the water will become turbulent and can excavate holes in the banks or bed. This is an especially effective way to erode bedrock when large sediment such as sand and gravel is available to swirl around and abrade the rocky bottom. These “potholes” may be observed in parks where water runs over bedrock.

If a channel has a bend, the faster water moves to the outside of the bend, just as a car will drift to the outside of a curve if it is going too fast. This fast water will undermine the outside of the bend and create a cut bank. Cut bank erosion allows a channel to move laterally within a stream valley.

Stream Transportation

Once the sediment has been eroded, the stream moves the sediment by suspension, along the bed or as dissolved material. The suspended sediment is primarily clay and fine silt and is supported by turbulence in the water. The bed load sediment bounces or rolls along the bottom and includes every size from sand up to boulders. Both the suspended and bed load of the stream vary with the velocity of the water. The dissolved material is moved along at any speed and is not visible in the water.

Stream Deposition

A stream deposits sediment whenever the water slows; the finest materials (silt and clay) are usually not deposited until the water is still or nearly so. This results in deposits that are sorted by size. Gravel bars are found near the fastest water, usually within the channel. Sand bars are found near slower water along the banks and, in many places, on top of the banks adjacent to the river. Silt and clay deposits are primarily located away from the channel within wetlands and on the floodplains where the water greatly slows or stops moving.

With respect to position in the stream, some sediment bars are located within the center of the channel and some on the sides. When a channel has a bend, deposition occurs on the inside of the bend where the water is the slowest; this "point bar" is located on the opposite side of the channel from the cut bank. As the point bar builds out, it moves the channel in the direction of the cut bank. As the point bar grows and the cut bank moves out, the channel forms a large loop known as a meander. Meandering river channels move back and forth, creating a broad flat valley, and are occasionally cut off and reform, leaving curving oxbow (or horseshoe) lakes and wetlands.

Meandering rivers: http://www.watersheds.org/earth/meandering.htm

During a flood, deposition shifts. As the water leaves the channel it slows considerably, so sand (and sometimes gravel) are deposited at the top of the bank creating a pile of sediment that can restrict future small floods to the channel. This deposit is known as a natural levee.

When a stream leaves a valley with a steep gradient or enters a body of water, it loses much of its capacity to transport sediment. The stream may drop a very large load of sediment in either location, creating a fan-shaped wedge. When a steep creek empties onto a river floodplain, or a mountain stream discharges to a flat basin, the resulting feature is an alluvial fan. When the sediment is dropped into a body of water such as a large river, a lake, or an ocean, the feature is a delta.

More on stream-shaped landforms: http://www.physicalgeography.net/fundamentals/10z.html

OTHER SURFICIAL PROCESSES ACTIVE IN SHAPING ILLINOIS

Groundwater

In many places, groundwater helps shape the landscape, and, when the conditions are right, the action of groundwater can be the dominant process. As in rivers, groundwater can erode by dissolving rock or abrading it. Because groundwater moves very slowly, it usually starts by dissolving rock. The rock most susceptible to dissolution is limestone, which reacts strongly with acid. After a cavity has been created, the rate of flow can increase, and abrasion can become a factor if loose sediment washes in from above. Over time, this type of erosion expands cavities in the rock and creates caves. If the erosion reaches the surface, a depression of hole called a sinkhole will form. Landscapes formed through the dissolution of limestone are called karst.

Erosion can also occur where the groundwater flows out of a spring or seeps out of the rock. The water may dissolve the cement binding the rock together, or mineral crystals may form and grow as the water evaporates. Either way, the rock or soil around the seep or spring will be slowly removed, undermining the overlying materials in a process called sapping. Sapping is responsible for creating features as small as gullies and as large as canyons (including canyons in Mattheissen, Starved Rock and Ferne Clyffe State Parks!)

Coastal Processes

Coastal processes have shaped the landscape of Illinois, but only in a limited way. Along Illinois' coasts, waves are the dominant process shaping the shorelines. The waves are created by both wind and boats and can be very damaging to unprotected shores. The largest body of water in Illinois is Lake Michigan, but lakes both large and small are located around the state, many within or adjacent to Illinois' State Parks.

More on coastal processes: http://www.physicalgeography.net/fundamentals/10ac.html

ILLINOIS STATE PARKS AND NATURAL AREAS OF NOTE FOR THEIR ROLE IN THE WATER CYCLE

River Flood Plain

- Anderson Lake
- Big River
- Buffalo Rock (great view of the Illinois River Valley)
- Cache River
- Delabar
- Donnelley
- Fort Defiance (Mississippi & Ohio Rivers converge)
- Fort Massac (great view of Ohio River Valley)
- Frank Holten (ox-bow lake)
- Fults Hill Prairie
- Golconda Marine
- Horseshoe Lake, Alexander Co. (oxbow lake)
- Horseshoe Lake, Madison Co. (oxbow lake)
- Illini
- Kidd Lake Marsh
- Lake DePue
- Marshall County
- Mermet Lake
- Mississippi Palisades (great view of upper Mississippi River valley)
- Mississippi River Area
- Nauvoo
- Pere Marquette (Illinois & Mississippi Rivers converge)
- Ray Norbut
- Rice Lake
- Sanganois (Illinois & Sangamon Rivers converge)
- Silver Springs
- Spring Lake
- Starved Rock (great view of Illinois River, deep canyons)
- Union County
- William G. Stratton
- Woodford County

Stream Erosion

- Apple River Canyon
- Beall Woods
- Castle Rock
- Franklin Creek
- Jubilee College
- Kankakee River
- Lowden Miller
- Middle Fork
- Rock Cut

Coastal

- Illinois Beach

Groundwater

- Cave-in-Rock (caves, groundwater erosion)

Kickapoo (salt springs)
Ferne Clyffe (groundwater seeps, erosion of canyons)
Hidden Springs (fresh springs)
Illinois Caverns(caves, groundwater erosion)
Kankakee River (filled-in caves)
Mattheissen (groundwater seeps, erosion of canyons)
Mississippi Palisades(caves, groundwater erosion)
Saline County (salt springs)
Siloam Springs(mineral springs
Silver Springs (fresh springs)
Starved Rock (salt spring, groundwater seeps, erosion of canyons)
Weldon Springs (fresh springs)
Woodford County (artesian springs)