Geology 800

- Today
  - Running Water – Chapter 14

- Next Class
  - Oceans and Coasts 15

Running Water: The Geology of Streams and Floods

Stream Flow

- Streams – Ribbons of water that flow down channels.
- Runoff – Water in motion over the land surface.
- Stream runoff is crucial for humans.
  - Drinking water.
  - Transportation.
  - Waste disposal.
  - Recreation.
  - Commerce.
  - Irrigation.
  - Energy.
Stream Flow
- Stream runoff is an important geologic agent.
  - Flowing water...
    - Erodes, transports, and deposits sediments.
    - Sculpts landscapes.
    - Transfers mass from continents to ocean basins.

The Hydrologic Cycle
- Stream runoff is a component of the hydrologic cycle.
- Hydrologic cycle processes.
  - Evaporation.
  - Transpiration.
  - Precipitation.
  - Infiltration.
  - Runoff.

Forming Streams
- Streamflow begins as water is added to the surface.

Forming Streams
- Streamflow begins as moving sheetwash.
  - Thin surface layer of water.
  - Moves down the steepest slope.
  - Erodes substrate.
- Sheetwash erosion creates tiny rill channels.
- Rills coalesce, deepen, and downcut into channels.
Forming Streams
- Intense scouring marks entry into the channel.
- Rapid erosion lengthens the channel upslope.
- This process is called headward erosion.

Drainage Networks
- Drainage networks often form geometric patterns.
- These patterns reflect underlying geology.
- Common drainage patterns.
  - Dendritic – Branching, “treelike” due to uniform material.

Drainage Networks
- Common drainage patterns.
  - Radial – From a point uplift (mesa, volcano, etc.)

Drainage Networks
- Common drainage patterns.
  - Rectangular – Controlled by jointed rocks.
Drainage Networks
- Common drainage patterns.
  - Trellis – Alternating resistant and weak rocks.

Drainage Basins
- Land areas that drain into a specific trunk stream.
- Also known as catchments or watersheds.
- Divides are uplands that separate drainage basins.

Drainage Divides
- Watersheds exist in a variety of scales.
  - Tiny tributaries.
  - Continental rivers.
- Large watersheds...
  - Feed large rivers.
  - Section continents.
- Continental divides separate flow to different oceans.

Permanent vs. Ephemeral
- Permanent streams
  - Water flows all year.
  - At or below water table.
  - Humid or temperate.
  - Sufficient rainfall.
  - Lower evaporation.
  - Seasonal discharge variation.
- Ephemeral Streams
  - Do not flow all year.
  - Above the water table.
  - Dry climates.
  - Low rainfall.
  - High evaporation.
  - Flow mostly during rare flash floods.
Discharge
- The amount water flowing in a channel.
  - Volume of water passing a point per unit time.
  - Given by cross-sectional area times flow velocity.
  - Varies seasonally due to precipitation and runoff.

Discharge
- Velocity is not uniform in all areas of a channel.
  - Friction slows water along channel edges. Friction is…
    - Greater in wider, shallower streams.
    - Lesser in narrower, deeper streams.
  - In straight channels, highest velocity is in the center.
  - Few natural channels are straight.

Erosional Processes
- Erosional processes – Streamflow does work.
  - The energy imparted to streamflow is derived from gravity.
  - Erosion is maximized during floods.

Erosional Processes
- Streams scour, break, abrade, and dissolve material.
  - Scouring – Running water picks up sediment and moves it.
  - Breaking and lifting – The force of moving water can…
    - Break chunks of rock off of the channel.
    - Lift rocks off of the channel bottom.
Erosional Processes
- Abrasion – Sediment grains in flow "sandblast" rocks.
  - Bedrock exposed in channels is often polished smooth.
  - Gravel swirled by turbulent eddies drills holes in bedrock.
    - These bowl-shaped depressions are called potholes.
    - Potholes are often intricately sculpted.
- Dissolution – Mineral matter dissolves in water.

Sediment Transport
- The material moved by streams is the sediment load.
- There are 3 types of load.
  - Dissolved load – Ions from mineral weathering.
  - Suspended load – Fine particles (silt and clay) in the flow.
  - Bed load – Larger particles roll, slide and bounce along.

Sediment Transport
- Sediment transport changes with discharge.
  - High discharge – Large cobbles and boulders may move.
  - Low discharge – Large clasts are stranded.
- Competence – The maximum size transported.
- Capacity – The maximum load transported.

Sediment Deposition
- When velocity decreases so does competence.
  - Sediment grains drop out; water sorts them by size.
    - Gravel settles in channels.
    - Sands are removed from the gravels; muds from both.
    - Sands drop out in near channel environments.
    - Silts and clays are suspended only to settle in slack water.
Sediment Deposition

- Fluvial sediments are called alluvium.
  - Channels may be decorated with mid-channel bars.
  - Sands build up the point bars inside meander bends.
  - Muds are deposited away from the channel during floods.
  - A stream builds a sediment delta upon entering a lake.

Longitudinal Changes

- The character of a stream changes with flow distance.
- In profile, the gradient describes a concave-up curve.

Longitudinal Changes

- The character of a stream changes with flow distance.
  - Near the headwater source of the stream...
    - Gradient is steep.
    - Discharge is low.
    - Sediments are coarse.
    - Channels are straight and rocky.

Longitudinal Changes

- The character of a stream changes with flow distance.
  - Toward the mouth...
    - Gradient flattens.
    - Discharge increases.
    - Grain-sizes are smaller.
    - Channels describe broad meander belts.
Base Level
- The lowest point to which a stream can erode.
  - Ultimate base level is defined by the position of sea level.
    - Streams cannot erode below sea level.
  - A lake serves as a local (or temporary) base level.
  - Base level changes cause stream re-adjustments.
    - Raising base level results in an increase in deposition.
    - Lowering base level accelerates erosion.

Valleys and Canyons
- Land far above base level is subject to downcutting.
- Rapid downcutting creates an eroded trough.
  - Canyon – Steep trough sidewalls form cliffs.
  - Valley – Gently sloping trough sidewalls define a V-shape.
- Determined by rate of erosion vs. strength of rocks.

Base Level
- The lowest point to which a stream can erode.
  - A ledge of resistant rock may define the local base level.
  - Erosive forces act to slowly remove the resistant layer.
    - This acts to restore the longitudinal profile.

Valleys and Canyons
- Stratigraphic variation often yields a stair step profile.
  - Strong rocks yield vertical cliffs.
  - Weak rocks produce sloped walls.
- Geologic processes stack strong and weak rocks.
Valleys and Canyons
- Active downcutting flushes sediment out of channels.
- Valleys store sediment when base level is raised.
- Renewed incision creates stream terraces.
  - Terraces mark former floodplains.

Braided Streams
- Form where channels are choked by sediment.
- Flow is forced around sediment obstructions.
  - Diverging – converging flow creates sand and gravel bars.
  - Bars are unstable, rapidly forming, and being eroded away.
- Flow occupies multiple channels across a valley.

Meandering Streams
- Channels can form intricately looping curves…
  - Along the lower portion of the profile with a low gradient.
  - Where streams travel over a broad floodplain.
  - When substrates are soft and easily eroded.
- Meanders increase the volume of water in the stream.
- Meanders evolve.

Meandering Streams
- Meanders change from variation in thalweg position.
- Maximum velocity swings back and forth across flow.
  - Fast water erodes one stream bank.
  - The opposite bank collects sediment.
Meandering Streams
- Erosion accentuates the cut bank.
  - High-velocity flow scours the outside of the meander bend.
  - Collapsed cut-bank material is transported away.
- Deposition builds the point bar.
  - Sediment accumulates inside the meander bend.
  - Continued addition expands the point bar laterally.

Meanders become more sinuous with time.
- The cut bank erodes; the point bar accretes.
- Meander curves become more pronounced.
- Meanders elongate.

Meander sinuosity increases until the meander is cut off.
- Cut banks converge and a meander neck thins.
- During flooding, high-velocity flow saws through the neck.
- The meander cut-off forms an oxbow lake.
- The oxbow fills with sediment, leaving an arcuate scar.

Deltas form when a stream enters standing water.
- Current slows and loses competence; sediments drop out.
- Stream divides into a fan of small distributaries.
- Shape due to the interplay of flow, waves, and tides.
Deltas

- Distinct lobes preserve past Mississippi Delta history.
- The river periodically switches course via avulsion.
  - River breaks through a levee upstream.
  - Establishes a shorter, steeper path to the Gulf of Mexico.
- Abandoned delta lobes are sediment-starved.
  - Sediments deposited before avulsion slowly subside.
  - Compaction, dewatering, and decay of organic matter.
  - Lack of sediment nourishment.
- Abandoned delta lobes are eventually submerged.

Drainage Evolution

- Landscapes evolve over time.
- Streamflow is the cause of most landscape changes.
- Example:
  - Uplift sets a new base level.
  - Stream cuts into former surface.
  - Valleys widen; hills erode.
  - Landscape eroded to base level.
Drainage Evolution

Stream rejuvenation is initiated by base level drop.
- Meanders initially develop on a gentle gradient.
- Uplift raises the landscape or base level falls.
- The river chainsaws downward creating incised meanders.

Superposed streams.
- Incises deformed terrain, yet ignores underlying structure.
  - Streams initially develop in younger, flat-lying strata.
  - The stream then chainsaws into the older underlying rocks.
  - Stream maintains the geometry developed at an earlier time.

Stream Piracy.
- A stream captures another’s flow.
- One stream, with more vigorous headward erosion (a steeper gradient), intercepts a neighbor.
- The captured stream flows into the new stream.
- Below the point of capture, the old stream dries up.