EROSION (& DEPOSITION)

- Seismic (earthquake-induced)
- Meteor impact
- Humans
- Animals
- Rain and snow
- Fluvial (rivers)
- Wind
- Glaciers
- Coastal
  - waves
  - currents

Doubtful Sound, New Zealand
FLUVIAL GEOMORPHOLOGY

MONGOLIAN ALTAI
Drainage basin

- Drainage divide
- Interfluve

Mill Creek watershed
Drainage patterns

EAST AFRICAN RIFT
dendritic drainage pattern, playa, Baja California
EAST AFRICAN RIFT
Centripetal drainage pattern, MYVATN, ICELAND
HORSE HEAVEN HILLS EAST OF WALLULA GAP
Barbed drainage, stream capture, Catskill Mountains, New York
Stream parameters

- **Stage (e.g. elevation)**
- **Width**
- **Depth**
  - Area = width x mean depth
- **Velocity**
  - Discharge = area x mean velocity
- **Slope**
- **Roughness**
Flood recurrence interval

What is
- a 100-year flood?
- a 50-year flood?
- a 10-year flood?
Pittsburgh, Pennsylvania, 1969-1972
How do stream parameters change

• at one place during a flood?
• downstream at one time?
• p. 234

Downstream of Edith Cavell Glacier, Jasper National Park, Alberta
Hydrograph

Mill Creek Flows

Discharge (cfs)

Day in Feb, 1996

0 5 10 15
Overland flow

- Zone of no erosion
- Micropiracy
Basin morphometry

- Stream order
- Bifurcation ratio
- 0-order stream

Mississippi River, New Orleans, Louisiana
Badlands National Park, South Dakota

- Drainage density
- Stream frequency
- Drainage texture
- As stream order increases:
  - Number of streams decreases
  - Mean length of streams increases
  - Main basin area increases
Mechanisms of slope erosion

- Raindrop impact
Soil erosion
Soil loss equation

- **A** = **R K L S C P**
- **R** = rainfall (precipitation)
- **K** = erodability (e.g. permeability, consolidation)
- **L** = slope length
- **S** = slope gradient (steepness)
- **C** = crop management (vegetation)
- **P** = erosion control practice
• Water ripples
  – Symmetrical
  – Asymmetrical
Standing waves: strong current
Wind waves: little current

Gulf of Alaska
18 September 1988
Water current bedforms

- None
  - threshold crossed
- Asymmetrical ripples
- Asymmetrical dunes
- Plane bed
- Antidunes
MELTWATER BELOW SCOTT GLACIER, AK
FORT ROCK, OR
Transportation

- Solution load
- Suspended load
  - saltation load
- Bed load

Mill Creek, 1996 flood
Suspended sediment load

Willamette River at Salem
- USGS data (1991-93)
- USACE data (1949-51)
- Best fit regression line

Suspended sediment load, in tons per day per square mile

Streamflow, in cubic feet per second per square mile
Stream power is the rate of energy dissipation against the bed and banks of a stream. It is given by the equation:

$$\Omega = \rho g Q S$$

where $\Omega$ is the stream power, $\rho$ is the density of water (1000 kg/m$^3$), $g$ is acceleration due to gravity (9.8 m/s$^2$), $Q$ is hydraulic discharge (m$^3$/s), and $S$ is the channel slope.
JOKULHLAUP,
SOUTH TAHOMA GLACIER
JULY 1988
Stream “erosion” of bedrock

- Abrasion
- Plucking
- Cavitation (bubble explosion)
- Corrosion (chemical weathering)
- Mass wasting

Meltwater pothole,
The Basin,
Franconia Notch,
New Hampshire
Abrasion
Flutes

Rio Grande
Big Bend National Park
Texas
NIAGARA FALLS

Silurian dolostone

Silurian shale
Stream equilibrium

- Graded stream: a stream in which, over a period of years, slope is adjusted to yield the velocity required for transportation of the load supplied from the drainage basin.

- Base level: the lowest point to which a stream can flow (ocean, lake, resistant rock).

- Knick point: a sharp change in channel slope resulting from differential rates of erosion above and below the knickpoint.
Channel patterns

lower Walla Walla Valley, Washington
W/D = width to depth ratio

<table>
<thead>
<tr>
<th>Meandering</th>
<th>Braided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow</td>
<td>Wide</td>
</tr>
<tr>
<td>Deep</td>
<td>Shallow</td>
</tr>
<tr>
<td>Gentle slope</td>
<td>Steep slope</td>
</tr>
<tr>
<td>Fine-grained load</td>
<td>Course-grained load</td>
</tr>
<tr>
<td>Efficient transport of suspended load</td>
<td>Efficient transport of bed load</td>
</tr>
</tbody>
</table>
Meandering streams

- Meander
  - Cut bank
  - Point bar
- Cutoff meander
- Oxbow
- Meander scar

Mississippi River just north of the Atchafalaya River, Louisiana/Mississippi
Why do rivers meander?

- Meanders decrease the stream gradient until an equilibrium between the erodibility of the terrain and the transport capacity of the stream is reached. (Riley, 1998)
- Obstacles instigate meander formation by deflecting the stream.
Incised meanders

- Entrenched meanders
- Ingrown meanders

Dead Horse Point, Colorado River, Utah
Mechanisms of braided channel change

- Development of the central bars
- Conversion a single transverse bars to mid-channel braid bars
- Formation of chutes (chute cutoff ?)
- Dissection of multiple-braid bars
- Bank erosion
- Channel incision
- Bar sculpting

(Wheaton et al., 2013)
Floodplains

- Natural levees
- Backswamps
- Oxbows
- Meander scars

Siuslaw River, Oregon
Accretion

**Vertical**
- Suspension load
- Overbank deposits (overbank silts)
- “Backswamp”
- Fine-grained

**Lateral**
- Bed load
- Channel deposits
- Point bar
- Coarse-grained
Mount St. Helens, Washington
STREAM TERRACES

SNAKE RIVER, WYOMING
HANGAY MOUNTAINS, MONGOLIA
Alluvial fans

- Most common in semiarid climate
- Distributaries
- Concave long profile
- Why deposition?
  - Gradient decrease?
  - Water spreading
  - Infiltration
- Fan area = f (drainage basin area)
- Fluvial and debris flow deposits
- Bajada
Clarks Fork Canyon, Wyoming
Desert pavement

- Overland flow (water)
- Deflation (wind)
- Upward migration of stones (shrink/swell)
  - Freeze/thaw
  - wet/dry
- Accumulation of eolian sediment below stones
Pediments
Pediments

- Much debate!
- Pediment
- Slope of transportation
- Gravels over suballuvial bench
- Inselberg
- Peripediment
- Backwasting
- Changing areas and relief reduction: reduction of precipitation and sediment
ZARKHAN, MONGOLIA
ALDRICH MOUNTAINS & JOHN DAY RIVER, OR
western Bighorn Basin, Wyoming
Pediment processes

- Slope of transportation
- Streams migrate laterally
- Sheetfloods
- Subsurface weathering
- Relic? (formerly more humid?)

W. M. Davis
PENEPLAIN

DANVILLE, VA
Pilot Knob, North Carolina

MONADNOCK

Pilot Knob, North Carolina
NILE DELTA, EGYPT

DELTAS

distributaries

NILE DELTA, EGYPT
What factors influence the characteristics of deltas?
DUCKABUSH DELTA, HOOD CANAL, WA

Topset beds
Foreset beds
Bottomset beds
Classification of deltas

**Sediment dominated**
- Birds-foot delta
- Mississippi Delta, Louisiana

**Wave dominated**
- “Longshore drift delta”
- Mouth of Columbia River
- Clatsop Plain, Oregon

Skokomish Delta, Hood Canal, Washington
Cross-axial drainage; water gaps

- Antecedence
- Superposition
- Headward erosion
- Damming (anteposition)
- Subsurface capture