Streams and Shoreline Deposits November 13, 2006

Stream profile and gradient—the elevation change over a given distance.

Base level = the elevation below which a stream cannot erode sediment.
Mediterranean Sea dried up causing base level to reset in the Rhone and Nile Rivers during the Pliocene (Messinian Salinity Crisis: 5.96-5.33 Ma).

Drainage Basin

With distance from the head waters:

1. discharge increases
2. stream cross section increases,
3. velocity increases slightly,
4. the gradient decreases

   the proportion of clay increases (***floodplains are "clay factories"***)

Stream Load--Three types of material transported:

1. **Bed load**
2. **Suspended Load**
3. **Dissolved Load**

Stream morphology: (1) Braided Streams, (2) **Meandering Streams**

Stream morphology

Point bars
Sedimentary structures
Channel levees.
Flood plains
Crevasse-splays
River Terraces
Deltas

Geologic Record

Pattern of facies controlled by (1) sediment supply, (2) subsidence rate, and (3) gradient Two main types: (1) **Sand-dominated systems**, (2) **Mud-dominated systems**.

Shoreline Processes and Deposits

1. Deltas
2. Wave reworking and longshore drift.
3. Rip currents

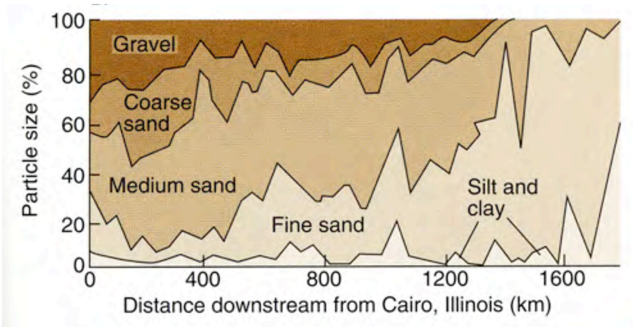
Sediment can also be generated locally by shoreline erosion

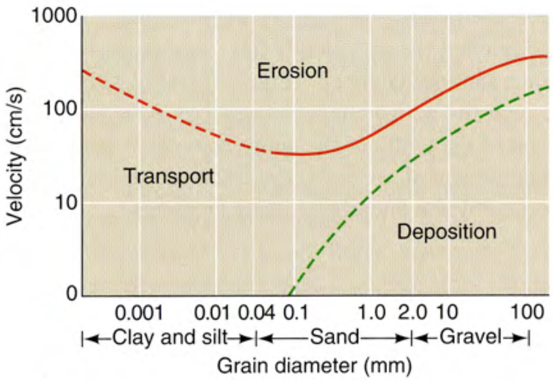
1. Sea cliffs
2. Winter storms

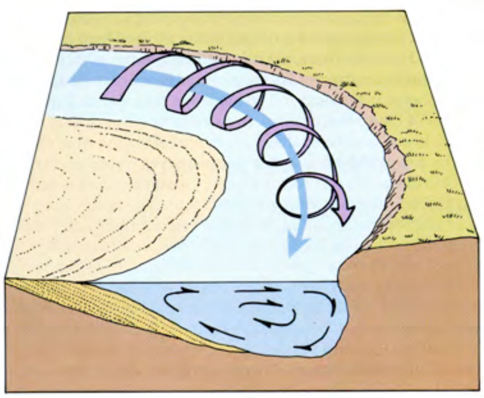
Sediment is redeposited into offshore bars and spits or deep sea fans

Carbonate Environments

1. *bioeroding* organisms
2. Beachrock
3. Atoll.


Gravel
Coarse sand
Medium sand
Fine sand
Silt and clay
Particle size (%)
100
80
60
40
20
0
0
400
800
1200
1600
Distance downstream from Cairo, Illinois (km)

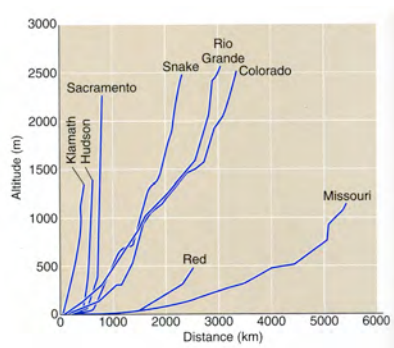

Erosion
Transport
Deposition
Velocity (cm/s)
1000
100
10
0
0.001
0.01
0.04
0.1
1.0
2.0
10
100
Clay and silt
Sand
Gravel
Grain diameter (mm)



Streams and Shoreline Deposits November 13, 2006

Streams are a primary means of transporting sediment and fresh water

All are characterized by a **stream profile**—the elevation change over a given distance. Profiles are concave-up surfaces that reflect the higher slope of rivers near their headwaters than near their terminations.

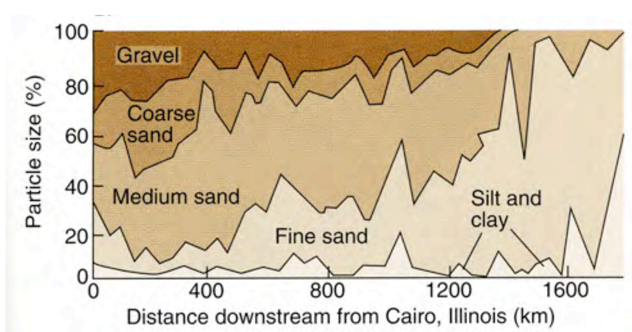


Base level = the elevation below which a stream cannot erode sediment. Stream profile is concave because the lower reaches of the stream are nearing base level for that stream.

Base level is often sea level, but may be higher if the stream is flowing into an interior basin or a dammed basin. Base level can decrease if sea level drops—eg. The Nile during the evaporation of the Mediterranean Sea (3000 m of water between 5.96-5.33 Ma) during the Pliocene. Hence base level can be reset by erosion or deposition.

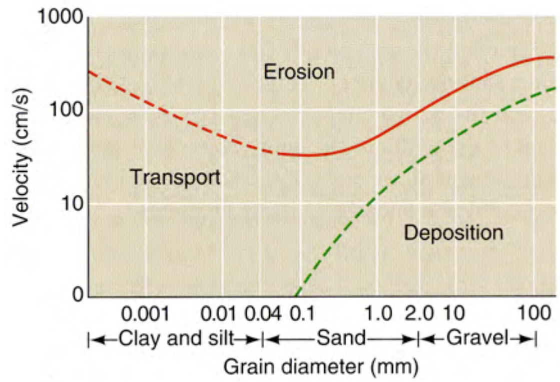
With distance from the head waters:

5. discharge increases (owing to an increase in the number of tributaries supplying water)
6. stream cross section increases,
7. velocity increases slightly,
8. the gradient decreases
9. the proportion of clay in transported sediment increases because gradient is lower and part because of chemical weathering in flood plains—***floodplains are "clay factories"*** working on grains for 1000's to 100,000's yrs.



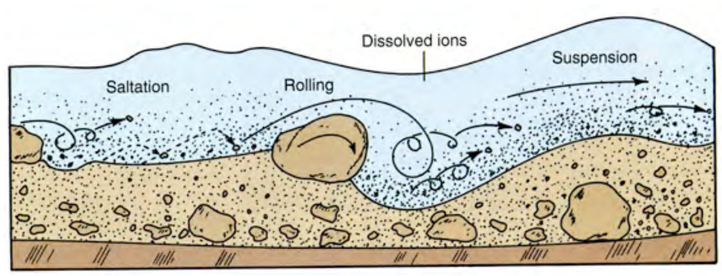
Stream Load

Stream velocity is also associated with ability of a stream to erode sediment. High velocities are needed to erode cohesive clays as well as coarse-grained sediment. The most readily eroded sediments are fine sand; something amiss in the diagram—no deposition at velocity of zero! (the axis should start at 0.1 cm/sec).



Three types of material transported:

4. **Bed load**—5-50% of stream load, carried by saltation, most coarse grained sediment in the stream
5. **Suspended Load**—fine grained sediment carried entirely within the water column (usually silt and clay)
6. **Dissolved Load**—up to 50% of the load, chemical species such as bicarbonate ($HCO3^-$), Ca^{2+}, Na^+, Mg^{2+}, K^+, Sulfate (SO_4^{2-}); can be high when there is substantial ground water recharge.



Stream morphology also changes:

Braided Streams--characteristic of the upper parts of many drainages. These have many channels that anastamose, a pattern that reflects:

1. ***high sediment load and high stream gradients***
2. ***episodic flow*** (due, for example to small discharge, high seasonality (say of snow melt or desert climate or high sediment supply due to glaciers).
3. ***Absence of vegetative cover*** (that would hold the stream banks)

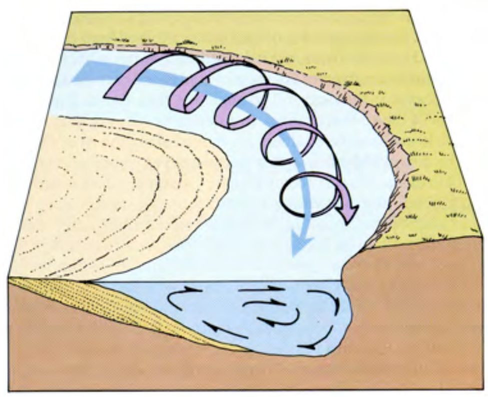
Meandering Streams—characteristic of low gradient drainages

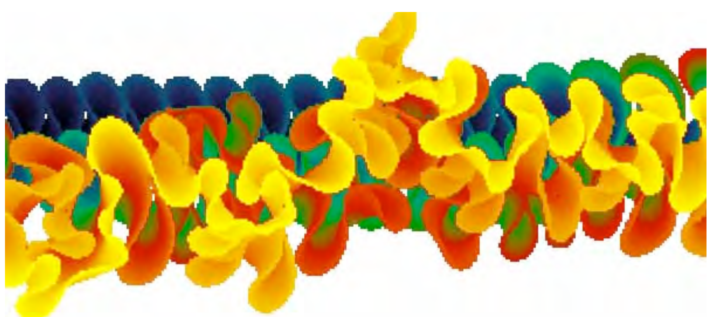
1. have wide flood plains
2. fine-grained sediment in the flood plain

3. Streams tend to meander if there are few limitations on their flow—watch water streaming down a window or sides of a bath tub—the stream will wiggle side to side as a function of frictional forces
4. Meanders migrate by cutting on the outside bends and depositing sediment on the inside bends.
5. **Oxbow lakes** form when meander loops touch and capture the flow, cutting off a meander and forming a lake.

In both river types, the ***fastest velocities are in the deepest part of the channel***, and ***channels are usually asymmetric***—the shallowest ends associated with deposition and the deepest cut banks associated with erosion.

Stream morphology
Point bars are sandy or gravelly sediment deposited on the inside of loops. **Sedimentary structures** change with flow, from ripples on the point bars to dunes (forming trough cross-beds) and gravel lags in the channels. Point bars **migrate perpendicular to stream flow**

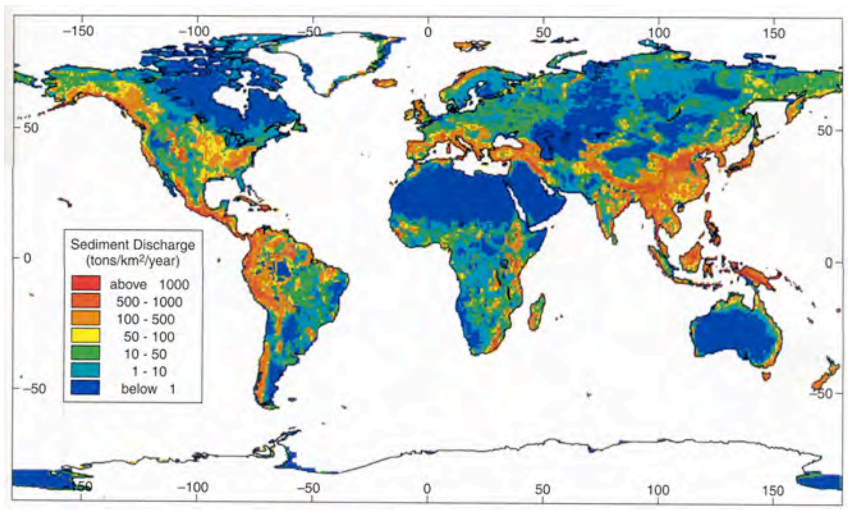




Channel levees--during floods, coarse sediment deposited close to the channel.
Flood plains—area within flood range of a river—site of deposition of fine grained sediment that settles from flood waters following flooding
Crevasse-splays—areas where a river channel breaks through its levees
River Terraces—the old floodplain or channel deposits of a river after the river has cut into its bed (usually because of a drop in base level).
Delta—area at the base level of a river where sediment load is deposited; Alluvial fans are an equivalent in terrestrial environments.

A key point is that rivers will follow the course to the **lowest gradient** whenever possible. Build up of sediment in a channel or in a delta will cause the channel to be abandoned and the river to cut a new course.

Hence, rivers are highly sensitive to changes in base level owing to tectonics or dams.



Sediment yield: Amount of sediment derived per unit area in a drainage basin. Typically highest in steep basins and areas with high rainfall.
Drainage Basin—the area that contributes water to a river. Rivers grow by headward erosion of first-order streams. Where two first-order streams meet, they produce a second order stream and so on….

[Skip] Drainage patterns reveal the underlying geologic history:

Taxonomy of streams is like this:

1. **consequent streams**—follow the local slope
2. **subsequent streams**—follow local structure, particularly weak, easily eroded rocks
3. **Antecedent streams**—cross-cut ridges indicating stream was present before the topography
4. **Superimposed streams**—initial course of the stream controls its subsequent shape, not underlying geology—e.g. many entrenched streams
5. **Captured streams**—headward erosion can cut into the headwaters of another stream, capturing part of the second stream's flow.

Geologic Record

Pattern of facies controlled by (1) sediment supply, (2) subsidence rate, and (3) gradient

Sand-dominated systems—in arid or mountain systems or areas with low subsidence rate where flood plains are recycled numerous times

Mud-dominated systems—often associated with high subsidence rates, high chemical weathering and distal, low gradient systems.

Shoreline Processes and Deposits

When sediment is delivered to the shoreline it is redistributed by a number of processes

4. Deposition in a delta (by turbidity flows (as during storms)
5. Wave reworking and longshore drift.
    a. Occurs when waves strike a beach face at an angle—causes sediment to zig-zag down a beach in the swash and backwash. Creates sediment movement down to the beach
6. Rip currents—form when water is piled up on a beach shoreward of offshore bars. The bars prevent the easy return flow and direct the flow into inter-bar channels which can have very strong offshore flows

Sediment can also be generated locally by shoreline erosion

3. Produces sea cliffs by erosion at the base
4. In temperate systems, strongest erosion during winter storms
    a. Large waves wash the sand off the beach where it accumulates in offshore bars
    b. Lack of sand exposes base of cliff to erosion by sand and hydraulic force of large waves.

Sediment is redeposited into offshore bars and spits—

1. The latter form where longshore drift distributes sediment across a river mouth or from the end of a point of land
2. Longshore drift can also direct sediment into submarine canyons where sediment escapes the shelf and is deposited directly into deep water.

Carbonate Environments

Many of the same principles apply, but carbonates also have a number of unique features:

4. In carbonate systems (as in the tropics), erosion can be by algae and *bioeroding* organisms that bore into the soft limestone, undercutting the cliff face.
5. Carbonates can become easily cemented in the surf zone forming "Beachrock"—with the consistency of concrete.
6. Bars or reefs can grow very rapidly because of
    a. biological processes of carbonate formation and formation of wave resistant structures
    b. Early cementation of sediment by chemical processes of dissolution and re-precipitation
7. Hence, Reefs can grow as fast as sea level rise
8. Case in point is the formation of an **atoll**
    a. As the volcanic island subsides (usually because of thermal subsidence of the underlying oceanic plate) the reef grows around it.
    b. Eventually, the volcanic island subsides below sea level leaving a ring of reef rock—an Atoll.