Indian Institute of Technology, Kanpur

Department of Earth Sciences

ES0213A: Fundamentals of Earth Sciences

Lecture 37. Landforms

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IITK Experimental Rock Deformation Laboratory

Aims of this lecture

Categories of various Landforms and their driving forces

Aeolian Landform*

Fluvial Landform*

Glacial Landforms

Readings:
Grotinger & Jordan's Book: Chapters 18-21

Surface-forms

A number of surface-forms we see on the Earth, both in lands and oceans, rivers and lakes – they are beautiful, mesmerizing, thought-provoking and sometimes, scary..

All such surface form do develop naturally and slowly; sometime fast (during hazards) and also man-made

GEOMORPHOLOGY: A discourse of Earth's surface forms

Earth's surface

The surface of the earth is not flat.. WHY?

Was is flat before and now developing more intense topography?

Was is extremely rugged before and now becoming flat?

a variety of geologic processes can cause one portion of the surface to move up or down relative to an adjacent region. We refer to the relative upward movement of a region as **uplift** and the relative downward movement of a region as **subsidence**.

The continuous uplift and subsidence contributes to develop and maintain the **dynamic topography** of the earth's surface

UPLIFT and SUBSIDENCE

- **Thickening of the crust.** At convergent and collisional boundaries, compression causes the crust to shorten horizontally (by development of folds, faults, and foliations) and thicken in the vertical direction.
Intrusion or extrusion of igneous rocks thickens the crust or builds volcanoes on top of the surface, and also can cause uplift.

- **Heating of the lithosphere.** Heating decreases the thickness and density of lithosphere, so to maintain isostatic equilibrium, lithosphere floats higher.

- **Rebound due to unloading.** Removal of a heavy load (such as a glacier or mountain) from the surface causes the Earth's surface to rise in a manner similar to the way a trampoline's surface rises when you step off it.

- **Delamination.** If dense lithospheric mantle separates from the base of the plate and sinks into the mantle, the surface of the lithosphere rises. The effect resembles the consequence of unloading ballast from a ship.

UPLIFT and SUBSIDENCE

- **Thinning of the crust due to stretching.** In rifts, where the crust undergoes horizontal stretching, the axis of the rift drops down by slip on normal faults.

- **Cooling of the lithosphere.** Cooling thickens the lithospheric mantle and makes it denser, so to maintain isostatic equilibrium, the lithosphere sinks down and its surface lies at a lower elevation.

- **Sinking due to loading.** Where a heavy load (such as a glacier or volcano) forms on the Earth's surface, the lithosphere warps downward, somewhat like the surface of a trampoline warps down when you stand on it.

- **Erosion.** Driven by natural agents like water, wind and ice.

Controlling Factors: Erosion

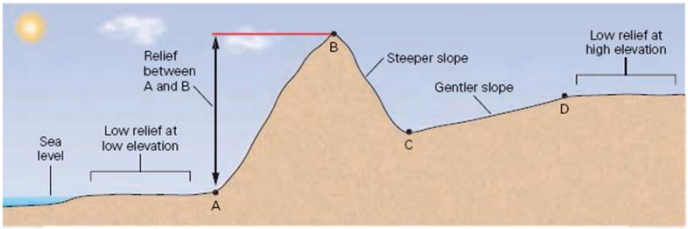
Eroding or transporting agents: Water (Fluvial), ice (Glacial), and wind (Aeolian) all cause erosion and transport sediment. But the shapes of landforms produced by each are different because of differences in the abilities of these agents to carve into the substrate and to carry debris. Of these three, water has the greatest impact, on a global basis.


Photo: Santanu Misra


Photo: Santanu Misra

Controlling Factors: Relief, Steepness, cohesion

Relief: The elevation difference, or relief, between adjacent places in a landscape determines the height and steepness of slopes. Steepness, in turn, controls the velocity of ice or water flow and determines whether rock or soil stays in place or tumbles downslope.



Mountains have high relief

Planes have low relief

Floodplains are cohesive

Deserts are non-cohesive

Controlling Factors: Climate, Weather, Materials

Climate & Weather: The average mean temperature, the volume of precipitation, and the distribution of precipitation through the year (in other words, the *climate*), determines whether running water, flowing ice, or wind serves as the main agent of erosion or deposition in a region. Climate also affects the way in which substrate weathers.

Substrate composition: The material comprising the substrate determines how the substrate responds to erosion. For example, strong rocks can stand up to form steep cliffs, while soft sediment collapses to generate gentle slopes.

Controlling Factors: Life and Time

Life activity: Some life activity weakens the substrate (by burrowing, wedging, or digesting), while some holds it together (by binding it with roots).

Time: Landscapes evolve through time, in response to continued erosion and/or deposition. For instance, a gully that has just started to form in response to the flow of a stream does not look the same as a deep canyon that develops after the same stream has existed for a long time.

AEOLIAN LANDFORMS

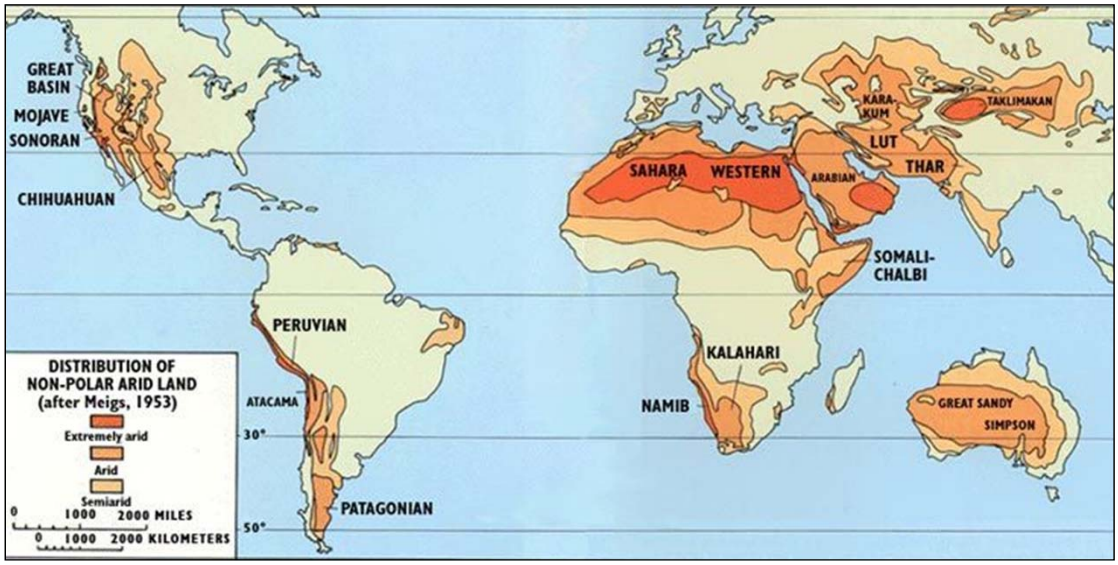
Aeolian Landform

Aeolian processes are those derived from wind activity, and they comprise erosion, transport, and sedimentation.

Small-sized particles are mobilized and, finally, deposited in different environments, sometimes at a great distance from their source area.

These are seen mostly in continental areas (deserts, dried rivers. lakes and its terraces, pediment covers and alluvial fans, lacustrine terraces). Marine beaches are also an important region to produce coastal dunes.

Aeolian Landform



Aeolian Landform: water influence

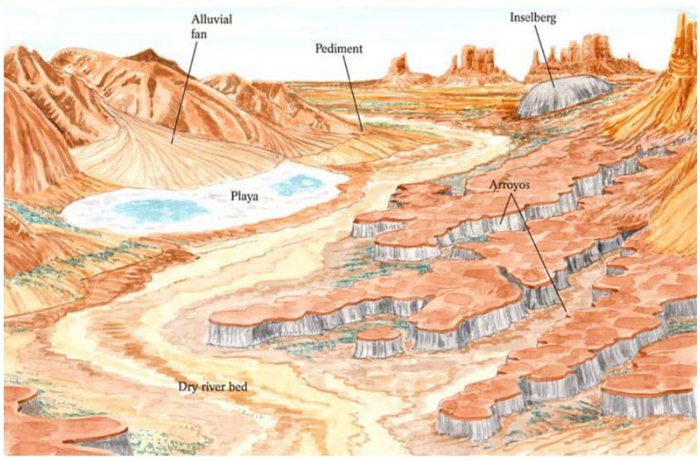
Bajada: broad slope of debris spread along the lower slopes of mountains by descending streams

Playa: Dried desert basins, occasionally filled with water

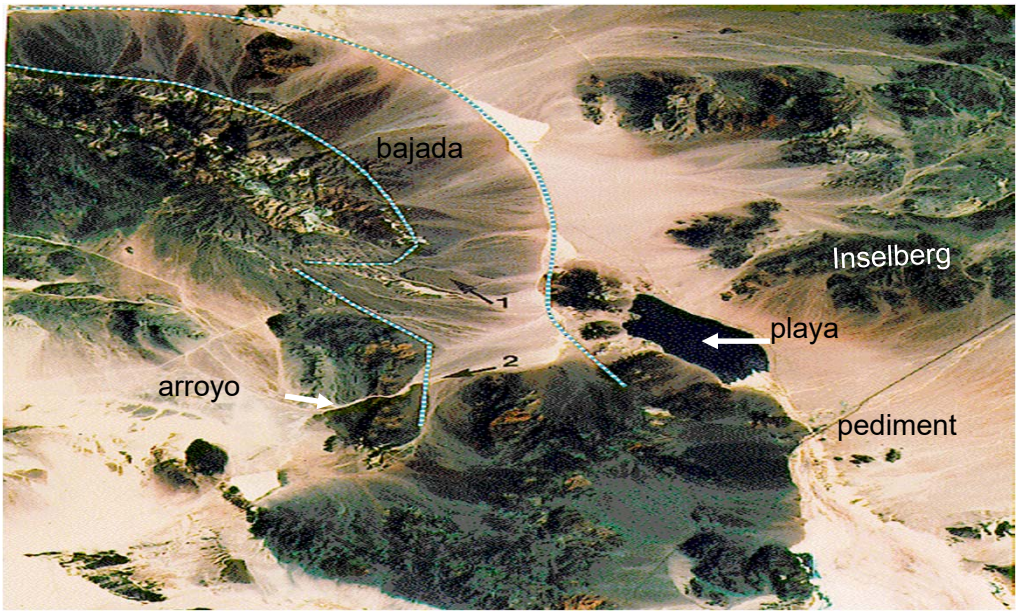
Pediment: Gently slopping surface at the base of steep slope

Arroyo: Dry river channel, often incised

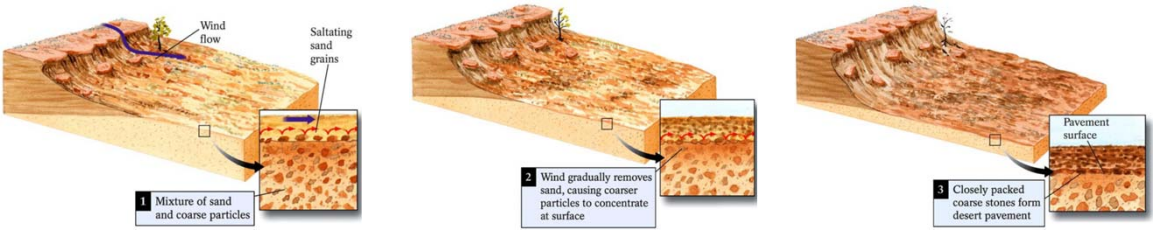
Inselberg: Isolated hill or ridge



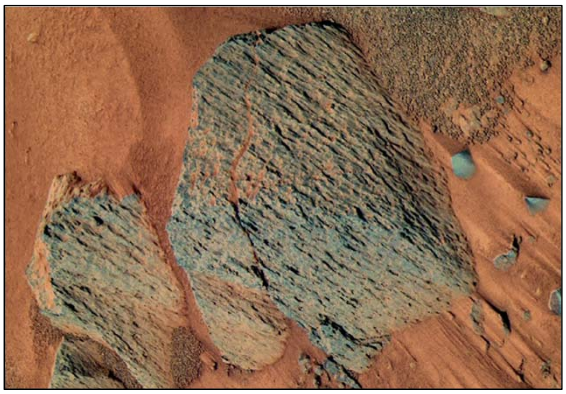
Aeolian Landform



Aeolian Landform: Pavements



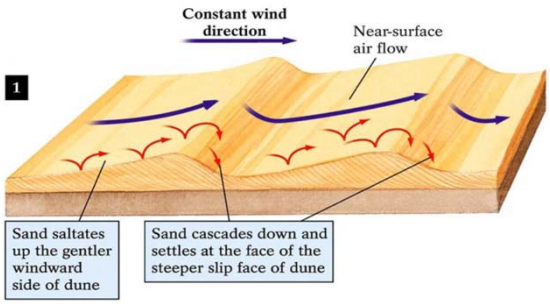
Aeolian Landform

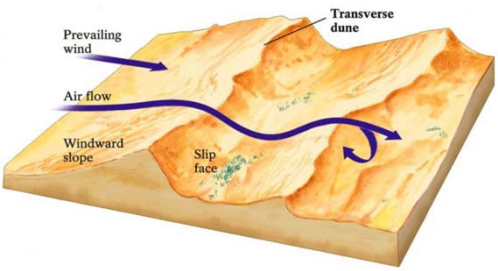


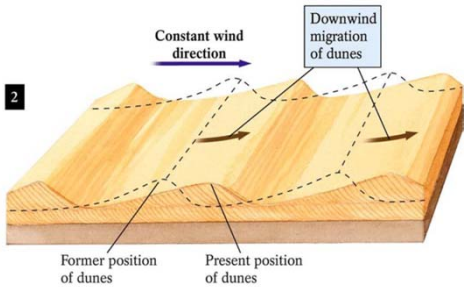
Ventifacts: Rocks that have been sculpted by wind-borne particles and worn, faceted, cut, or polished by the abrasive action of windblown sand.

Yardang: sharp irregular ridge of compact sand/rock lying in the direction of the current wind in exposed desert regions.

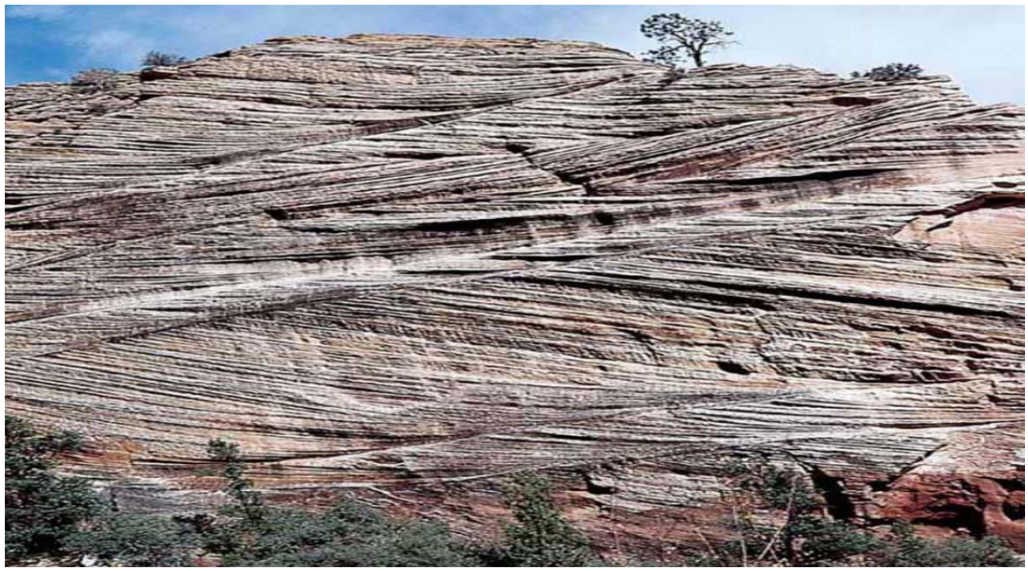
Aeolian Landform: Transverse Dunes



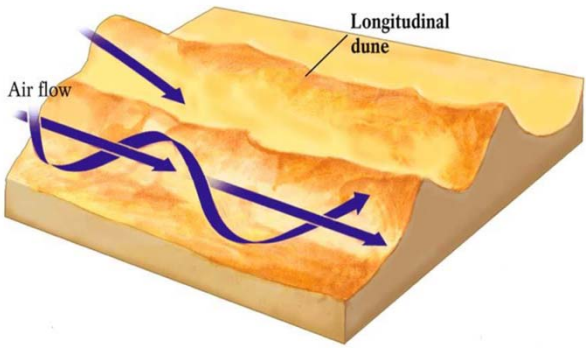




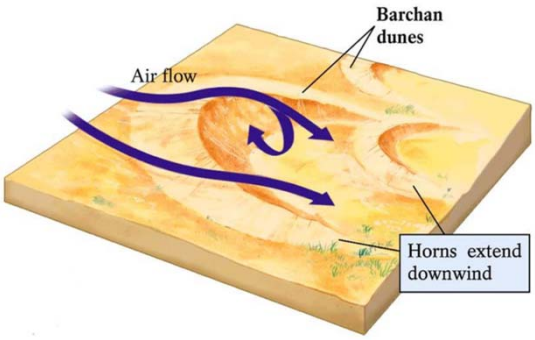
Aeolian Landform: Lithified Dunes



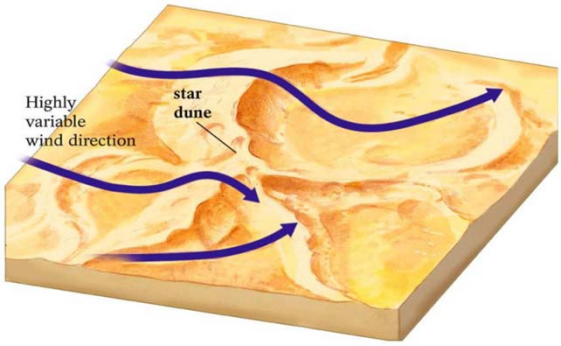
Aeolian Landform: Longitudinal Dunes



Aeolian Landform: Barchan Dunes



Aeolian Landform: Star Dunes

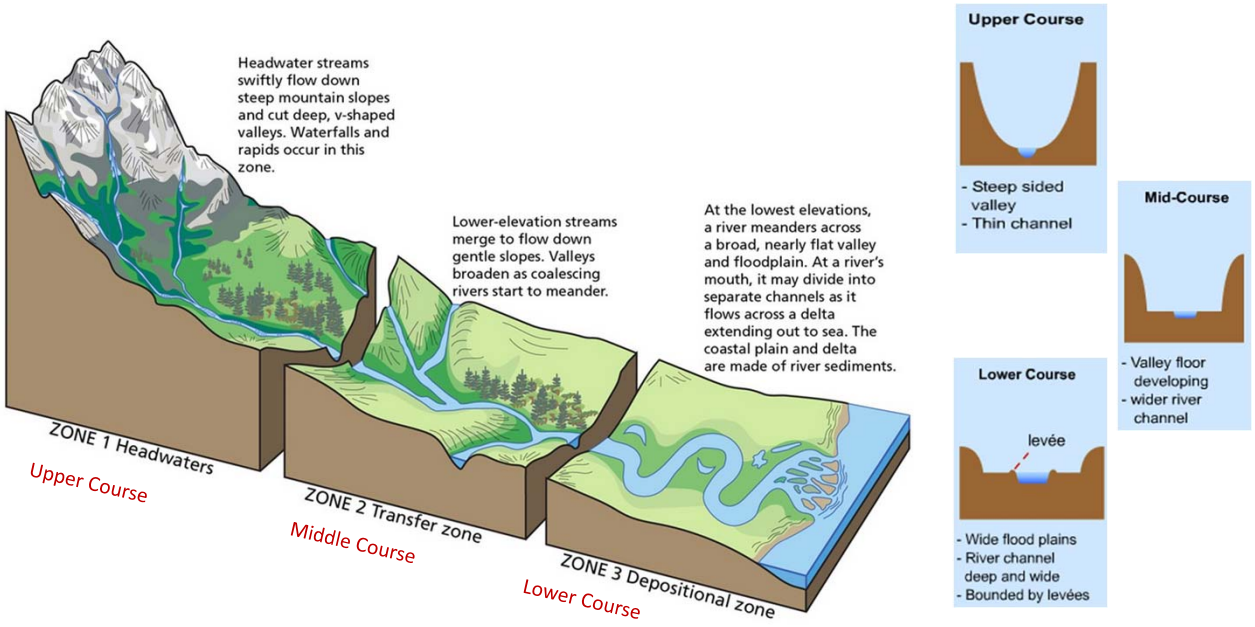


FLUVIAL LANDFORMS

Fluvial Landform

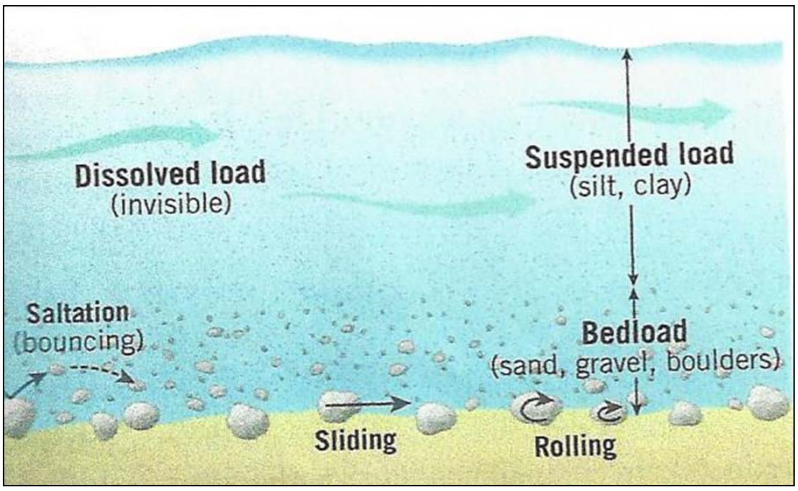
- Open Channel Hydraulics and Downstream Changes:
  - Channel Hydraulics: Stream Discharge, Velocity, Stream Power, etc.
  - Stream Channel Flow and Stream Channel patterns
  - Longitudinal Profile of Stream Channel
- Highways for moving people and goods
- Source of irrigation water for agriculture.
- Source of domestic and industrial water; hydro-electric Power
- Source of natural hazards
- River systems, as part of the hydrologic cycle

Fluvial Landform



Fluvial Landform

Sediments in a River



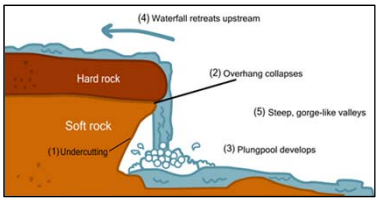
Headwaters (Upper Course):
Bedload

Transfer Zone (Middle Course):
Dissolved + Suspended + Bedload

Depositional Zone (Lower Course):
Dissolved + Suspended

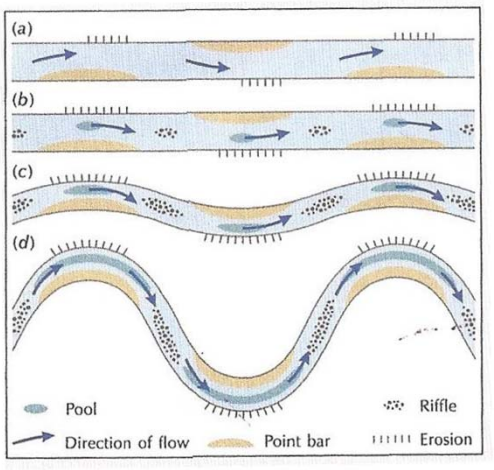
Fluvial Landform: Headwaters

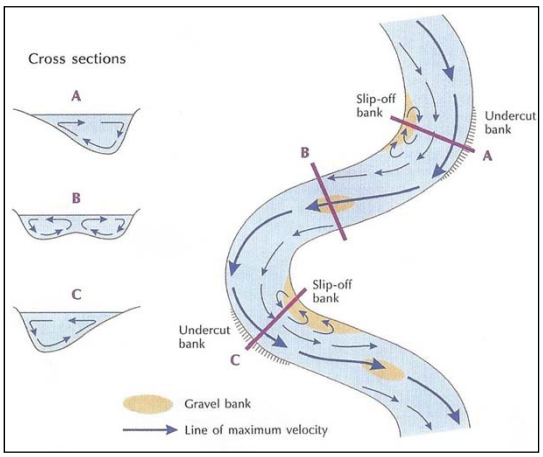
Waterfall; Canyon & Gorge; Underground Caves; Potholes; Rapids



Fluvial Landform: Transfer Zone

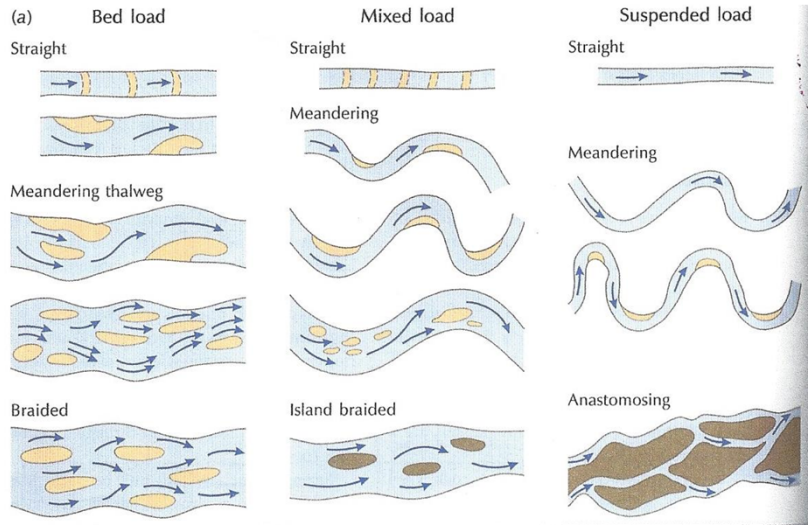
Sinuosity and meandering of a River





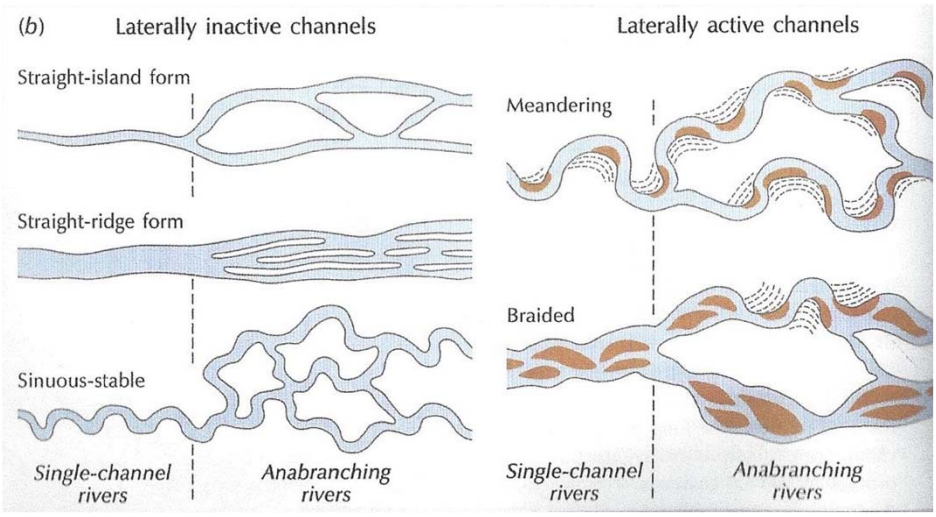
Fluvial Landform: Transfer/Depositional Zones

River Channel Patters

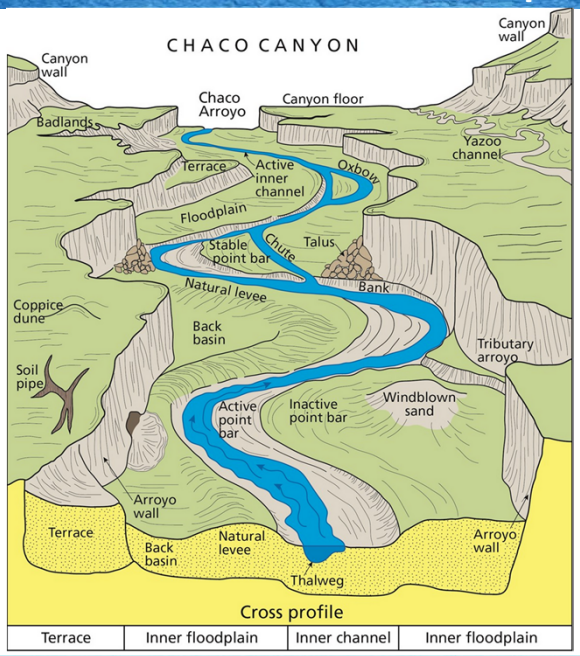


Fluvial Landform: Transfer/Depositional Zones

River Channel Patters



Fluvial Landform: Transfer/Depositional Zones



Fluvial Landform: Depositional Zone

An ***estuary*** is an area where a freshwater river or stream meets the ocean – the mouth of the river. In *estuaries*, the salty ocean mixes with a freshwater *river*, resulting in brackish water. Brackish water is somewhat salty, but not as salty as the ocean. An *estuary* may also be called a bay, lagoon, sound, or slough

Fluvial Landform: Delta

Deltas are wetlands that form as *rivers* empty their water and sediment into another body of water (generally Ocean, sometimes lake or another river).

Fluvial Landform: Delta

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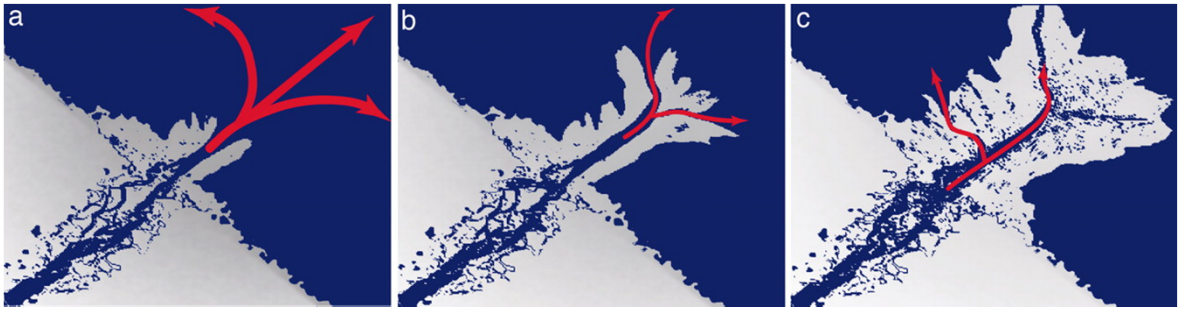

Seybold et al., 2007, PNAS

Next Lecture

Weathering & Erosion