EESC 2200
The Solid Earth System

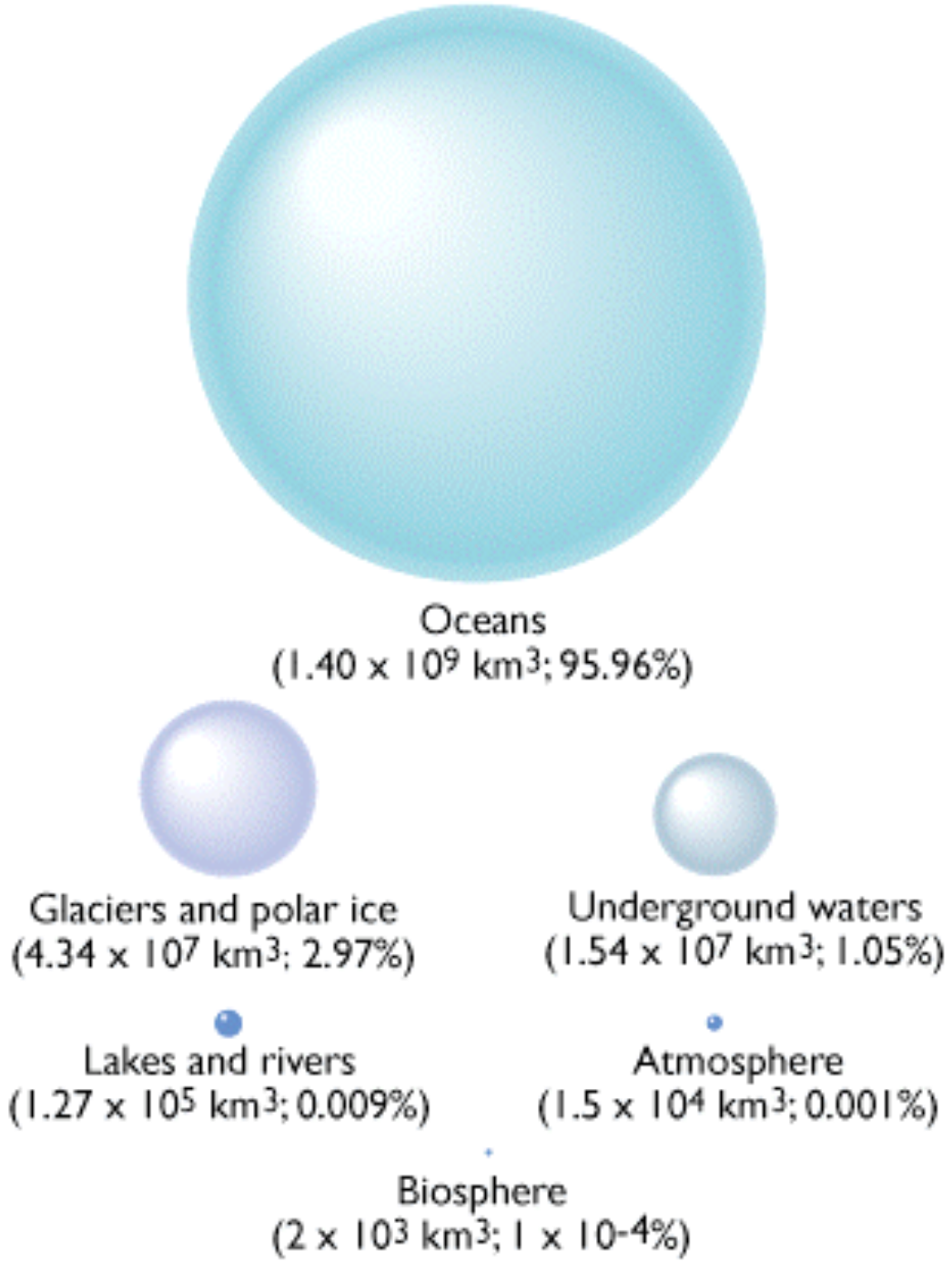
Homework 3:
Due Wednesday

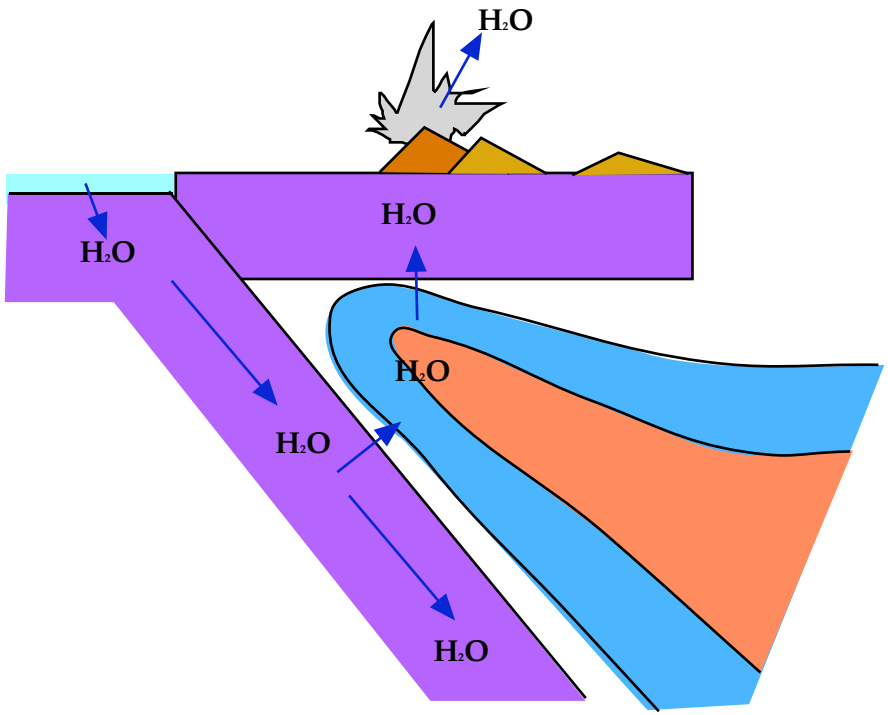
Rain & Streams

6 Oct 08

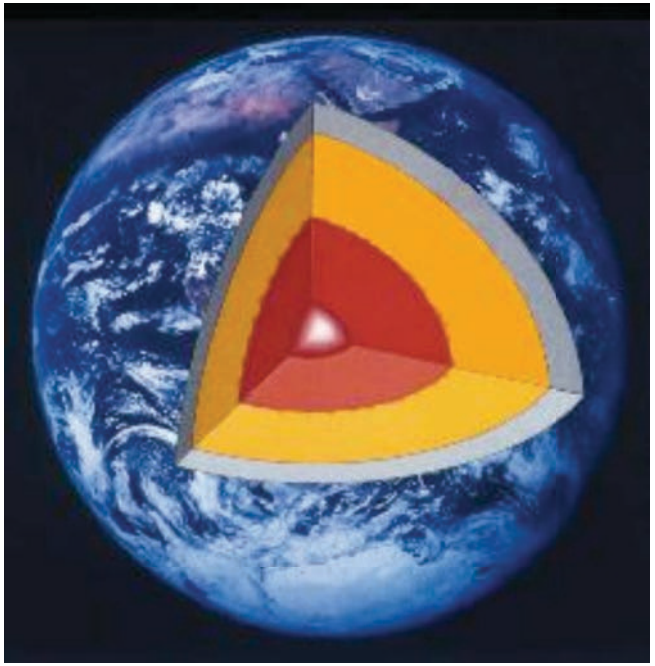
Global Near-surface Water Budget

What about the solid Earth??





Return of Water to Mantle



100 -1000 ppm H_2O in mantle

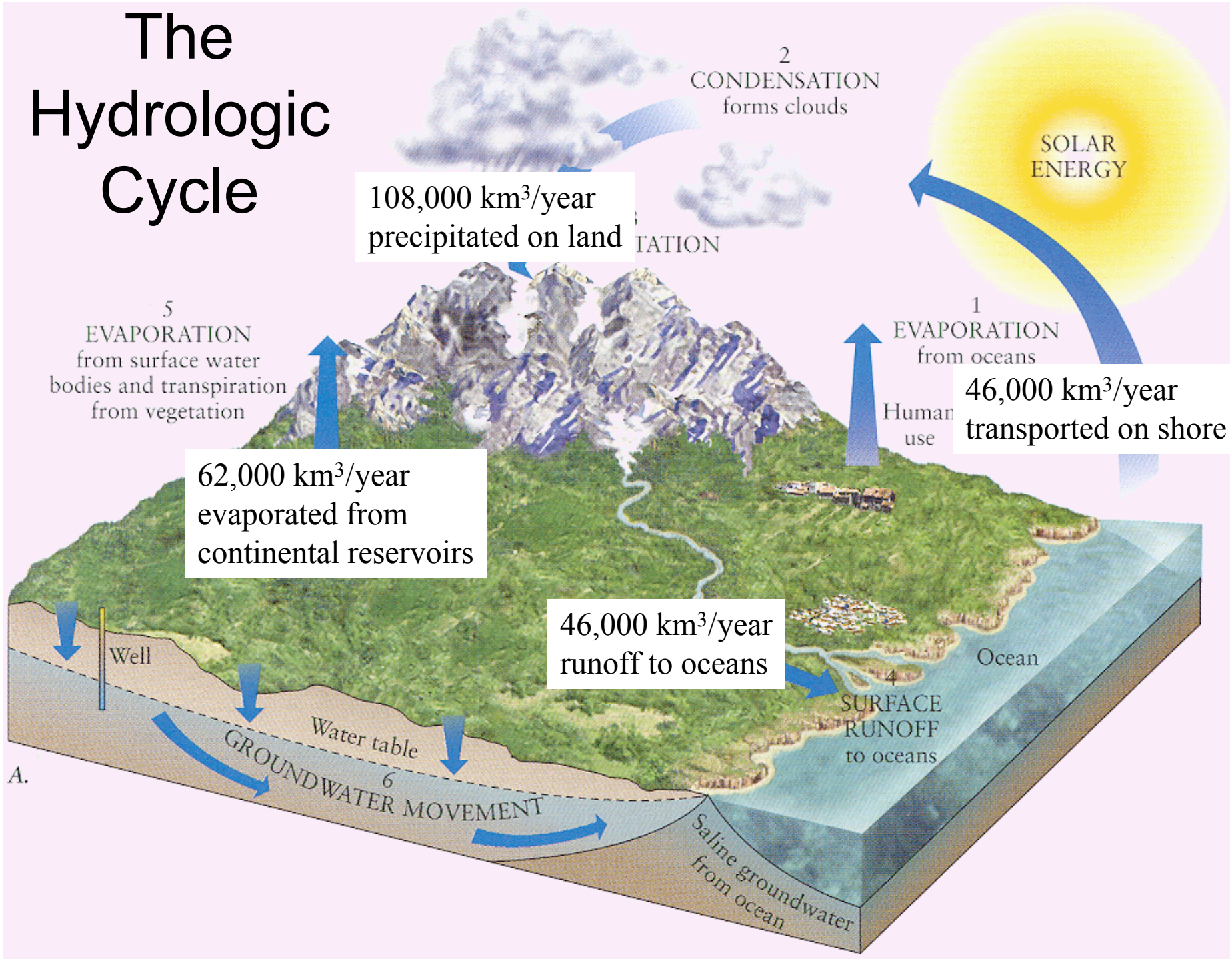
4×10^{27} g mantle

$4 \times 10^{23\text{-}24}$ g H_2O in mantle

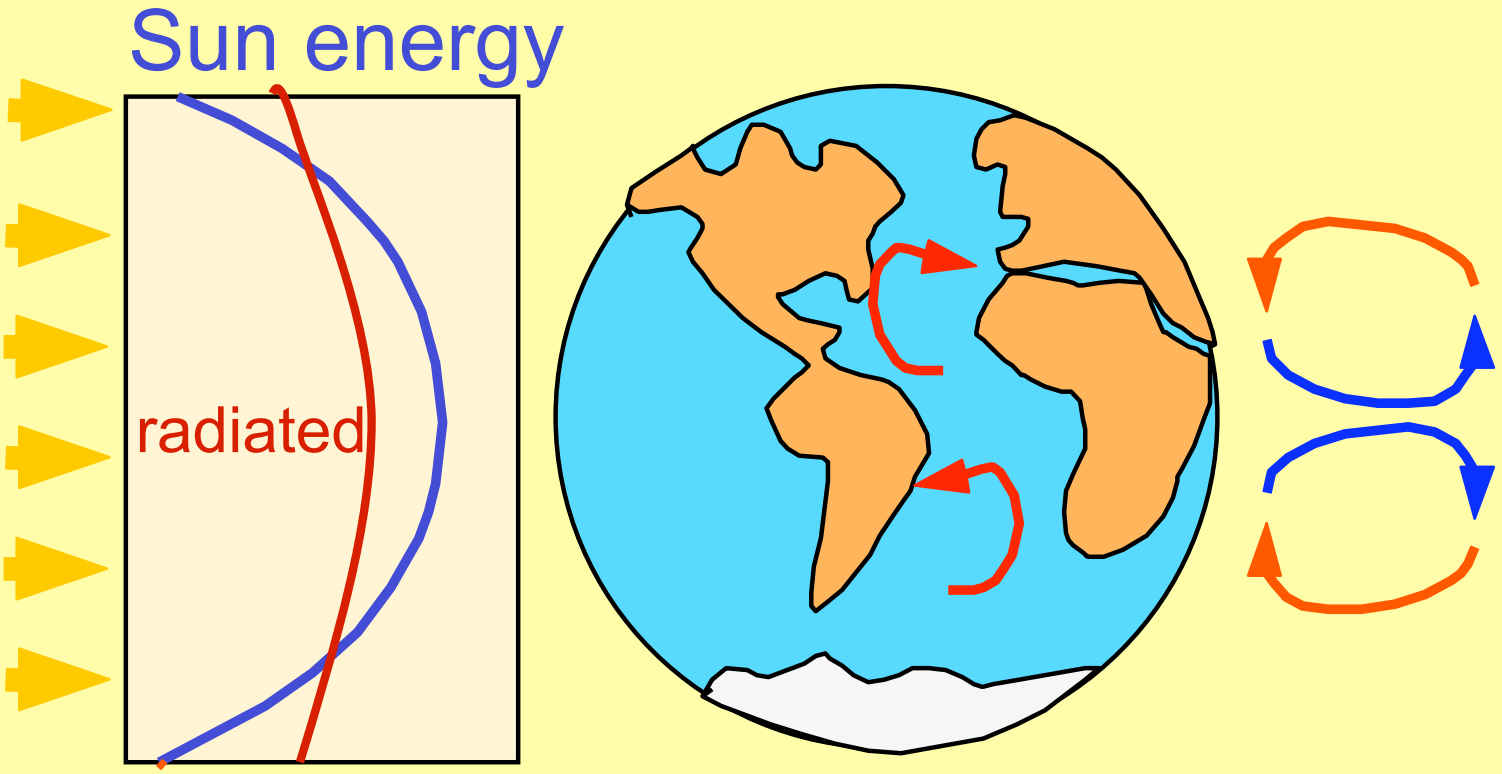
1.4×10^{24} g H_2O in ocean

0.5 - 3 oceans in mantle!

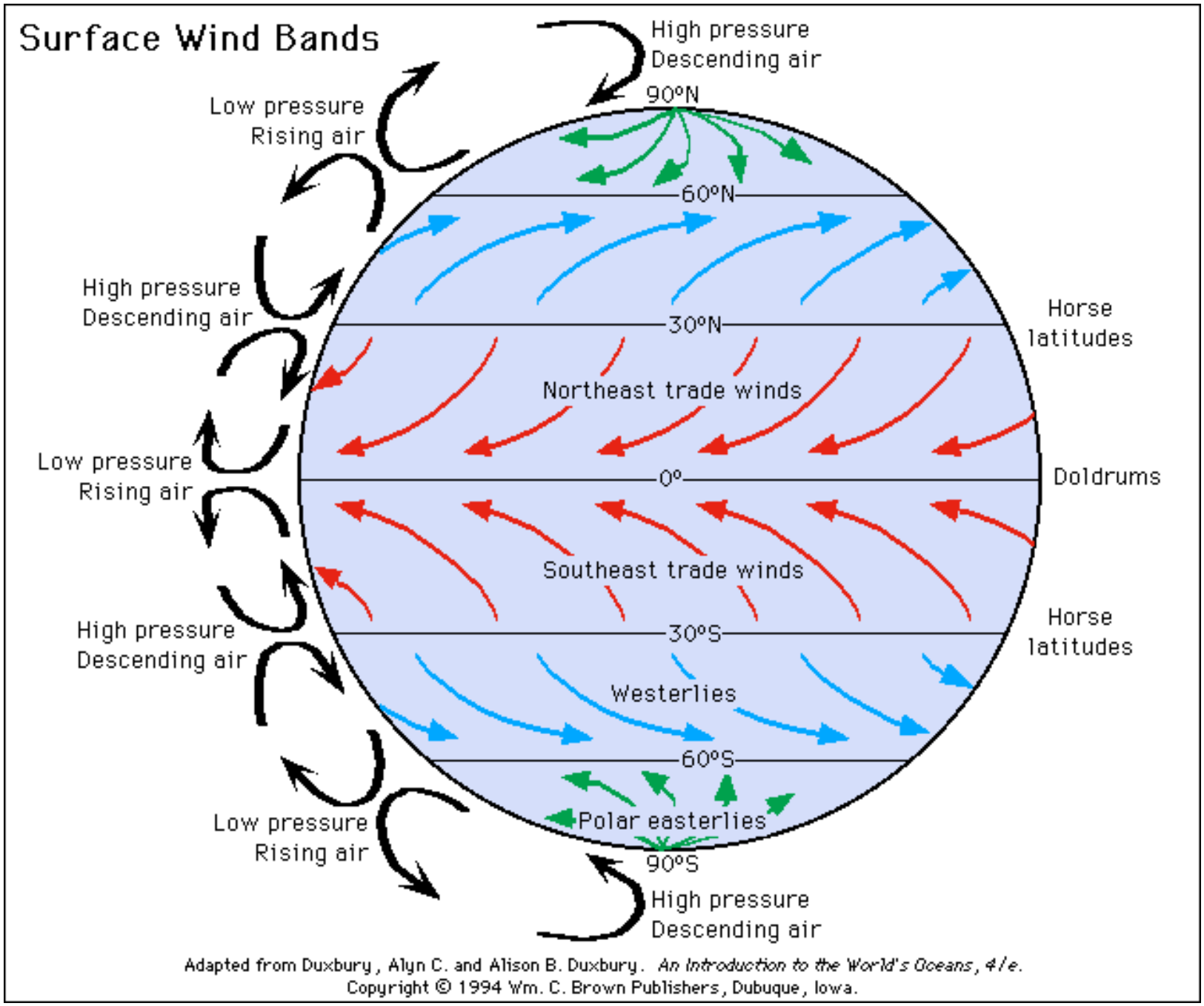
The Hydrologic Cycle



What drives wind?

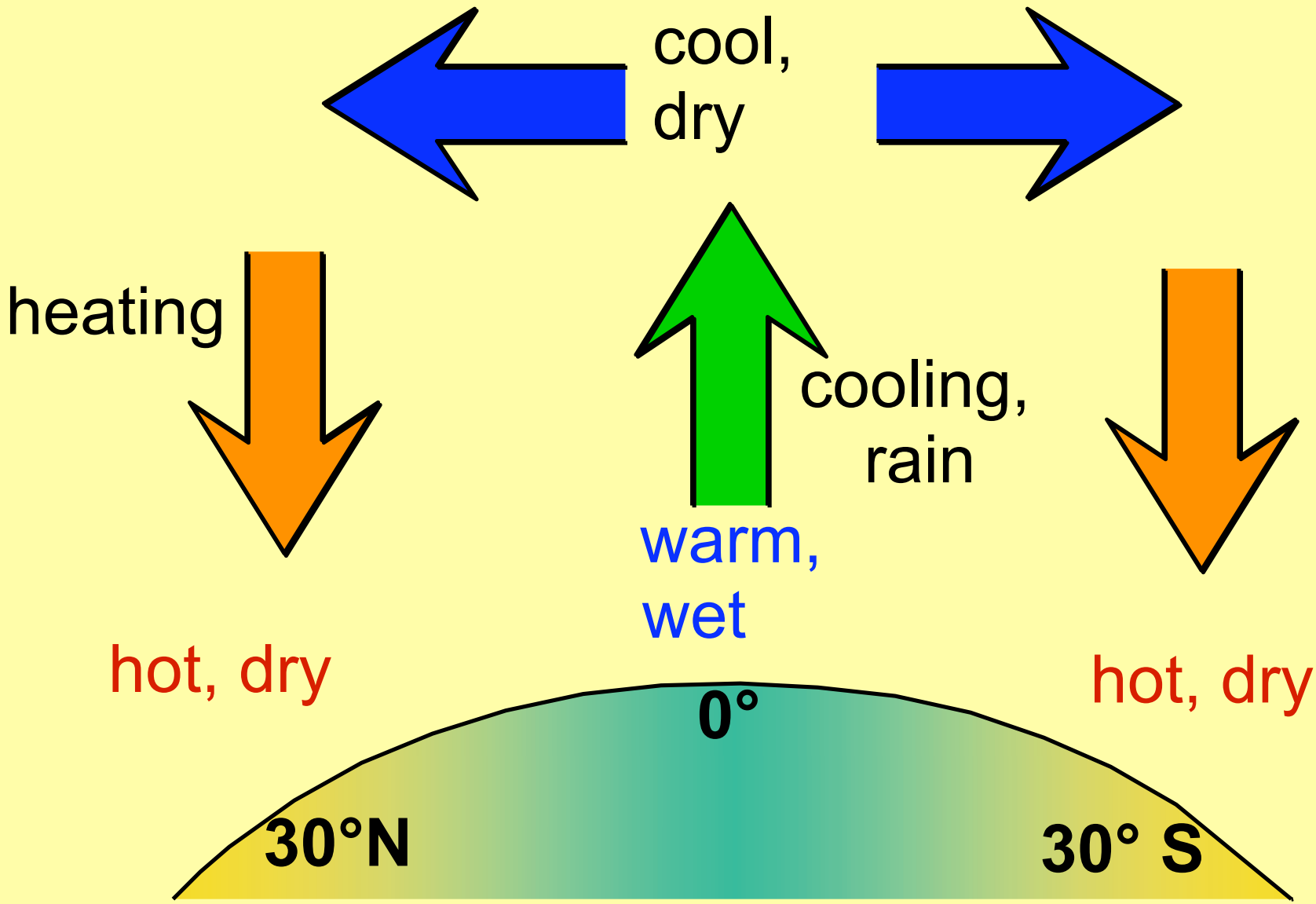


hottest at equator + Coriolis "force" Global circulation

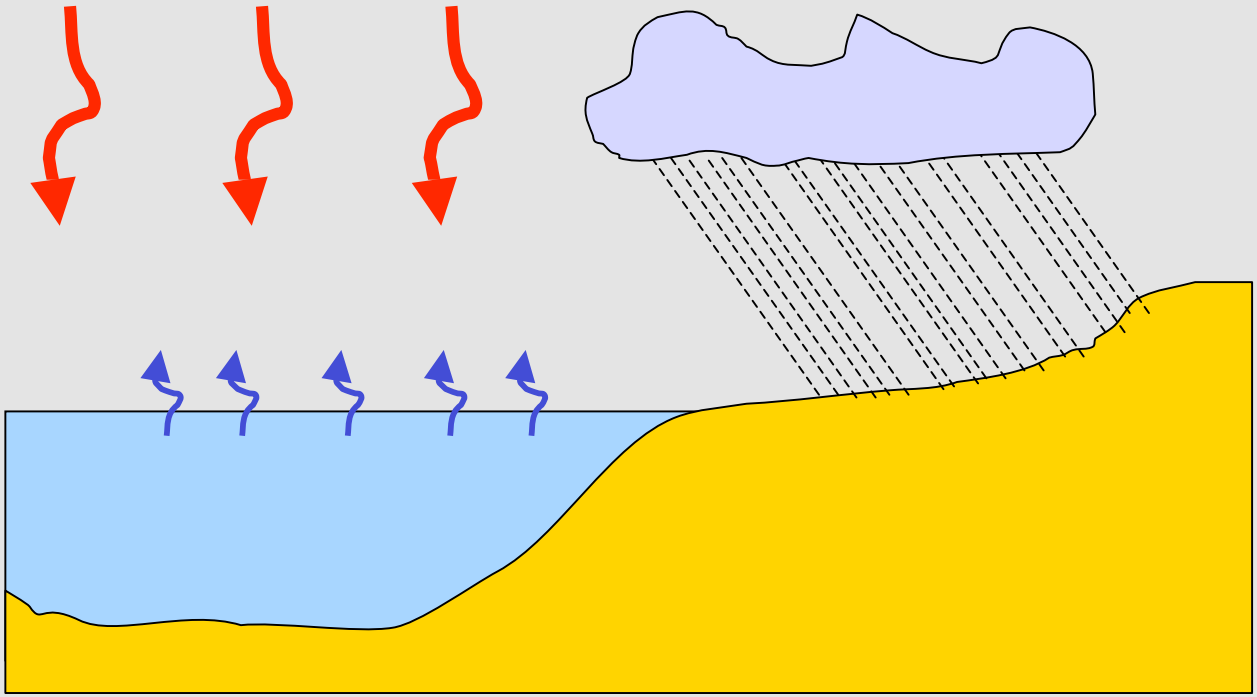


Adapted from Duxbury, Alyn C. and Alison B. Duxbury. *An Introduction to the World's Oceans, 4/e.*

Vertical Circulation



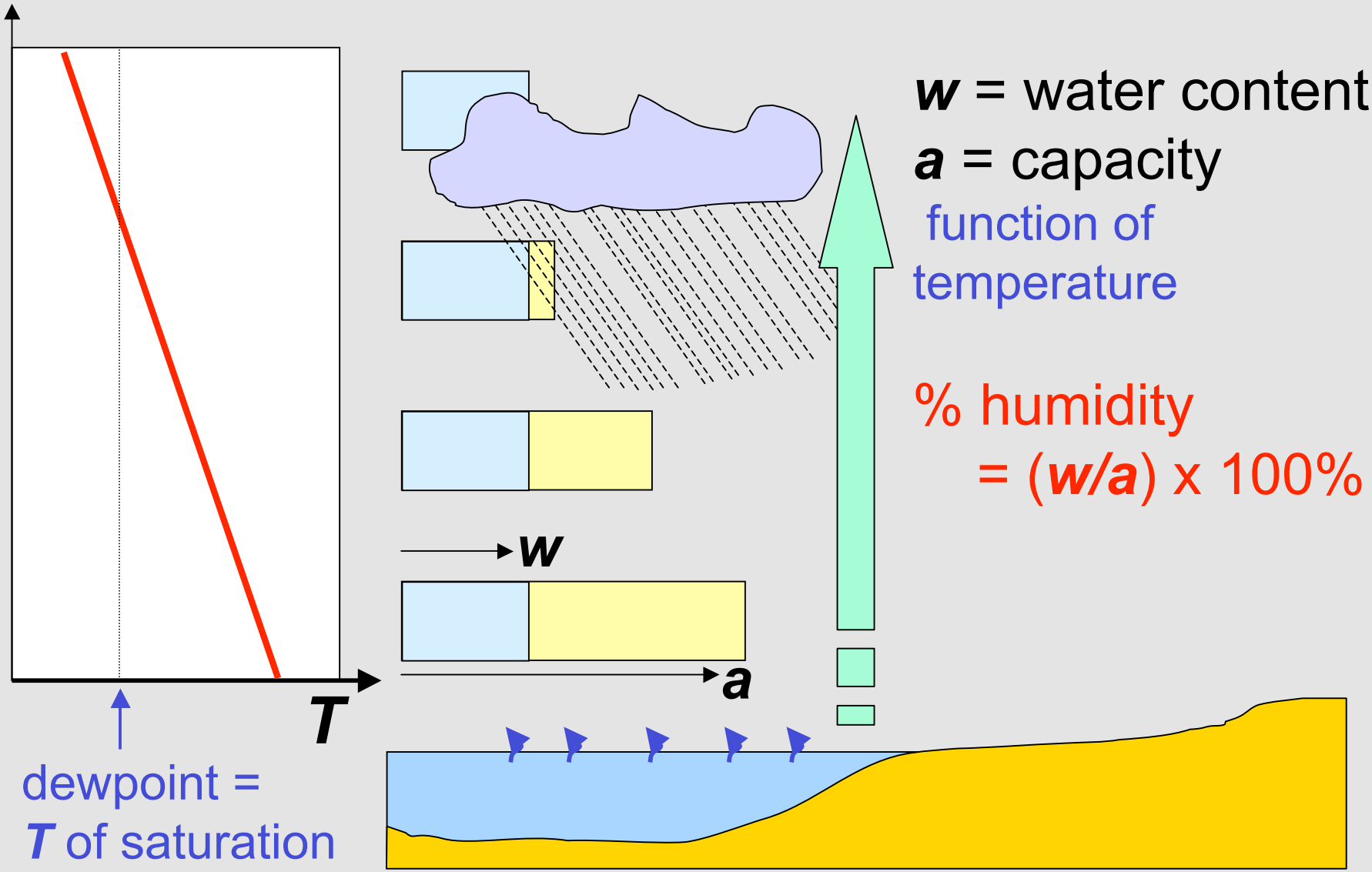
Latent Heat



- **Evaporation** absorbs heat
- **Condensation** releases heat

*H_2O in atmosphere stores **latent heat***

Saturation of ascending air



w = water content

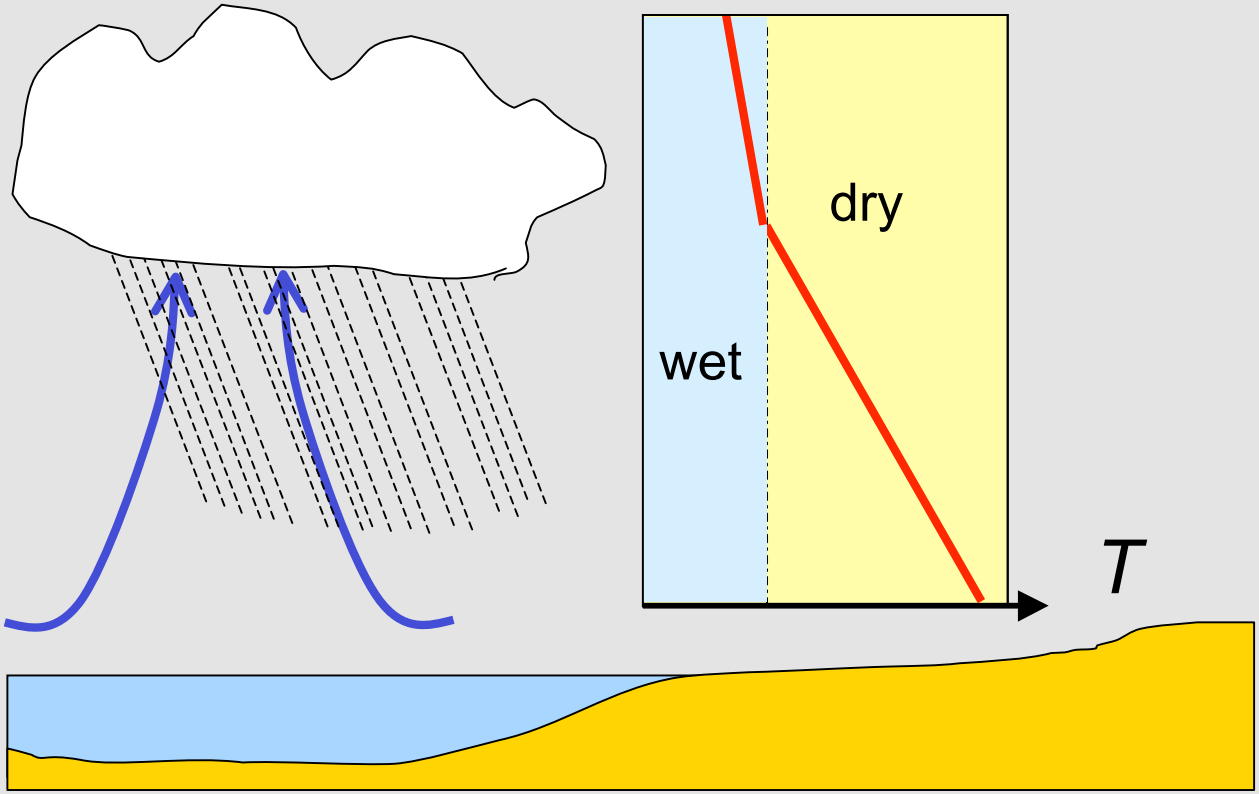
a = capacity

function of temperature

% humidity

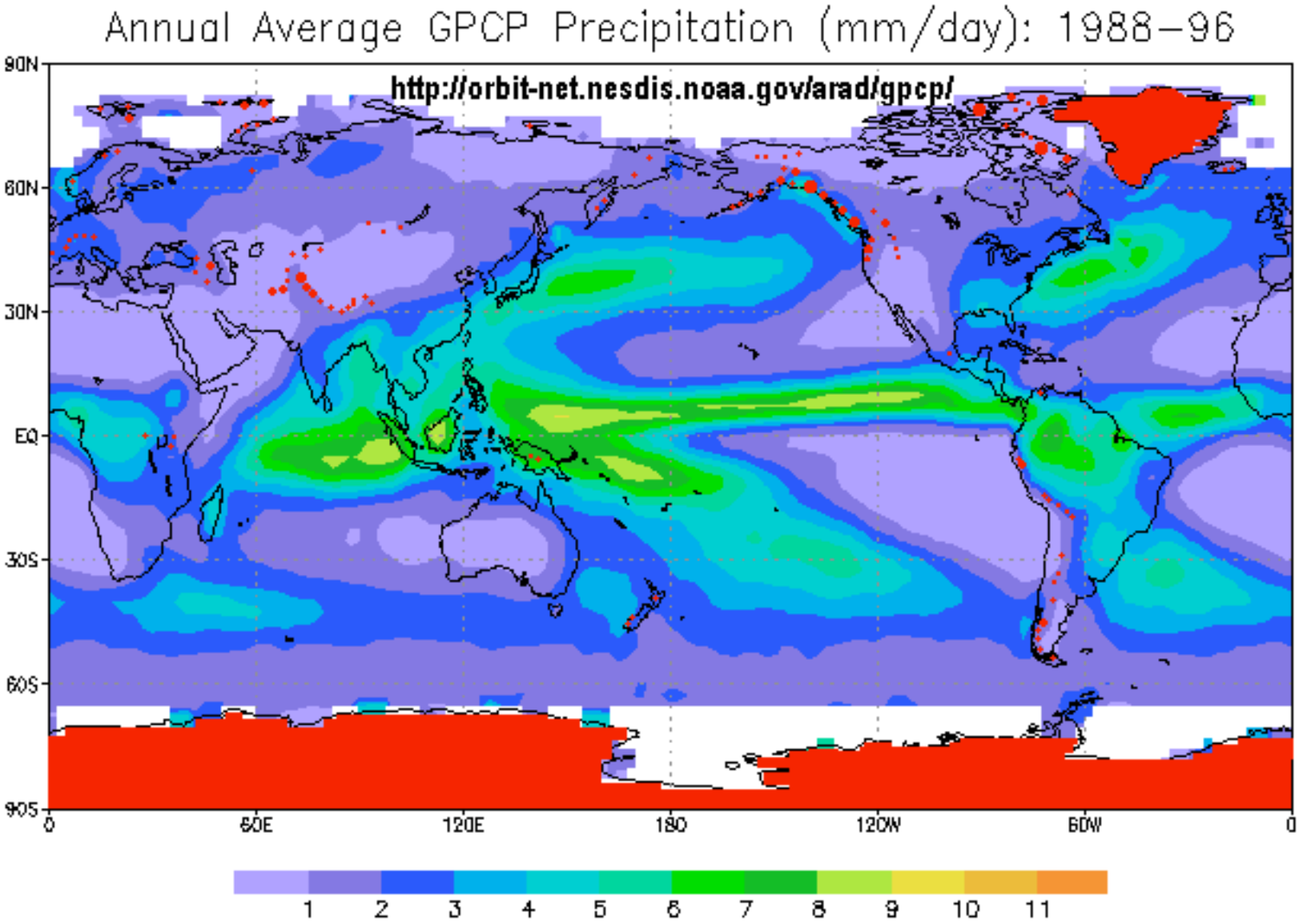
= (***w/a***) x 100%

Adiabatic Uplift

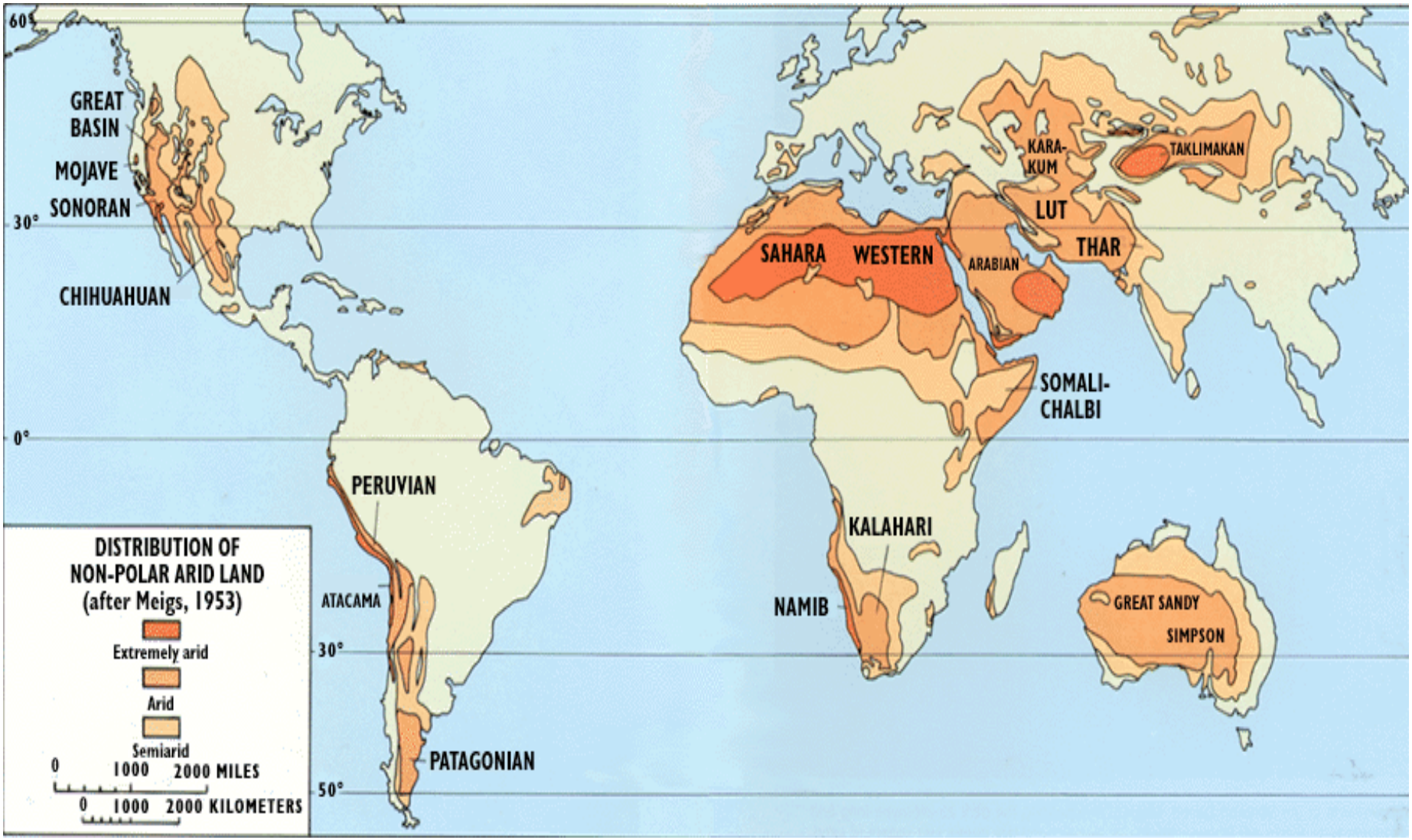


- As air rises, it expands
- Conserve energy: temperature drops

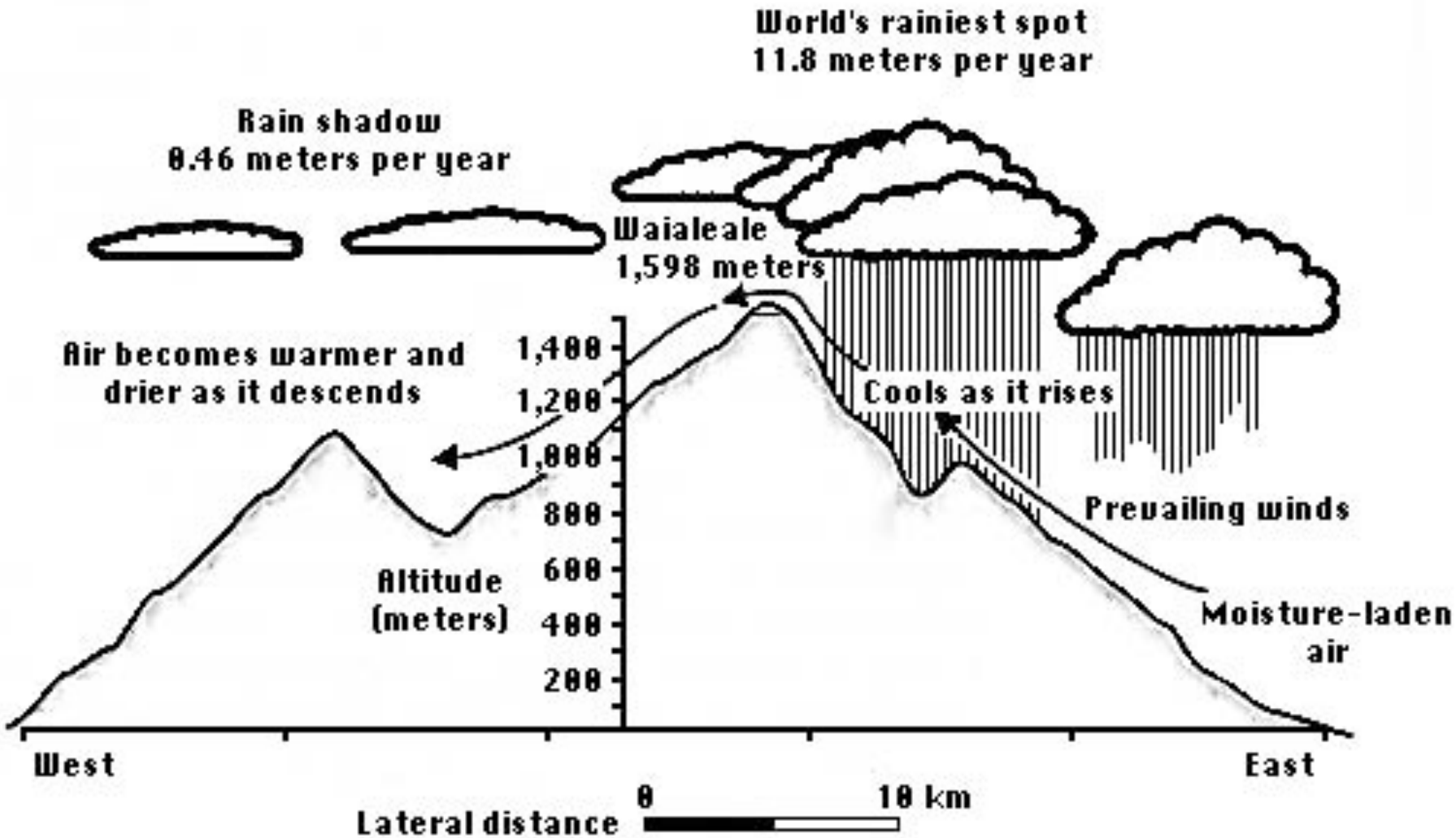
H_2O released when cools to saturation


Annual Average GPCP Precipitation (mm/day): 1988–96
http://orbit-net.nesdis.noaa.gov/arad/gpcp/
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
1
2
3
4
5
6
7
8
9
10
11

World's Deserts

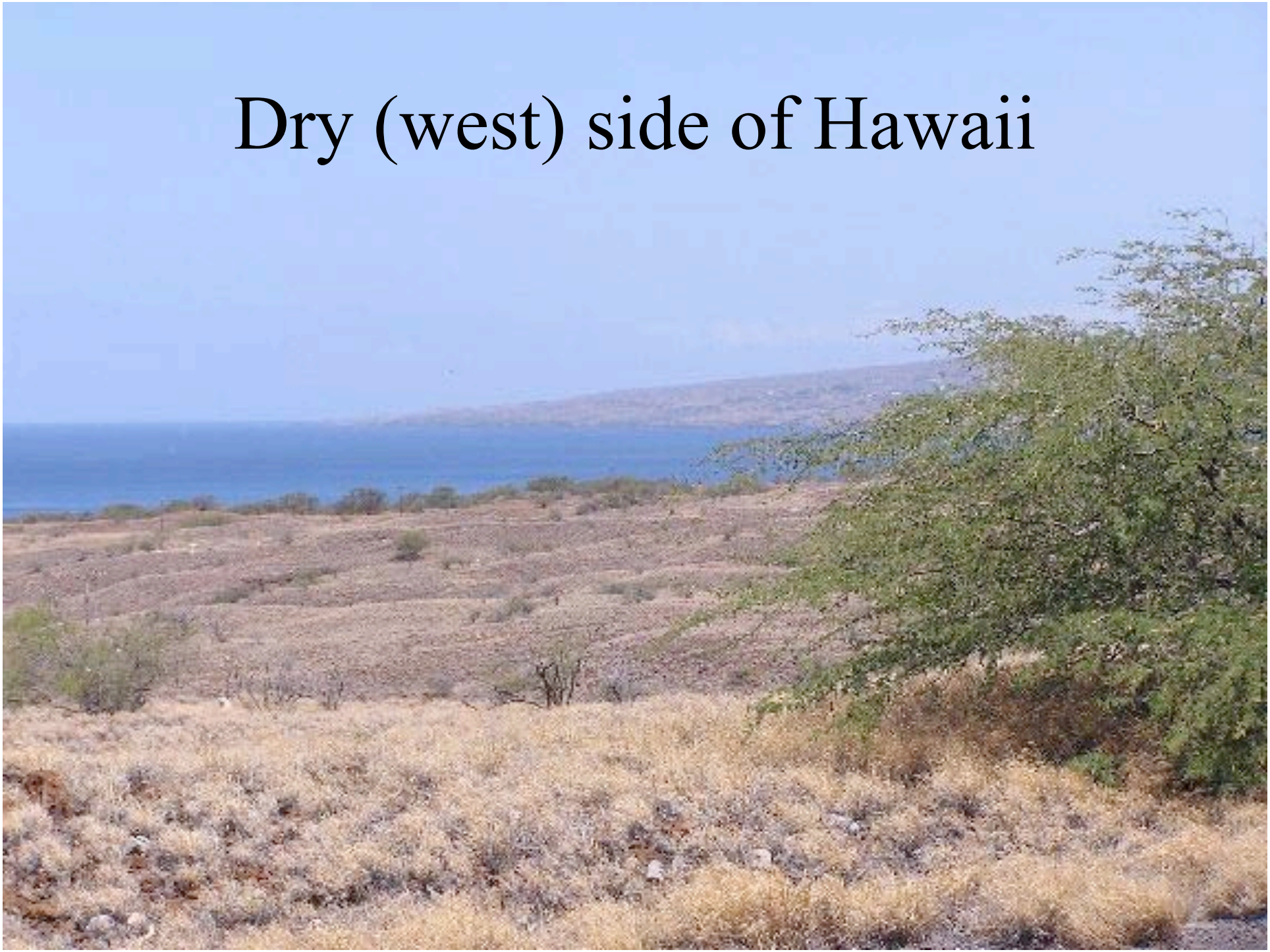


Rain shadow effect (Hawaii)

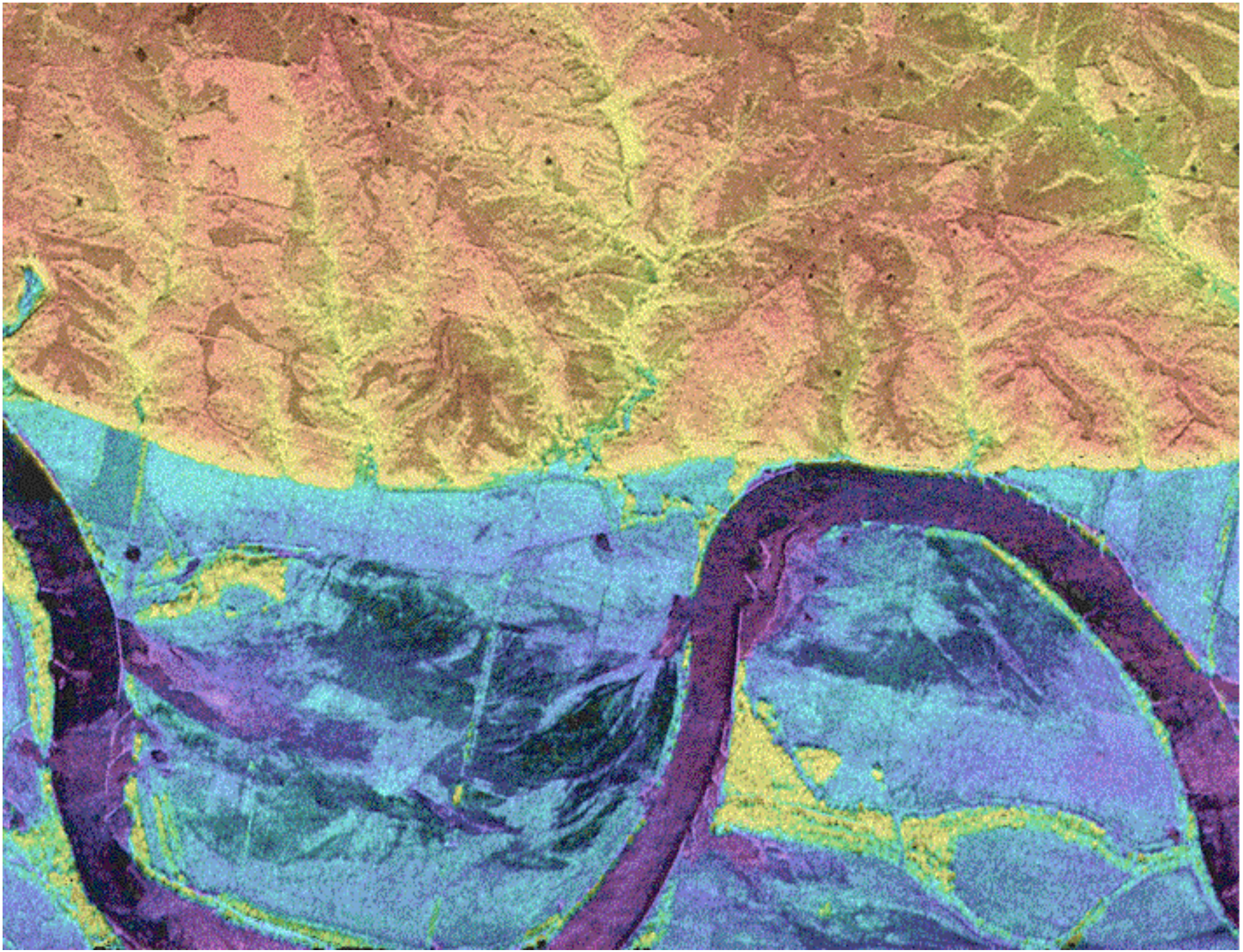


Wet (East) side of Hawaii

Dry (west) side of Hawaii



Streams:
The Geology of Running Water



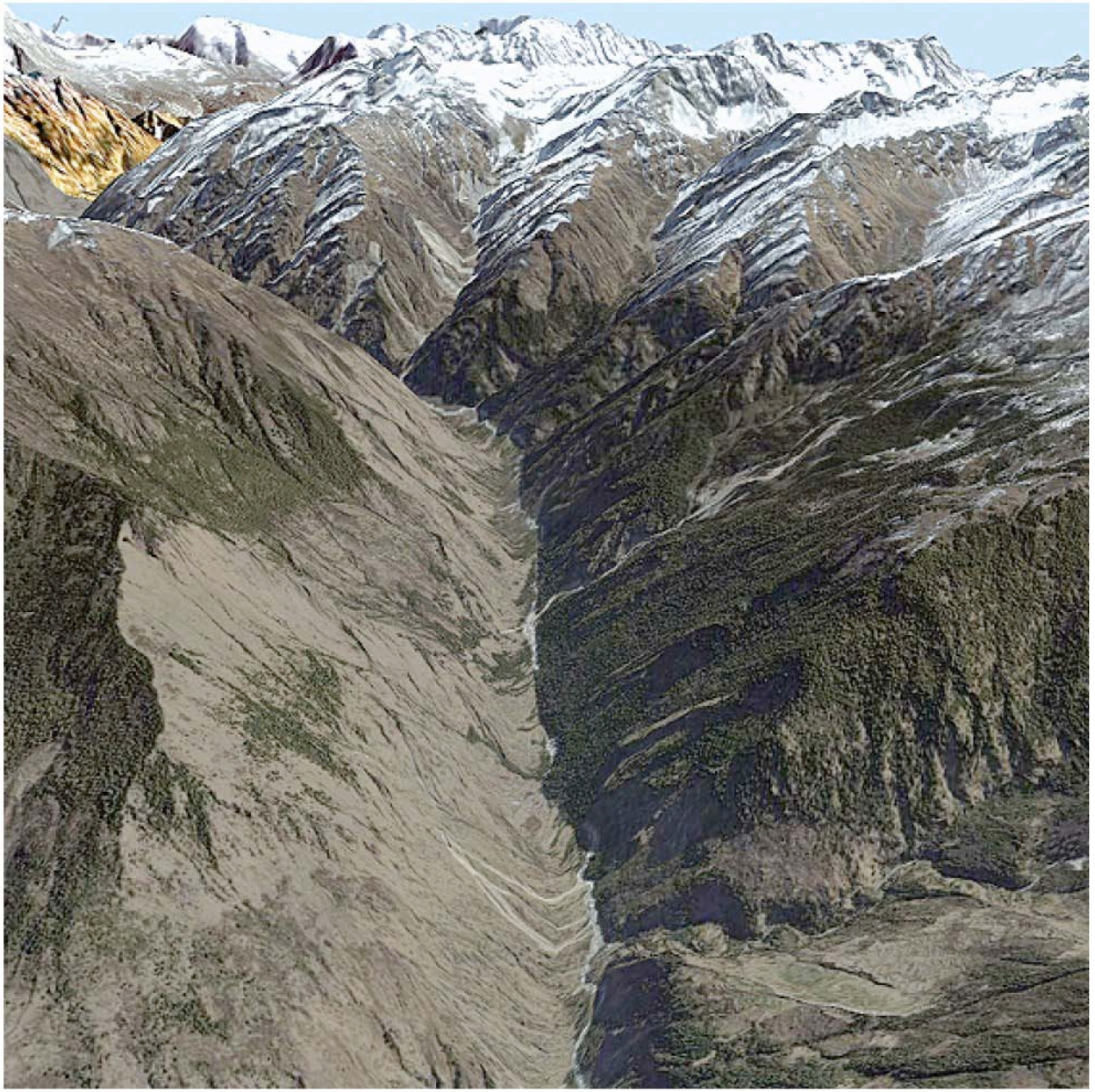


Figure G17-1 Earth: Portrait of a Planet 3/e
Images provided by Google Earth™ mapping service/DigitalGlobe, TerraMetrics, NASA, Europa Technologies—copyright 2008.

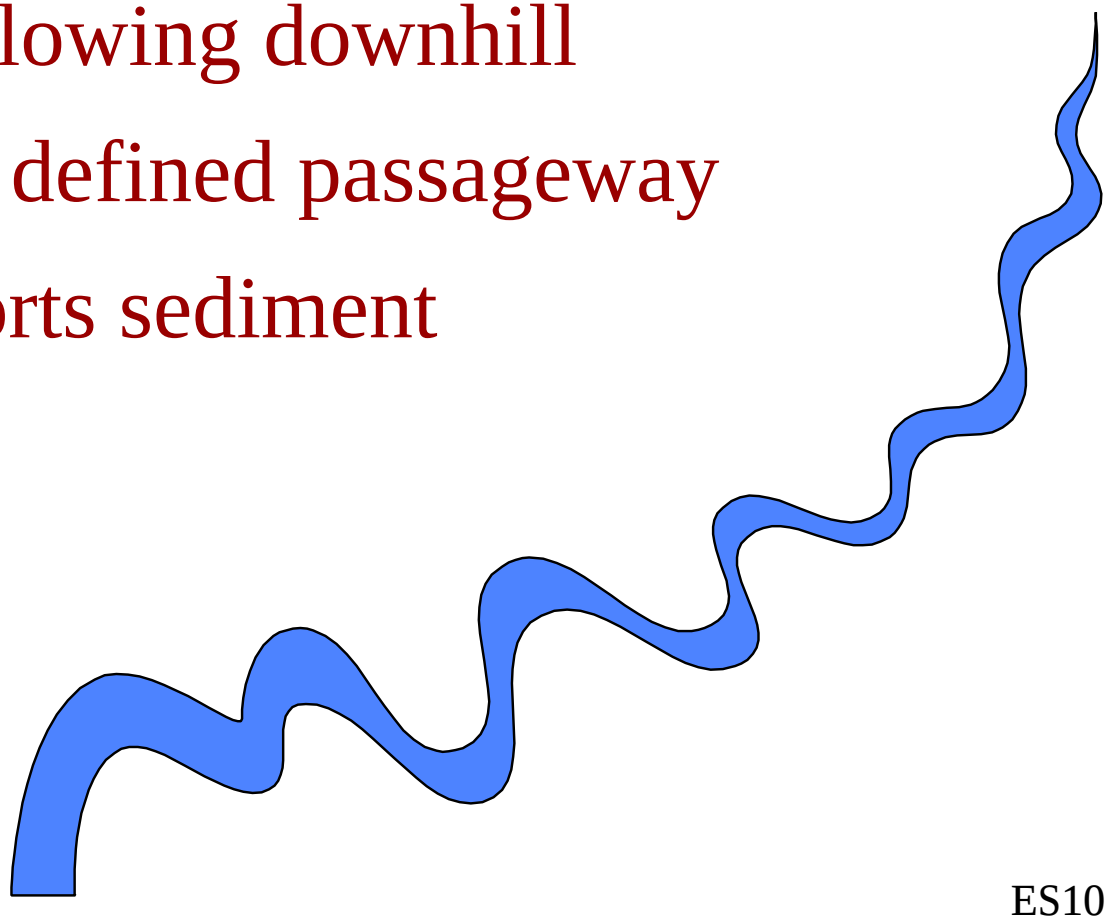
Streams are vital geologic agents

- They carry most of the water that goes from land to sea
- They transport billions of tons of sediment to the ocean each year
- They transport billions of tons of soluble salts to the oceans each year
- They shape the surface of the Earth

A stream

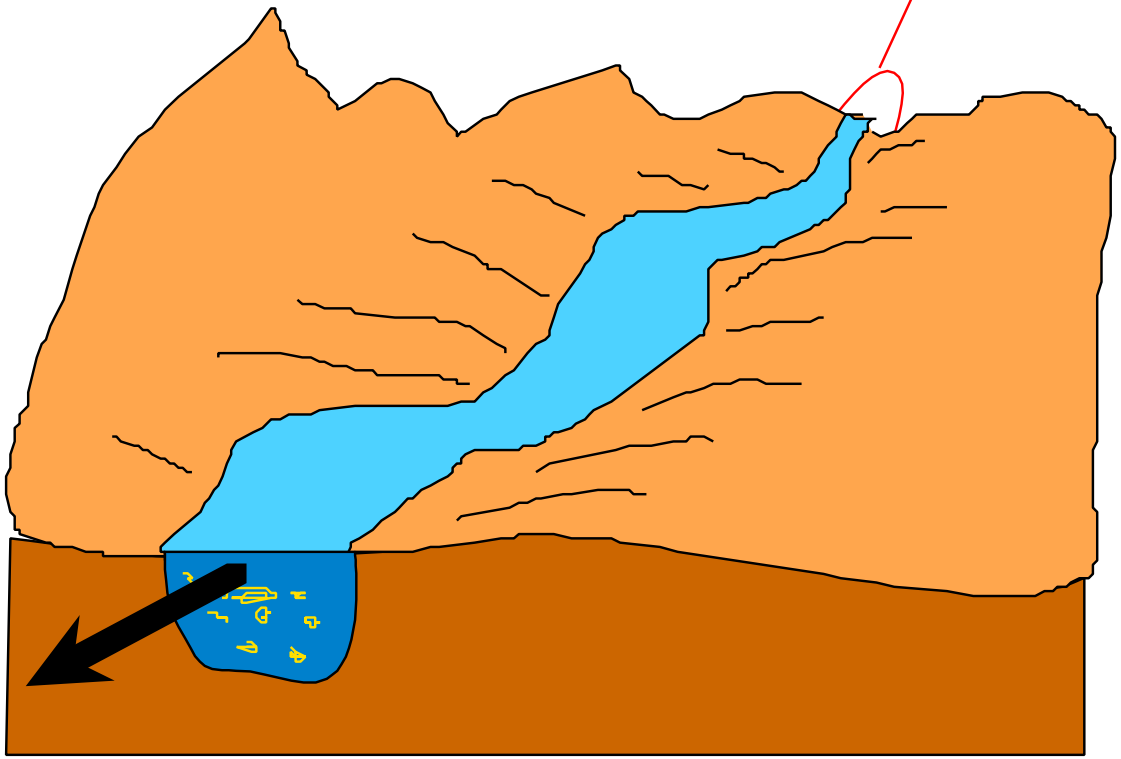
Geologist's Definition:

- water flowing downhill
- clearly defined passageway
- transports sediment
- natural

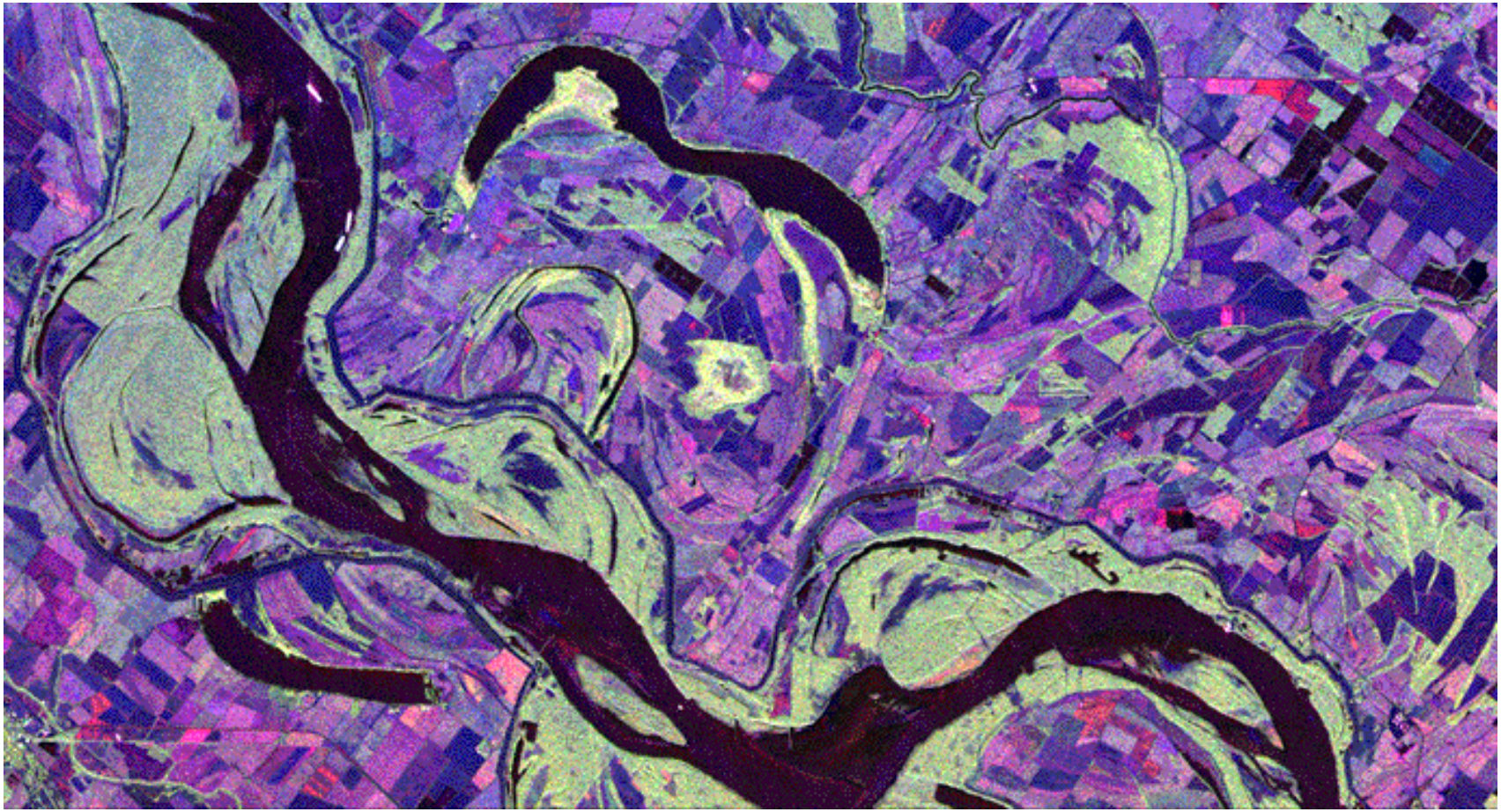


Anatomy of a Stream

passageway = **channel**



The Lower Mississippi floodplain



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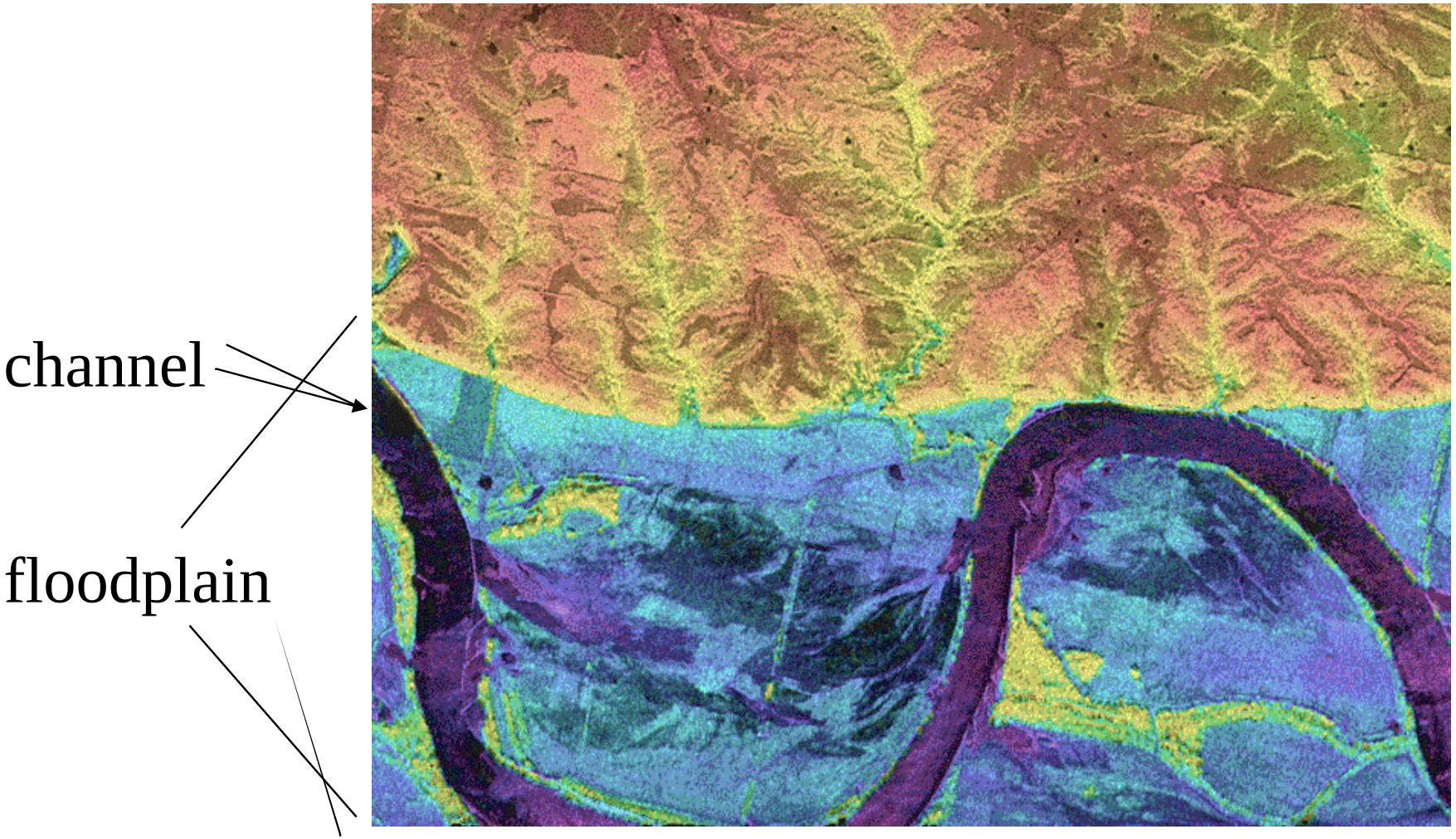
Flood Plain



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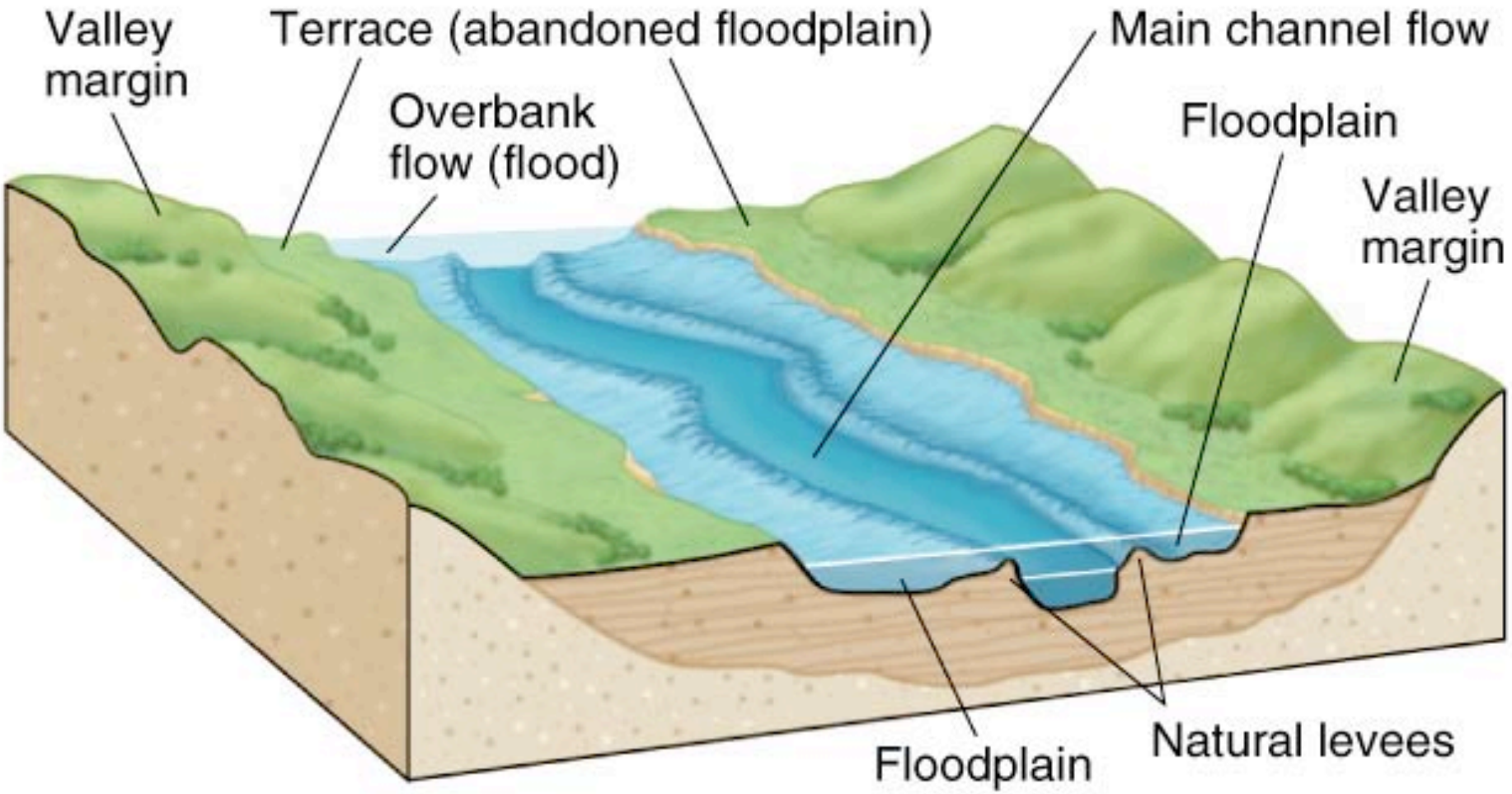
Main features of an alluvial valley



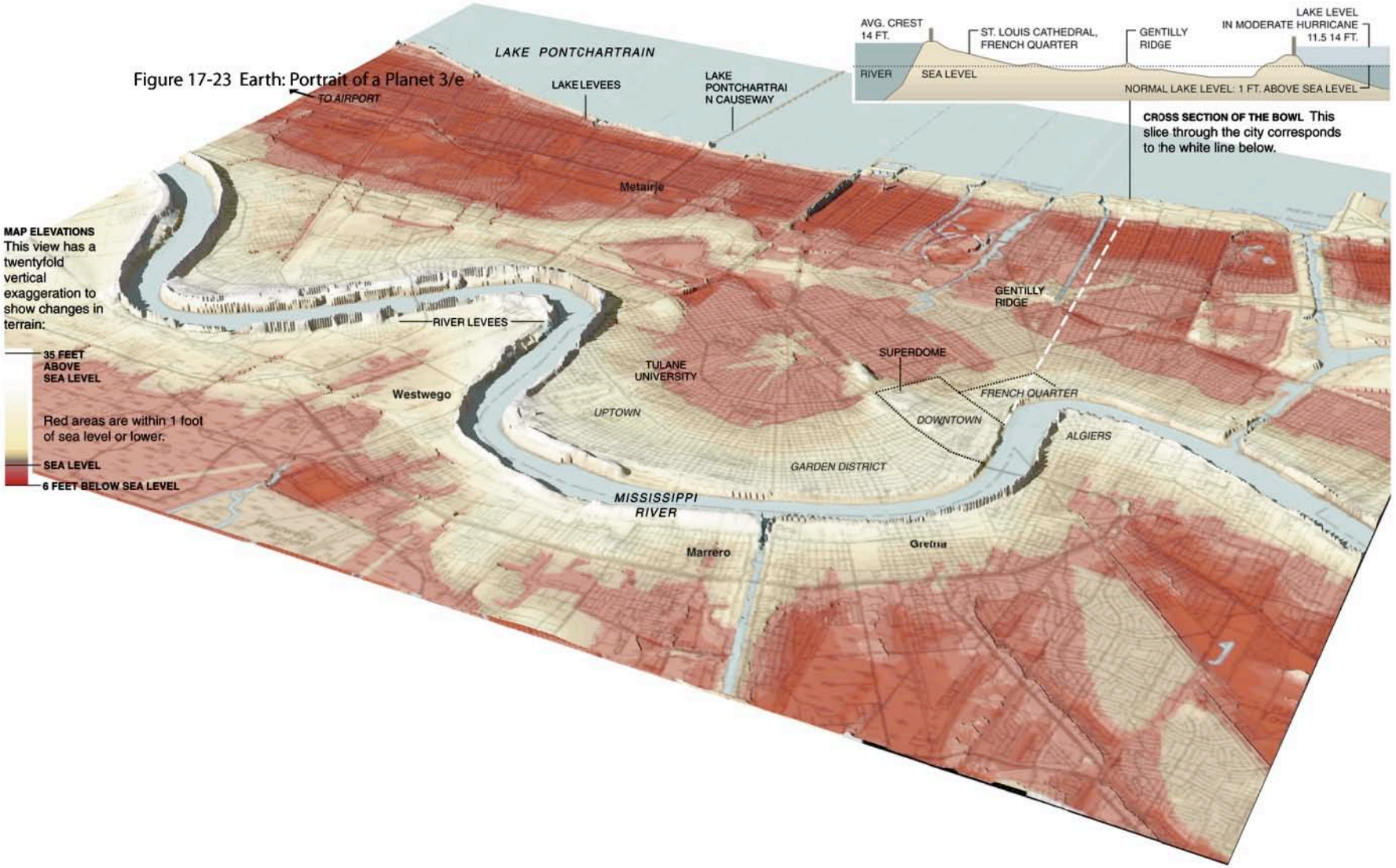
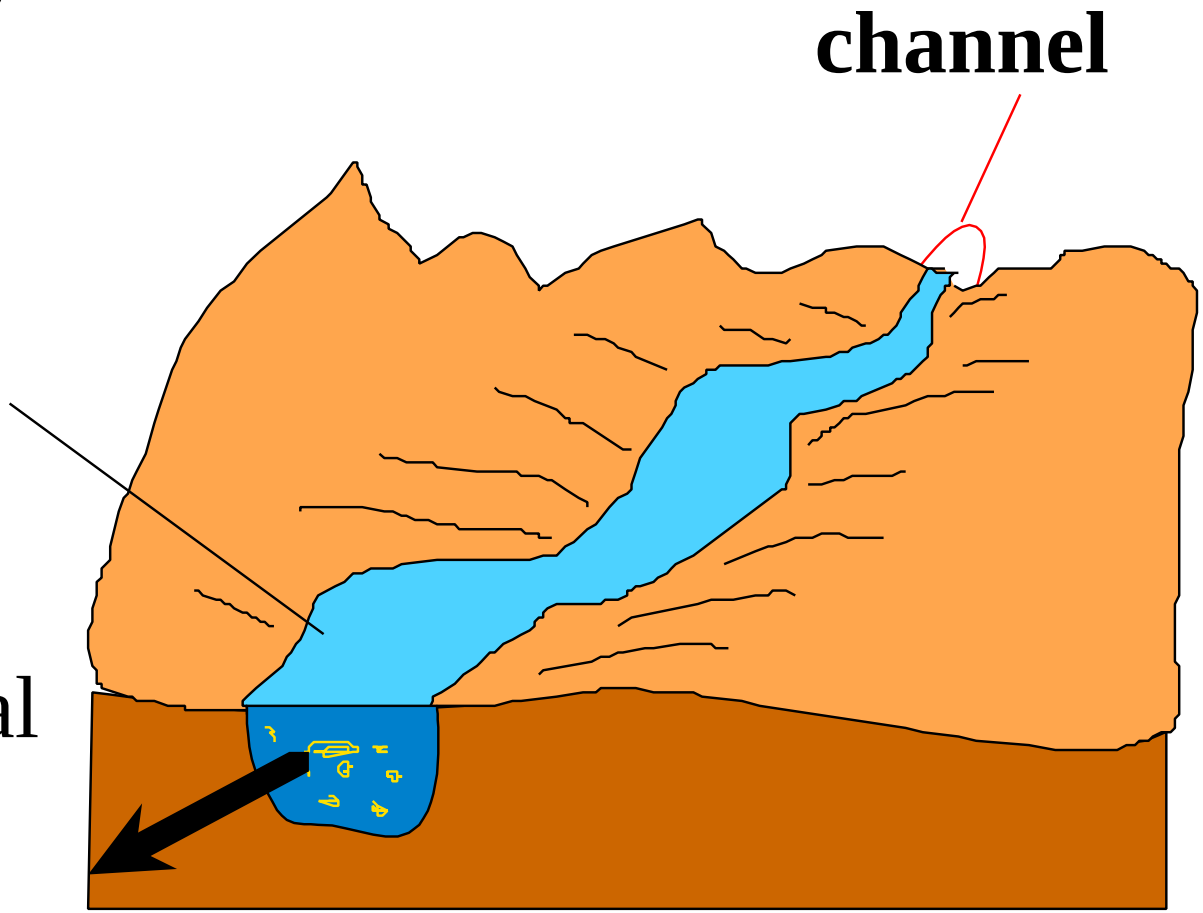


Figure 17-23 Earth: Portrait of a Planet 3/e
New York Times Graphics

Anatomy of a Stream



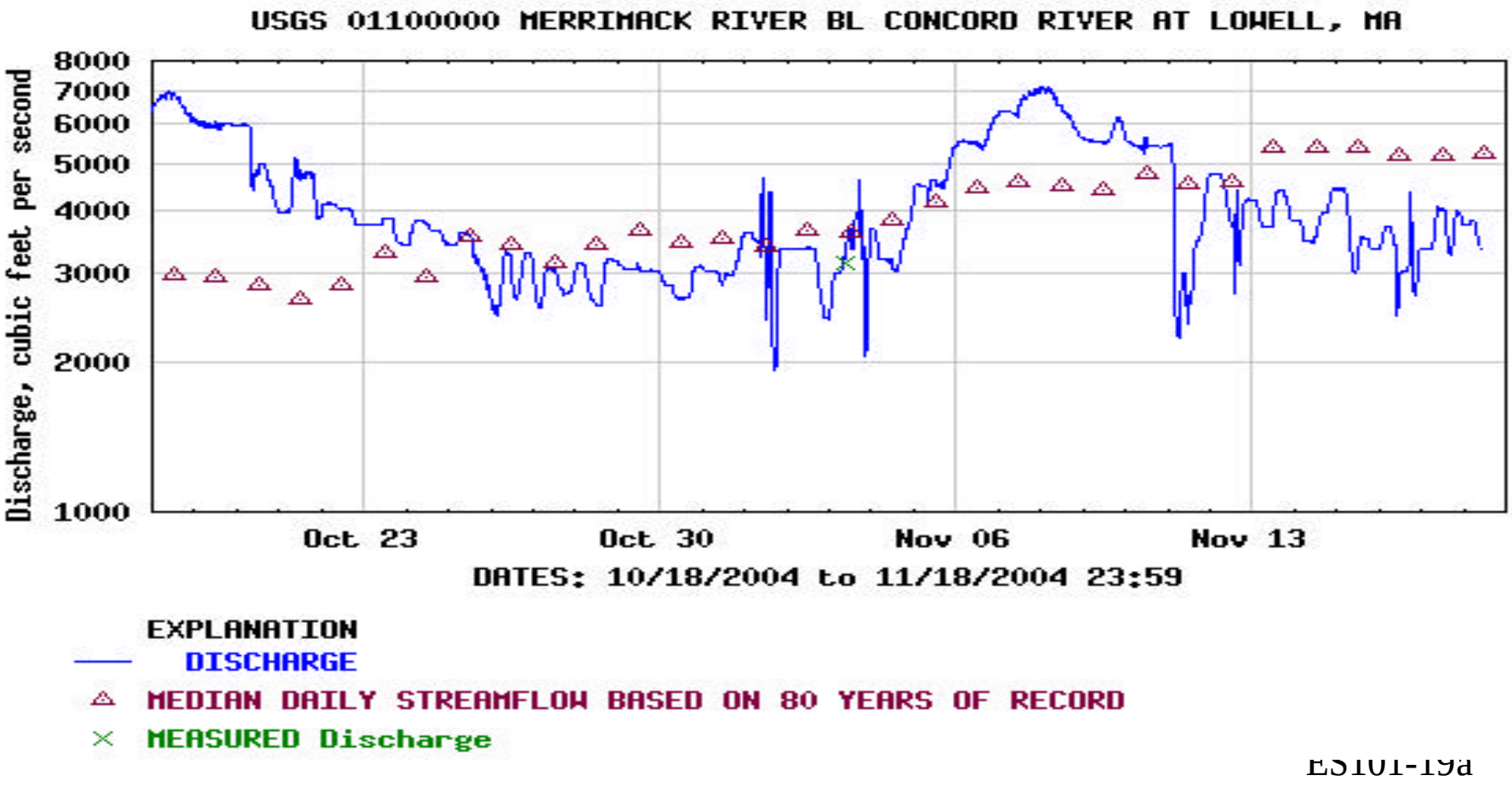
water discharge

= volume flow per time interval (m^3/s)

Discharge measurements made during floods are used to develop stage-discharge relations at each gaging station. (Photograph, Lawrence Journal World, Lawrence, Kans.)

Most USGS stream-gaging stations transmit river stage and other water information directly to geostationary satellites and on to a national hydrologic data network that disseminates information to cooperating agencies and to the public throught the Internet.

Discharge of Merrimack River



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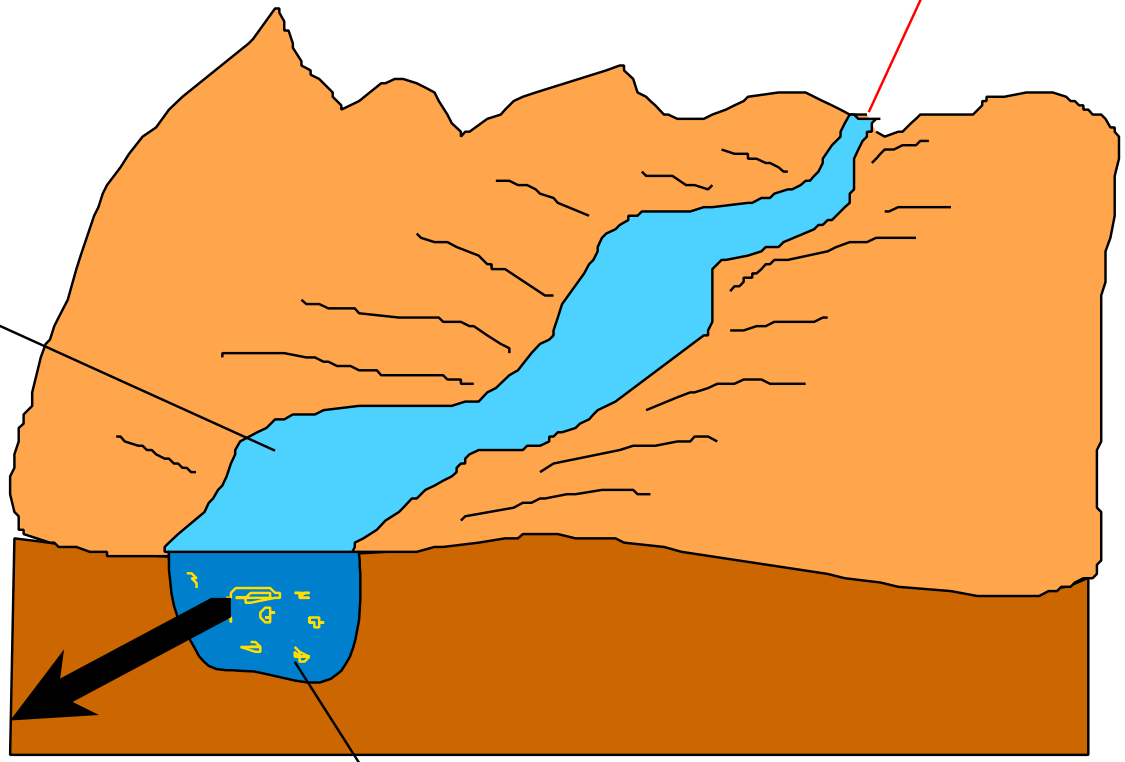
Anatomy of a Stream



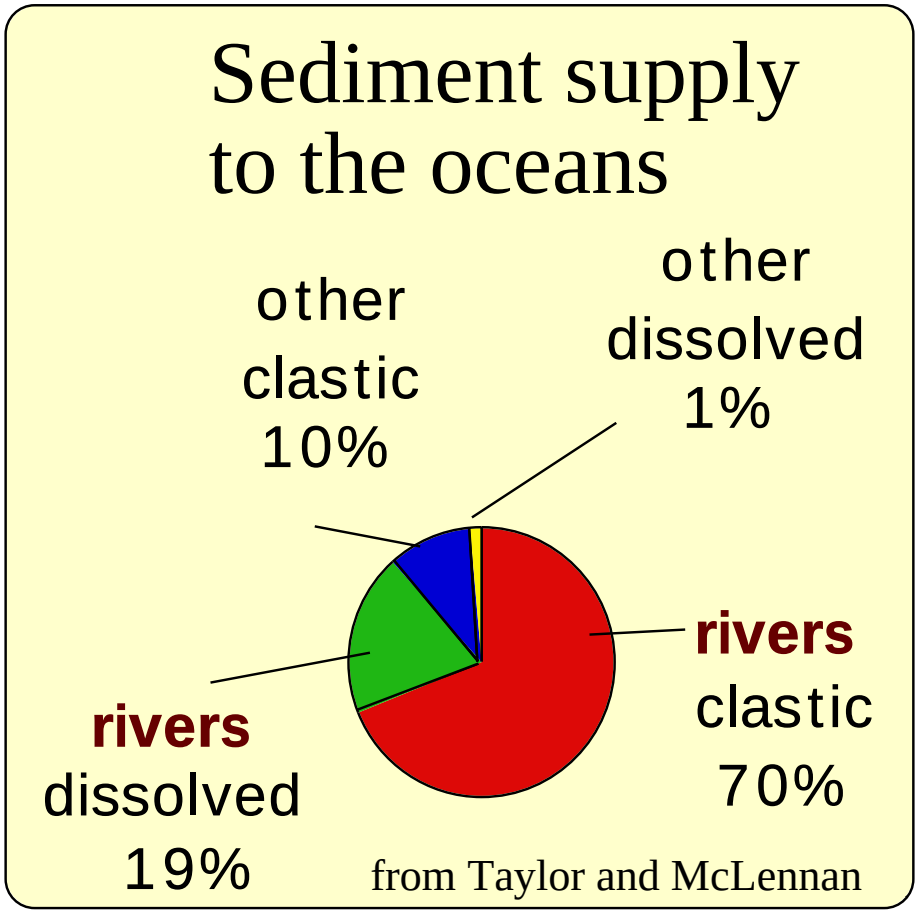
= solids and dissolved matter transported

** Future sediments?*

Discharge includes

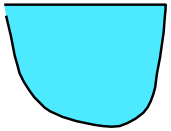
- most of Ocean's water supply (~90%)

The load includes

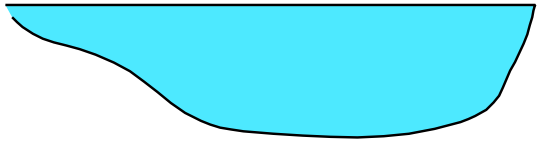


In cross-section, channel shapes vary

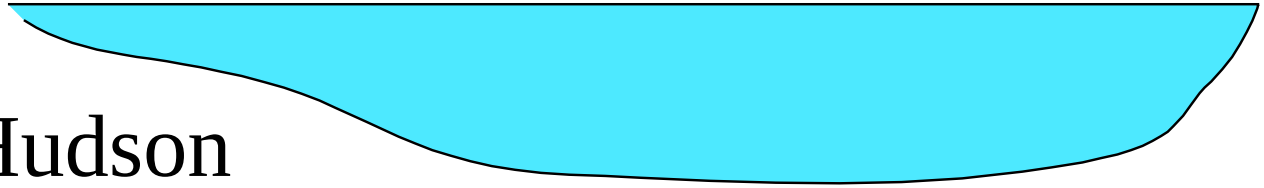
Aberjona



Charles



Hudson



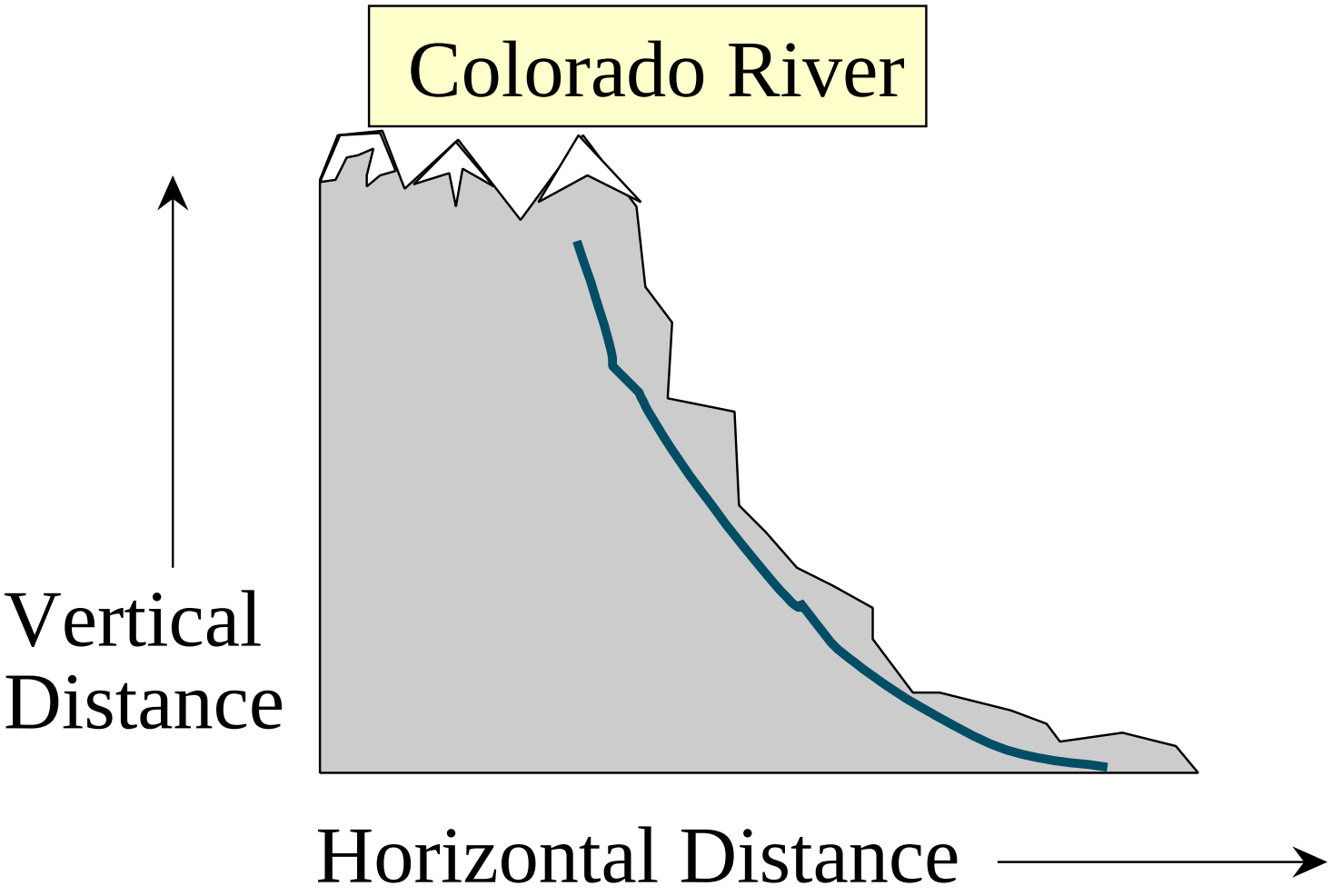
width >> depth

high discharge


Fast-Moving River
high gradient


Slow-Moving River
low gradient

Stream Gradient



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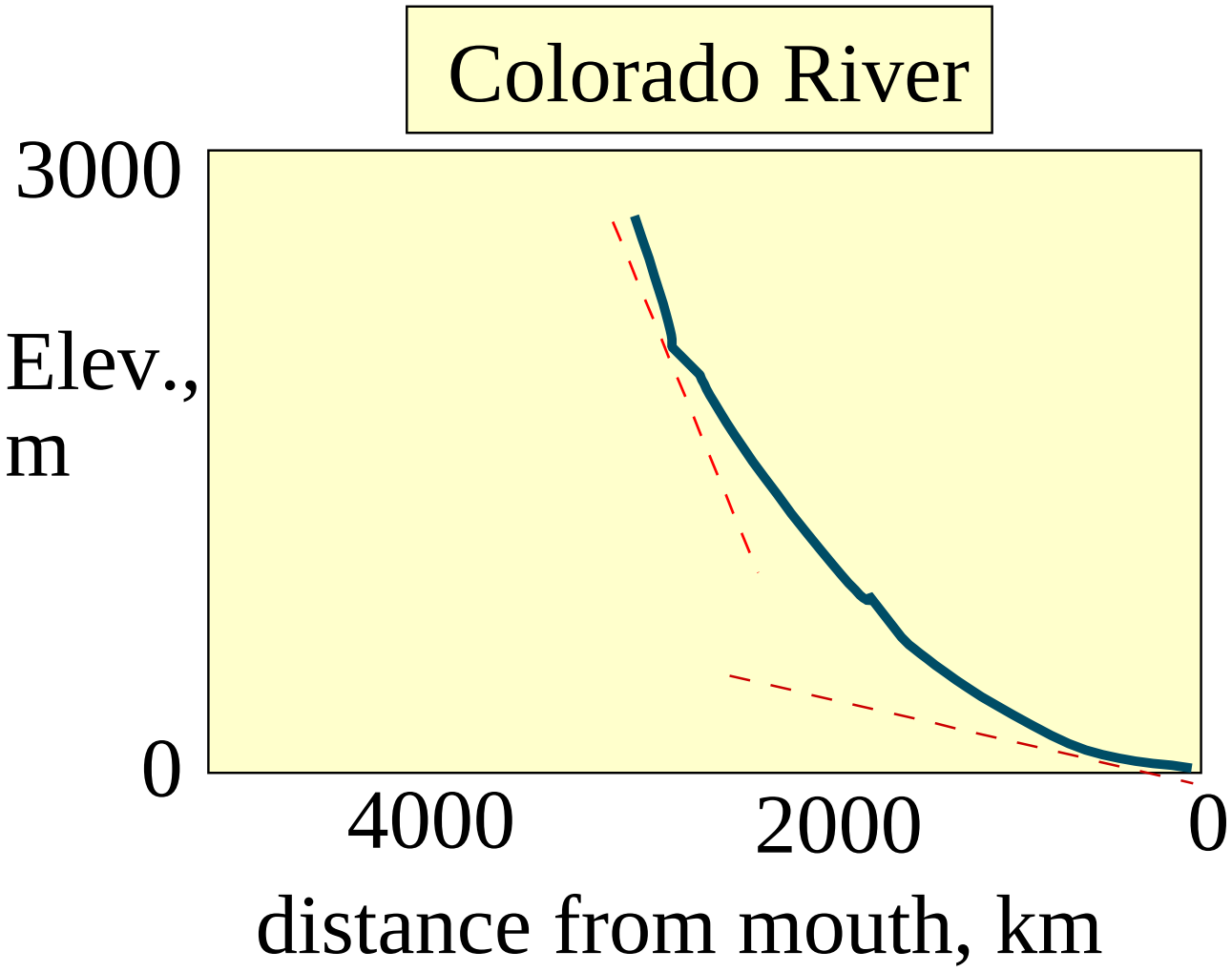
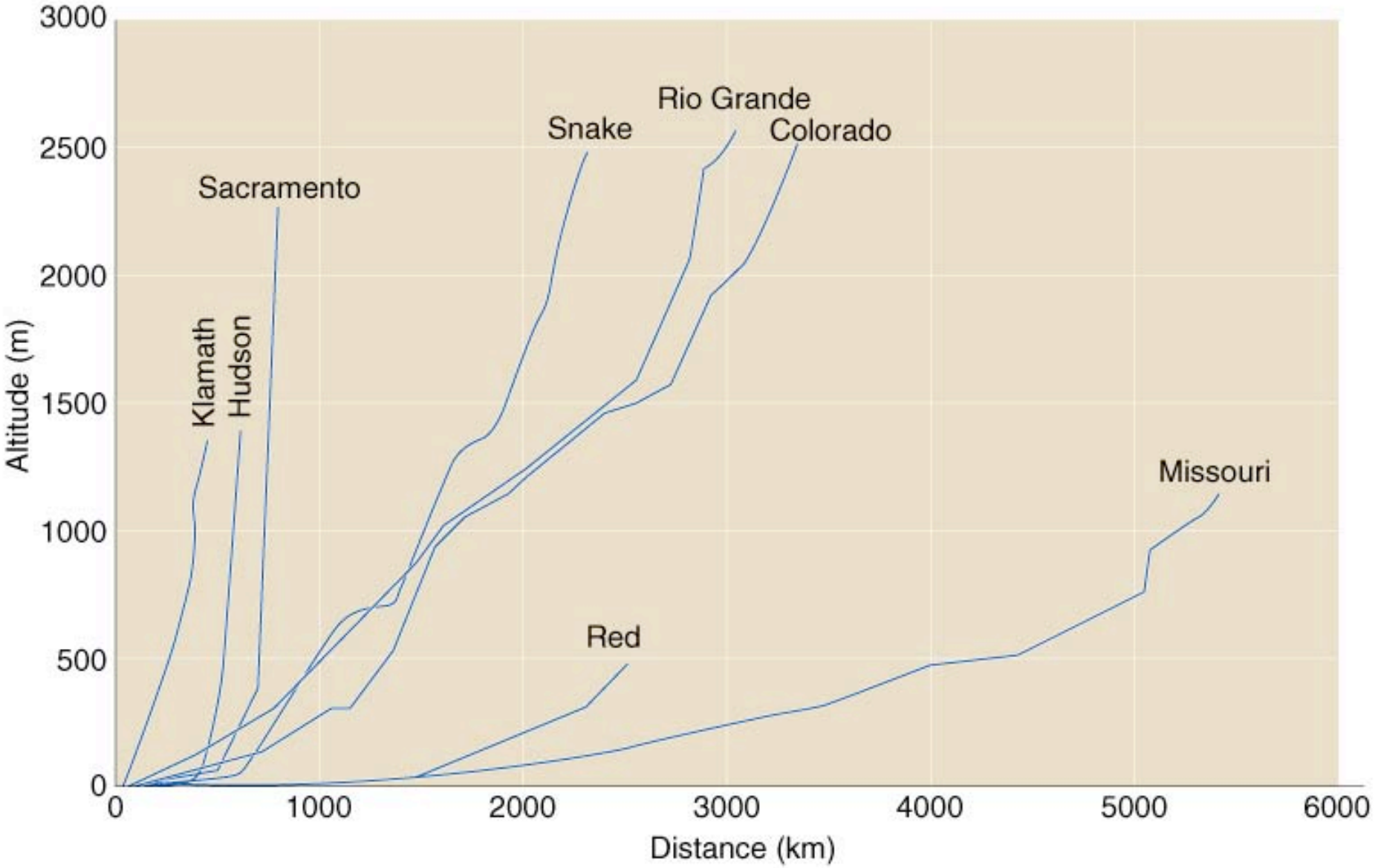
Stream Gradient

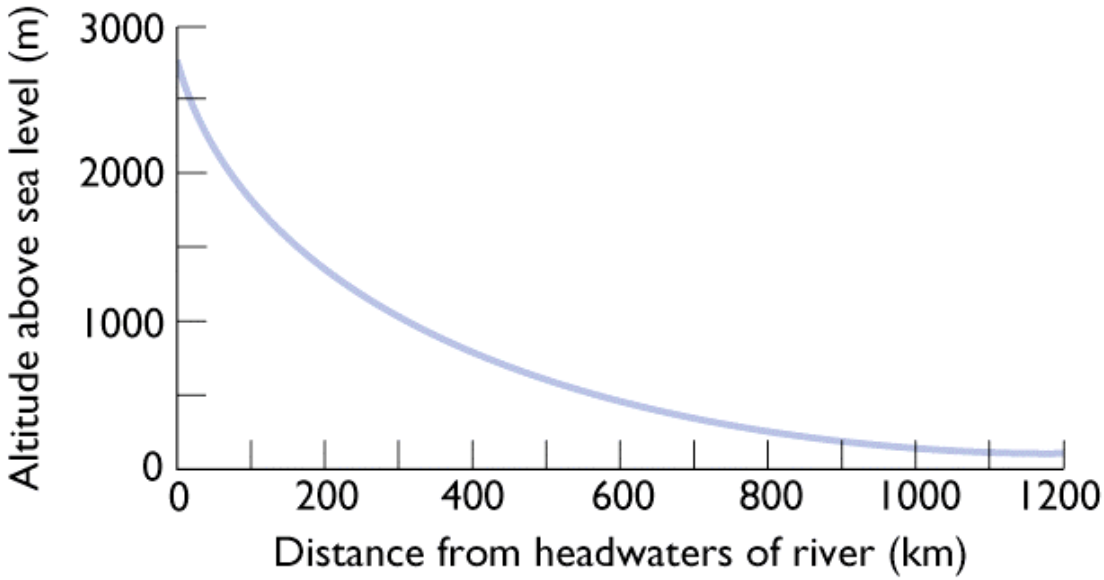
going downstream, gradient decreases



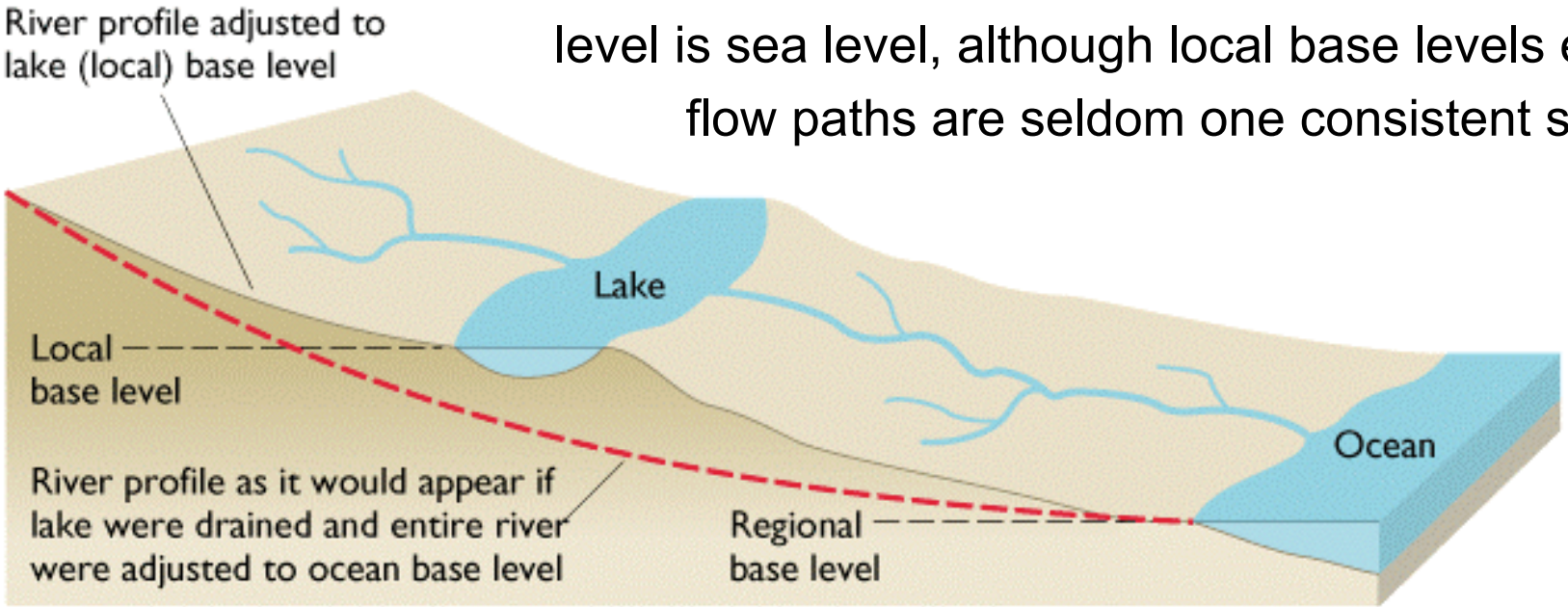

3000
2500
2000
1500
1000
500
0
Altitude (m)
0
1000
2000
3000
4000
5000
6000
Distance (km)
Sacramento
Klamath
Hudson
Snake
Rio Grande
Colorado
Missouri
Red

Base Level

The ability of a stream to erode is based on velocity of water. Velocity is proportional to slope.



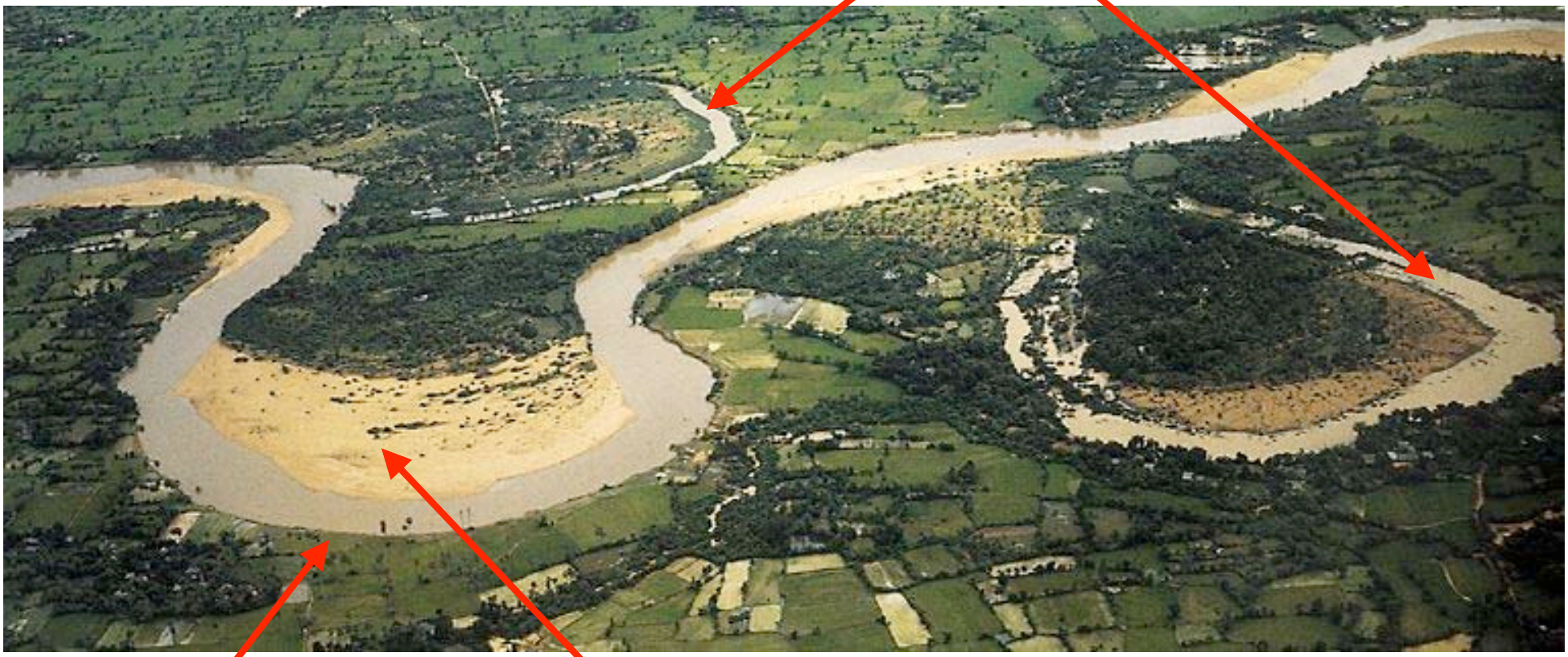
At a sufficiently low slope, streams will run without eroding: this is called the ***base level***. The ultimate base level is sea level, although local base levels exist, since flow paths are seldom one consistent slope.



Forms of Channels

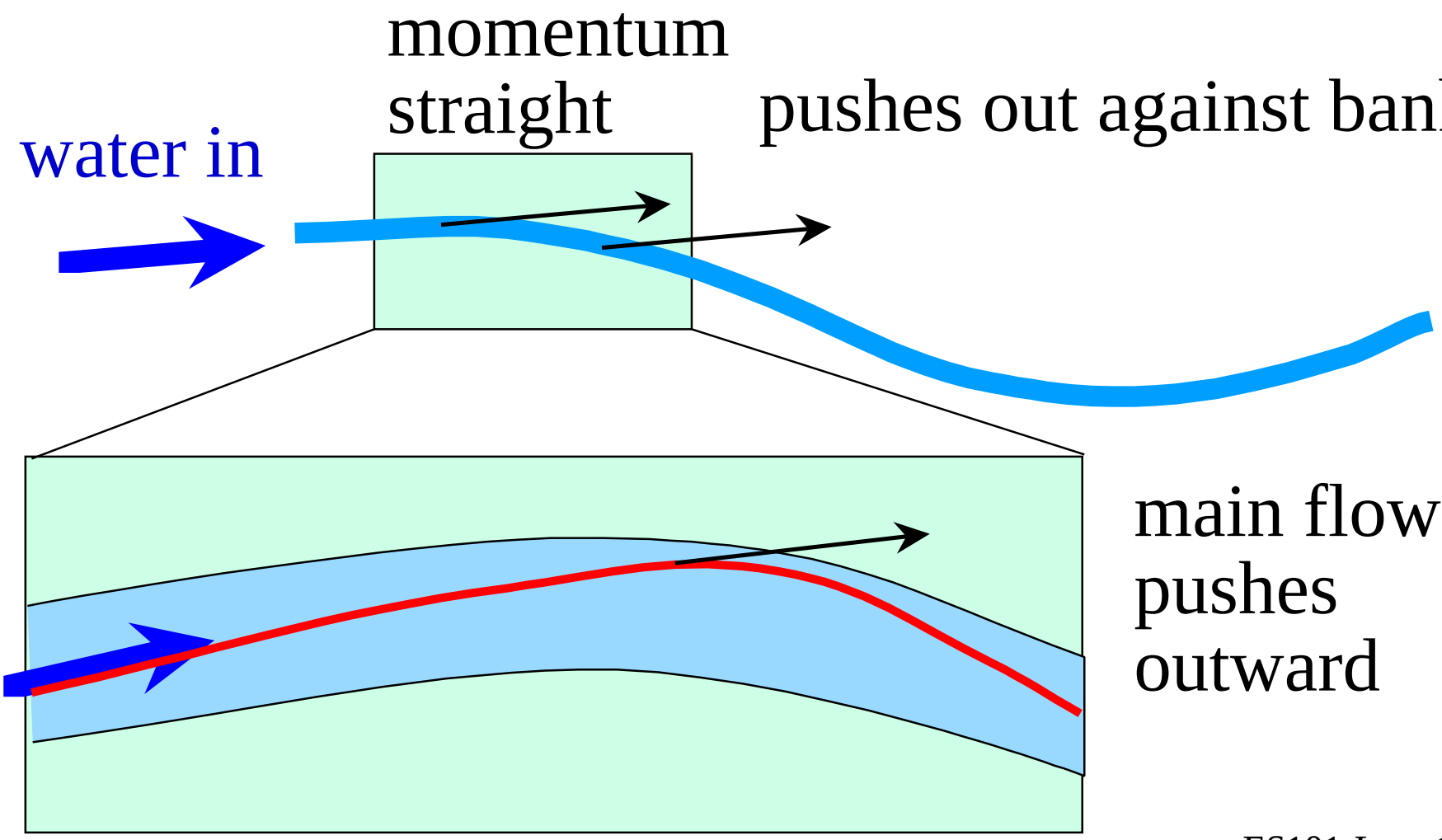
- Straight (rare)
- Meanders
- Braided

Meandering Streams

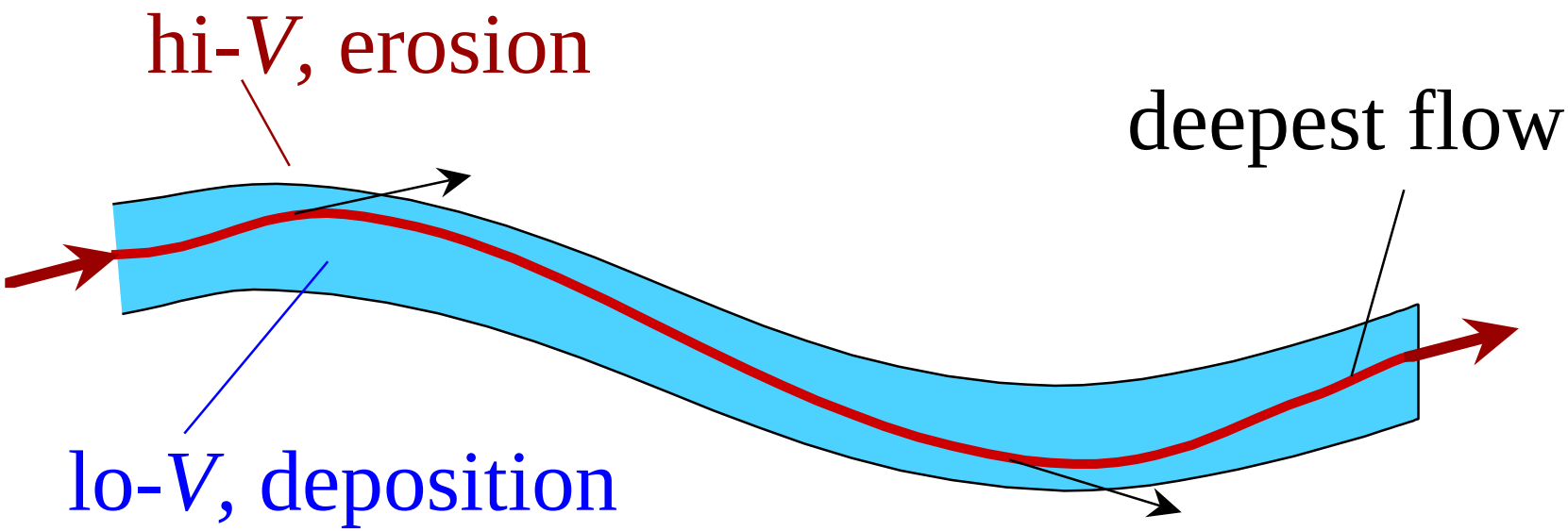


Meandering Streams

Channels rarely straight

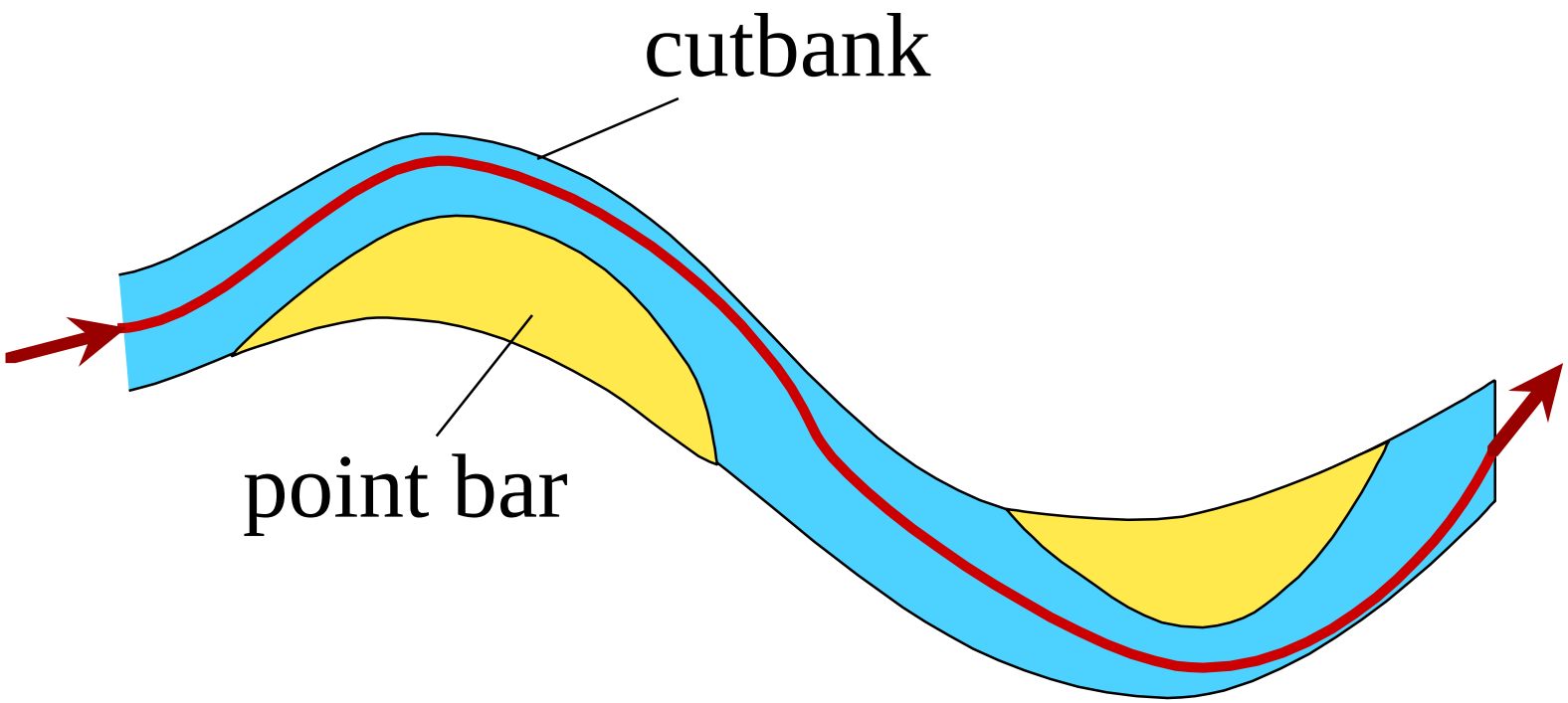


With time, meanders grow

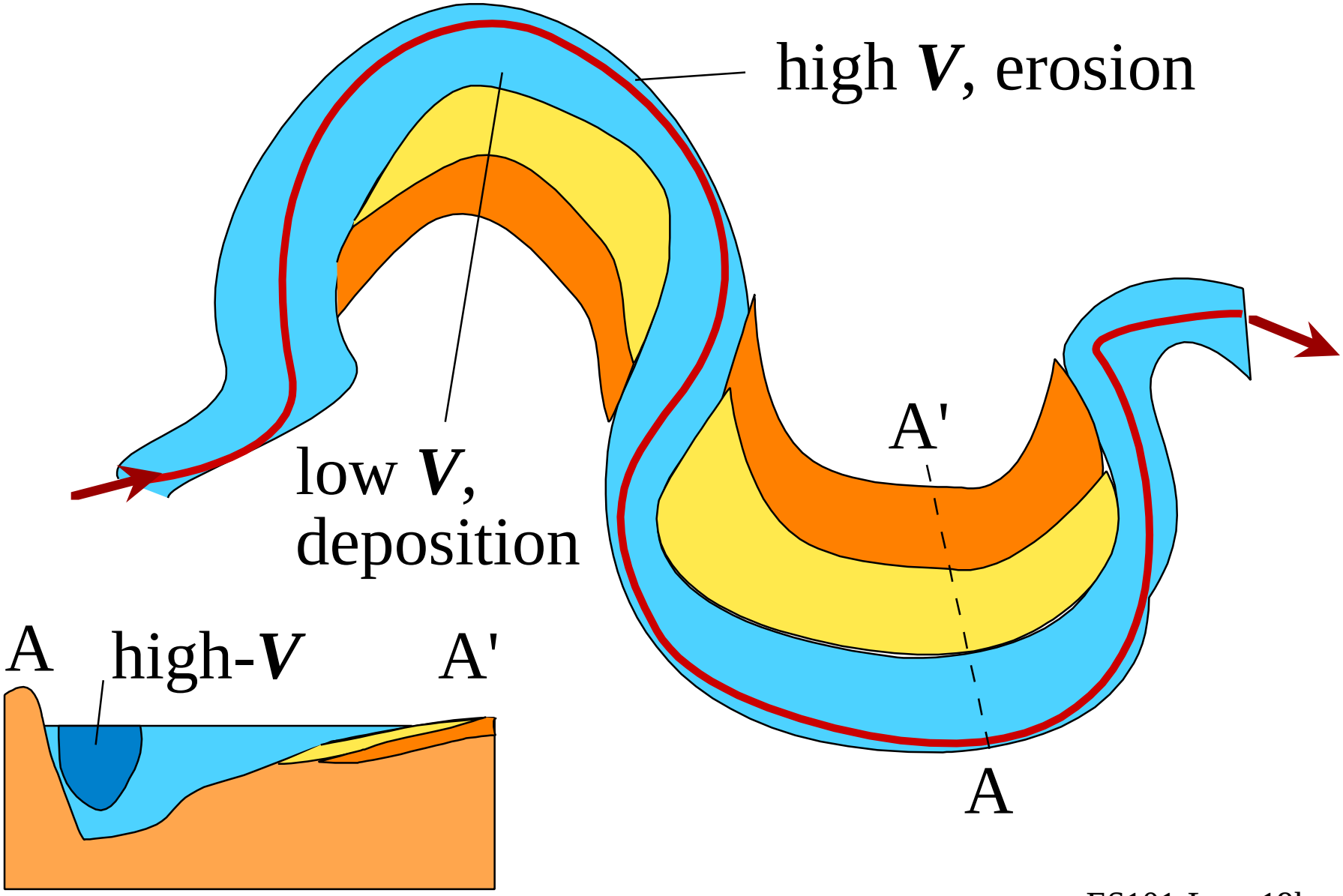


(this erosion, deposition creates landscape)

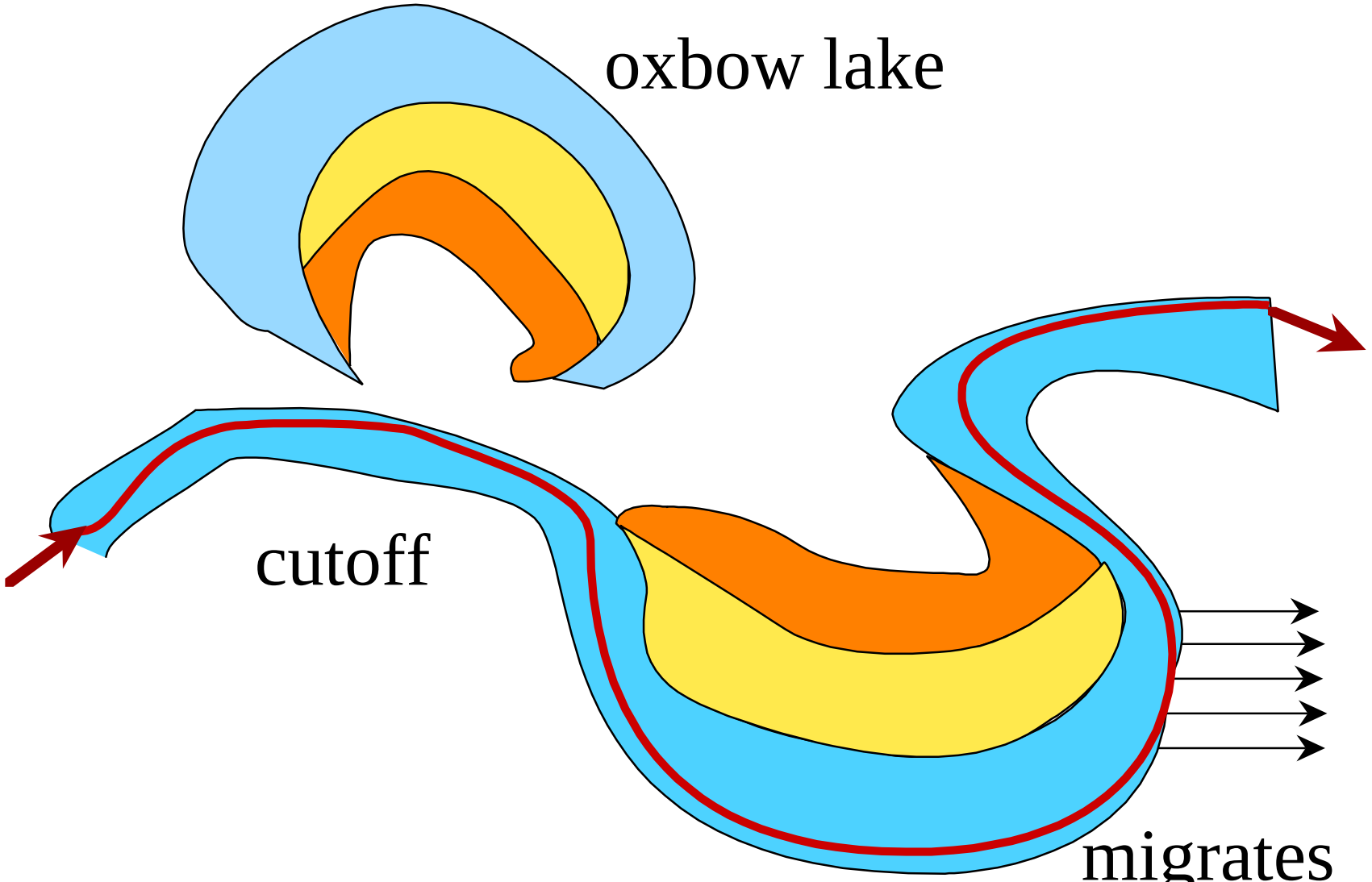
*...and deposit sand **bars** on inner sides...*



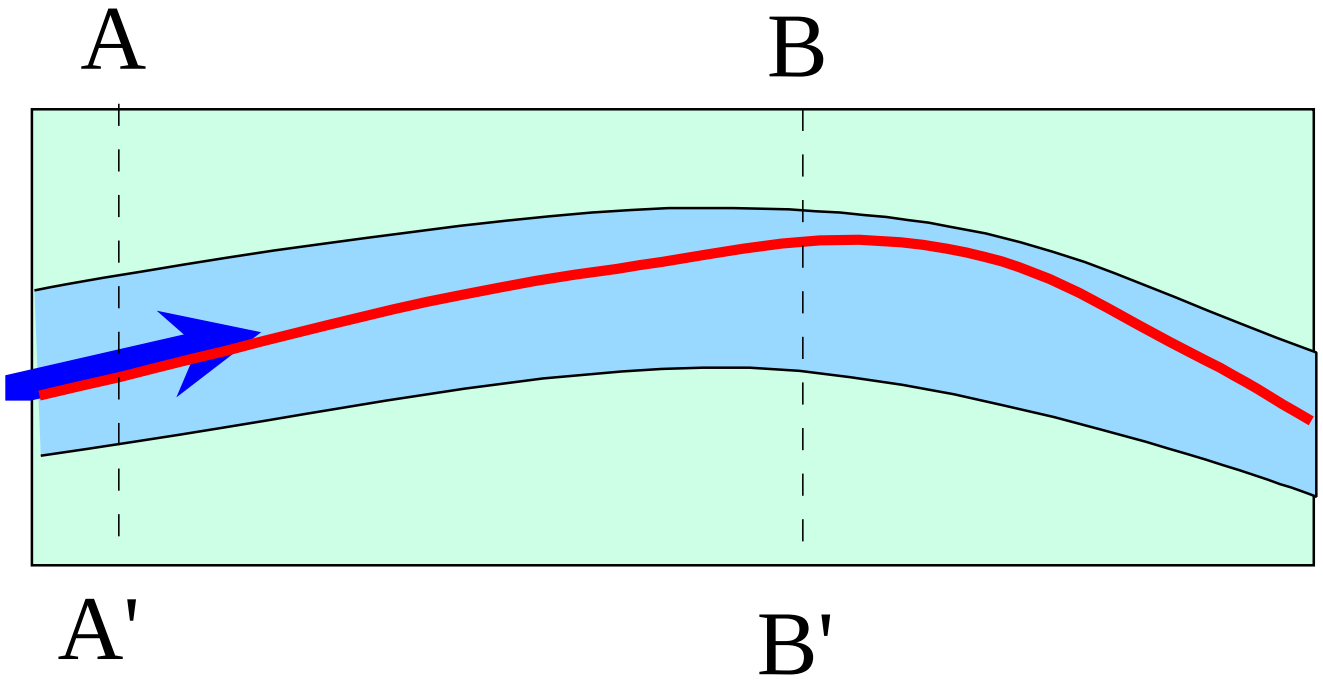
...meanders grow to high curvatures...

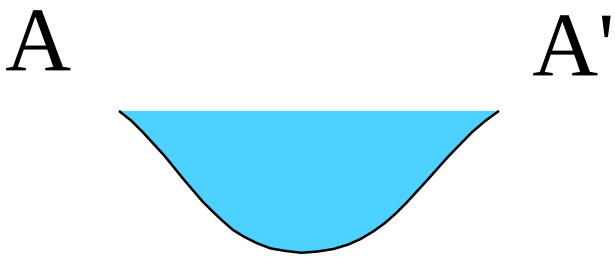


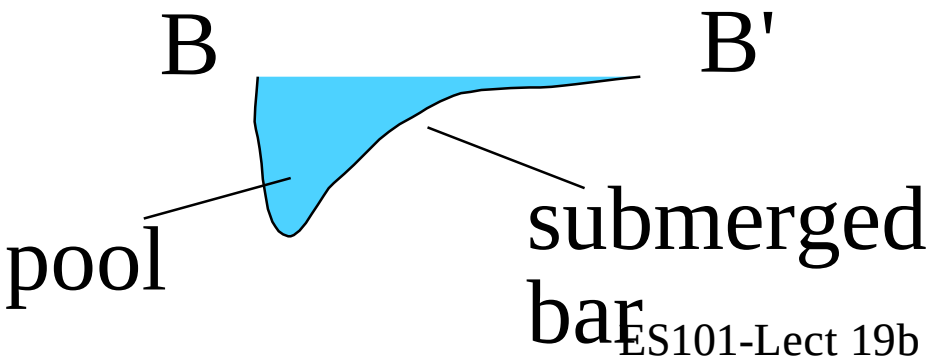
...eventually, ***oxbow lakes*** *can form*



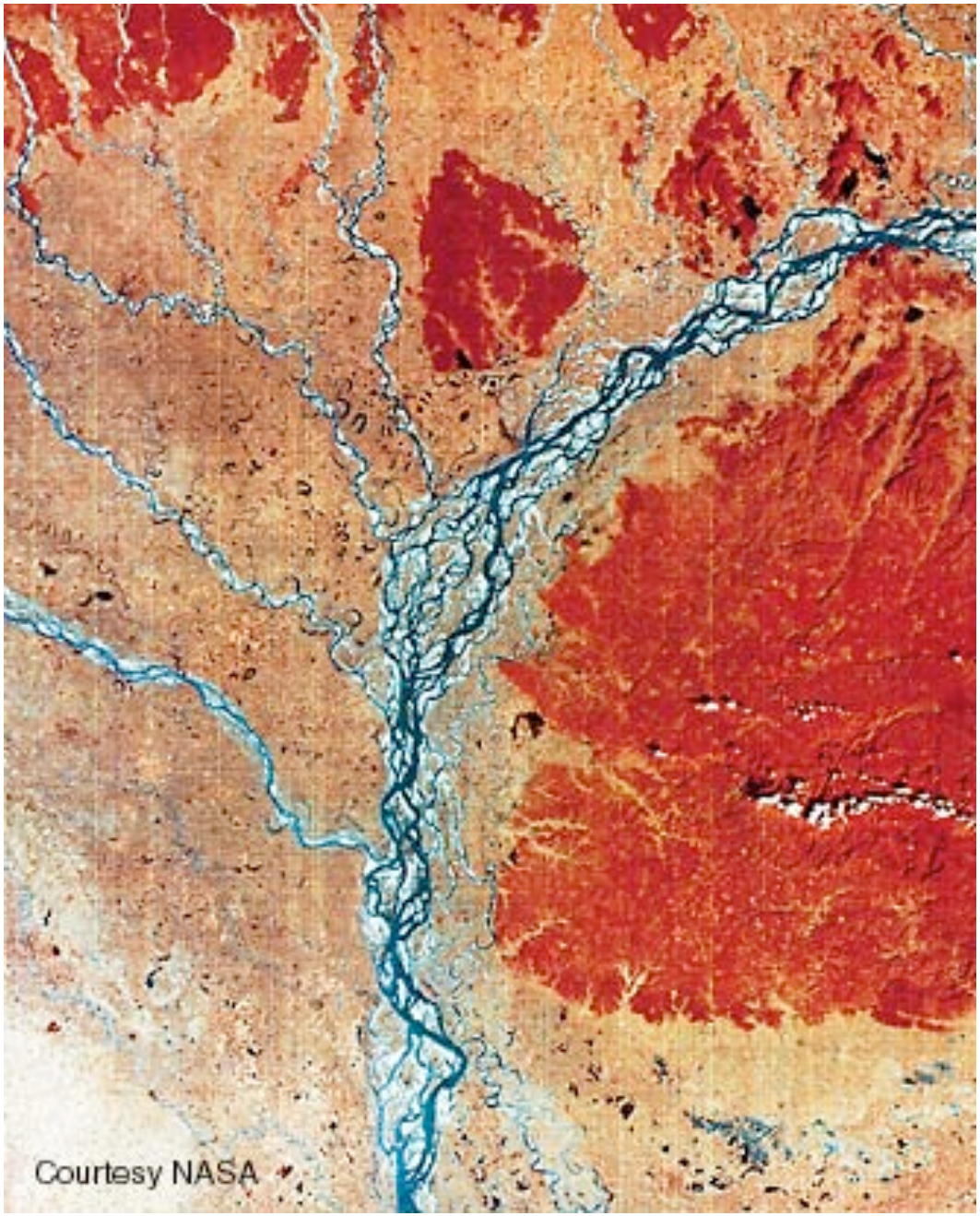
Flow also controls cross-sectional shape







Braided Streams

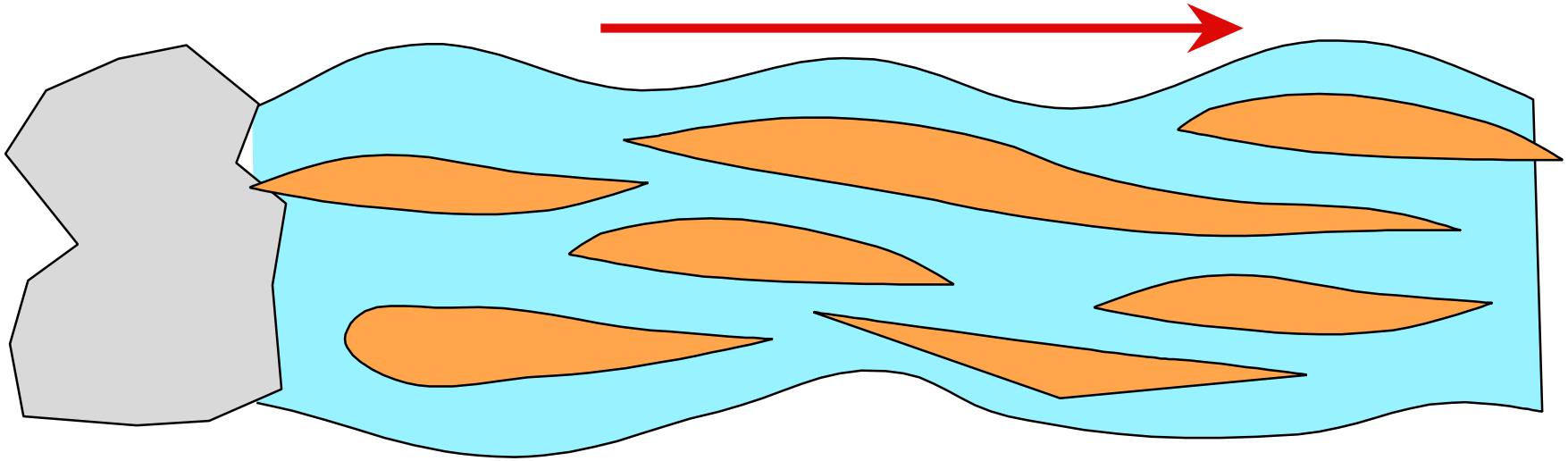


© Gary Braasch Polar climate change: Arctic tundra, warmest in 400 years.

Braided Streams

- deposition in middle of stream
  -> divided channel

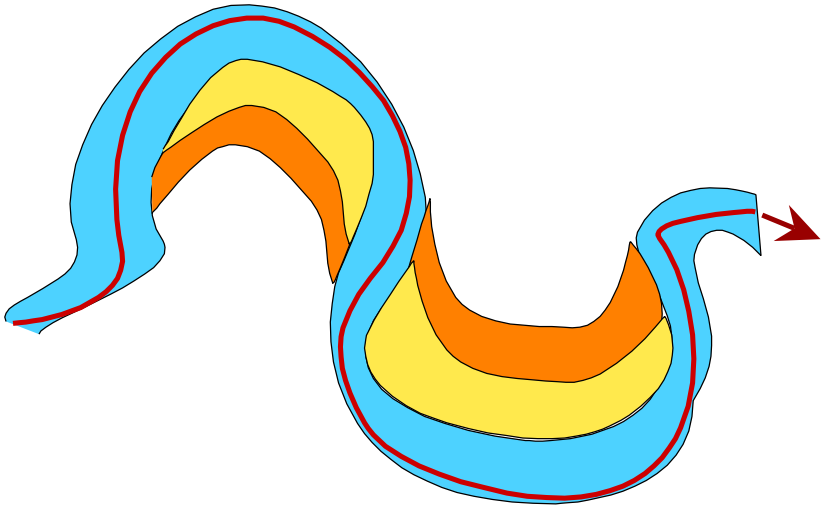
- high energy, high sediments
- highly variable discharge

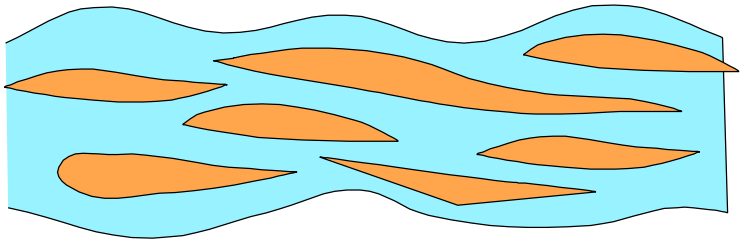


e.g. below glaciers

Meanders:

Low gradient,
fine sediment

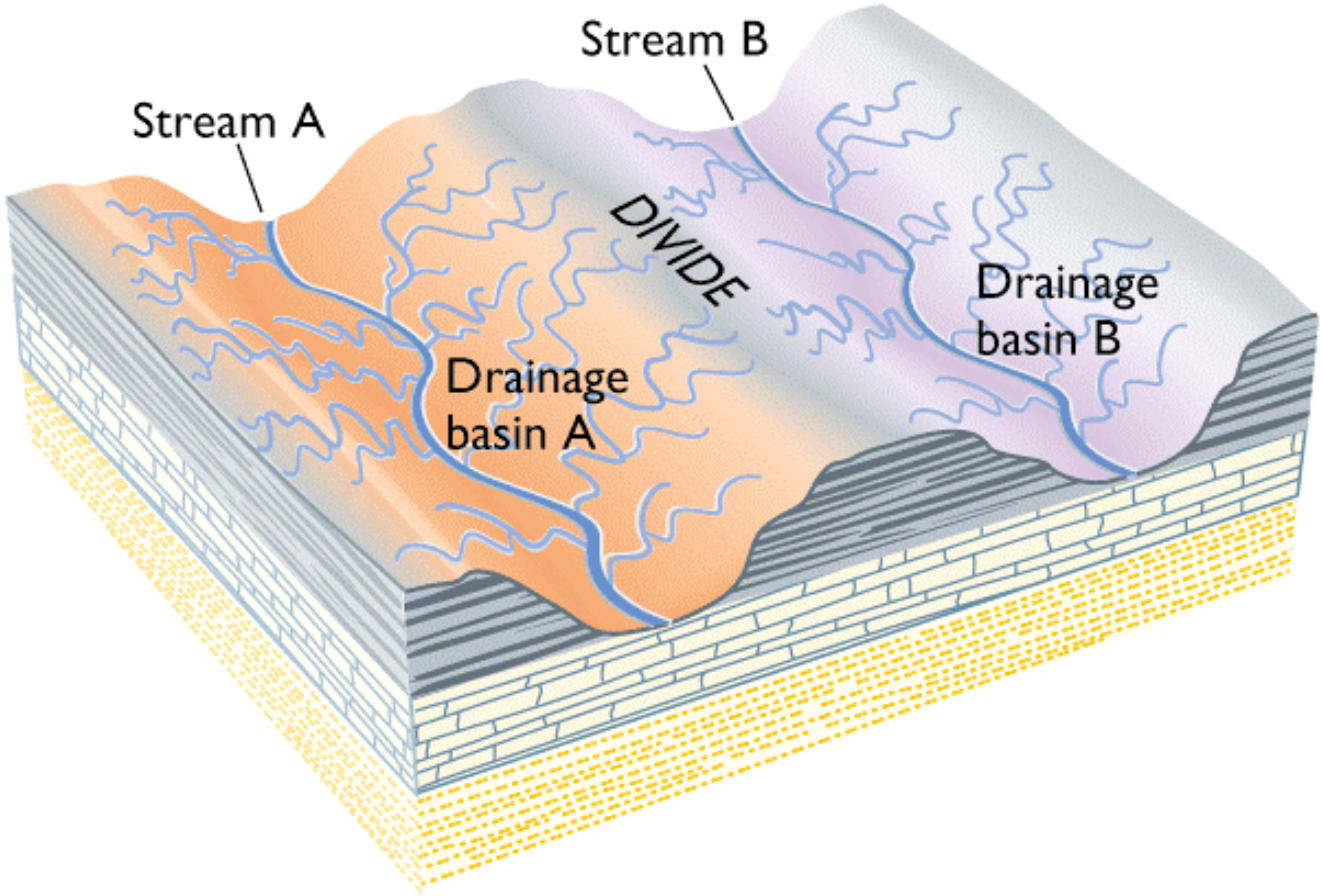




Braided:

Variable discharge,
large sediment load

Watersheds



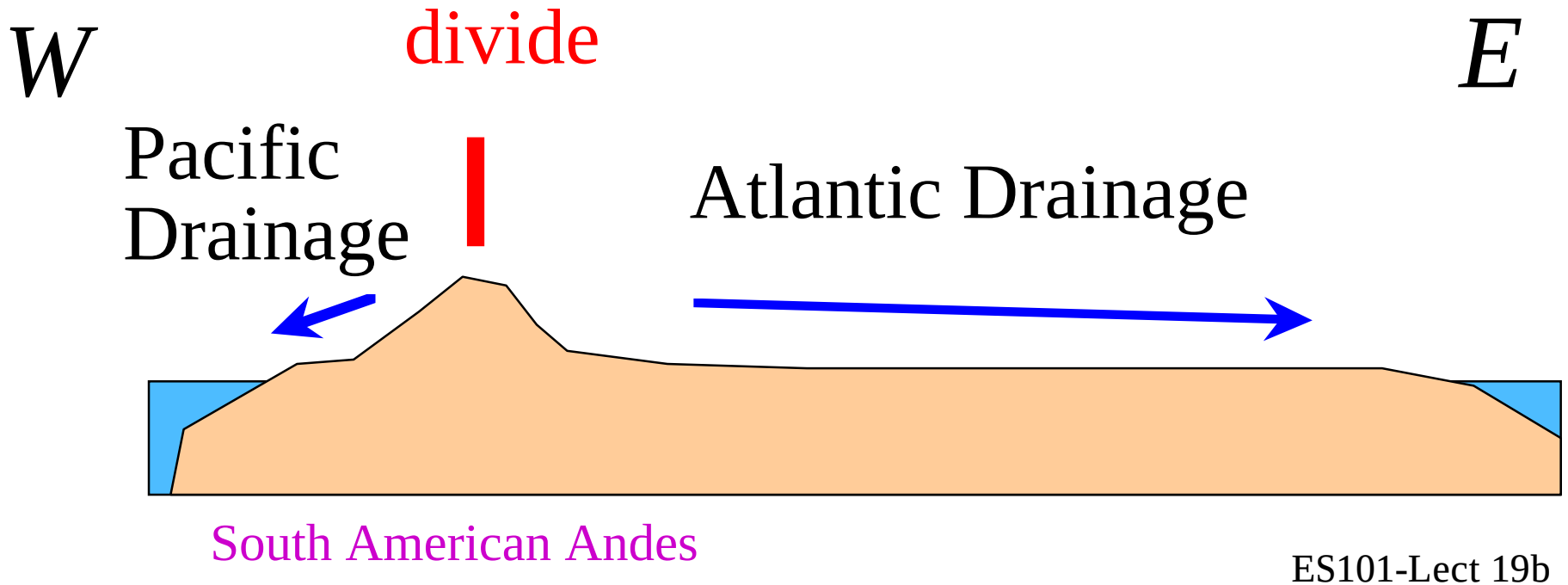
Every stream is defined by an area on the ground where incident precipitation will all flow into that stream. These ***drainage basins*** or ***watersheds*** are separated by topographic highs: ***divides***.

The Continental Divide

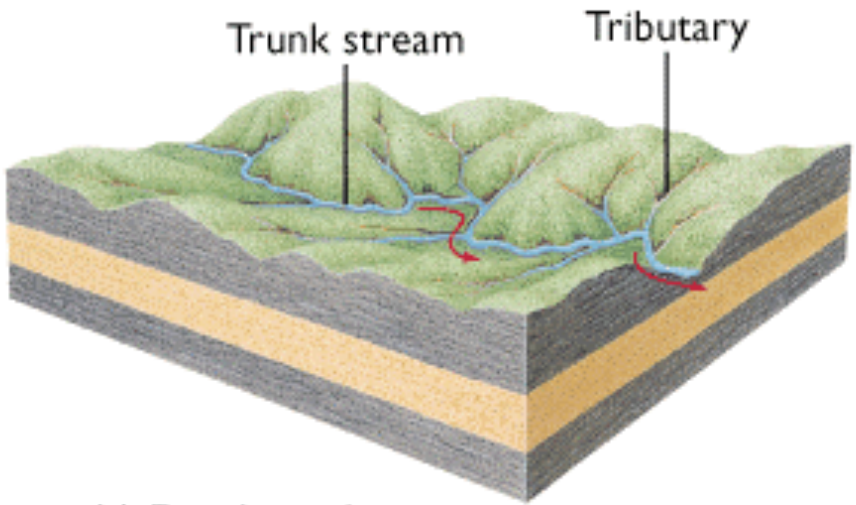

Arctic Ocean
Mississippi River basin limit
Drainage divide
Hudson Bay
Pacific Ocean
Atlantic Ocean
Great Basin
Continental divide
Mississippi River
Gulf of Mexico

What controls divide location?

- Tectonics creates topography
- As mountains evolve, streams follow...

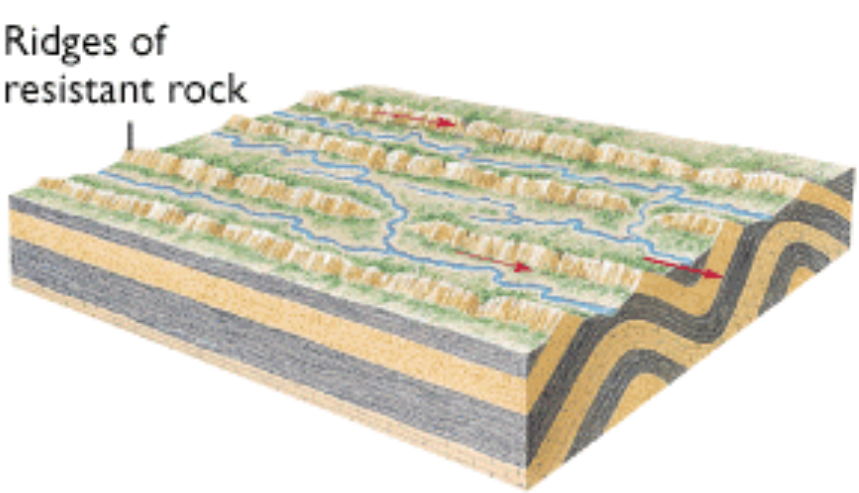


Drainage Patterns

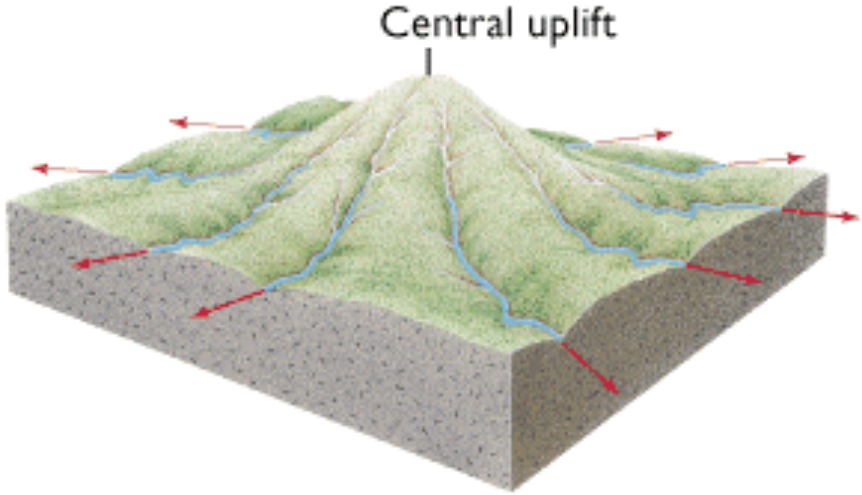


(a) Dendritic drainage

(b) Rectangular drainage



(c) Trellis drainage

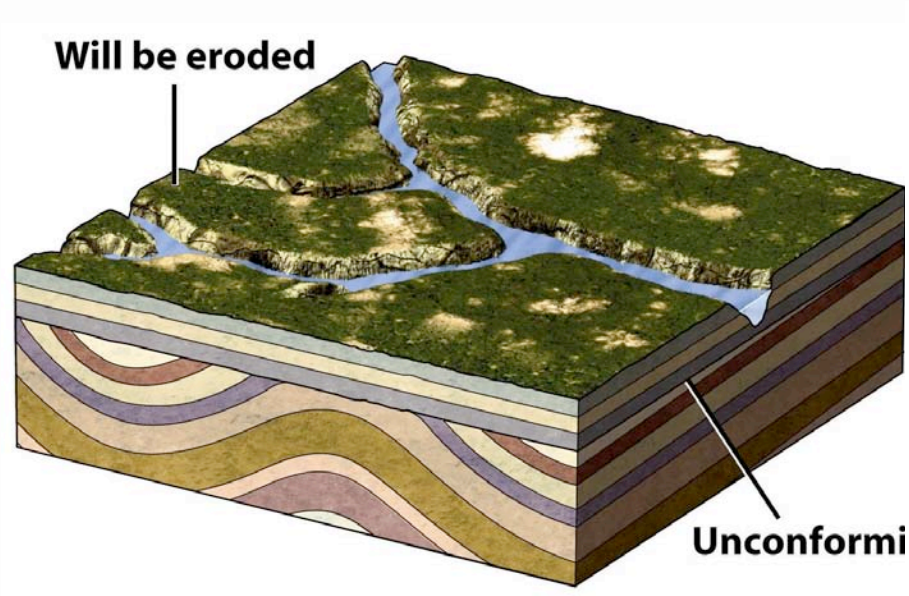


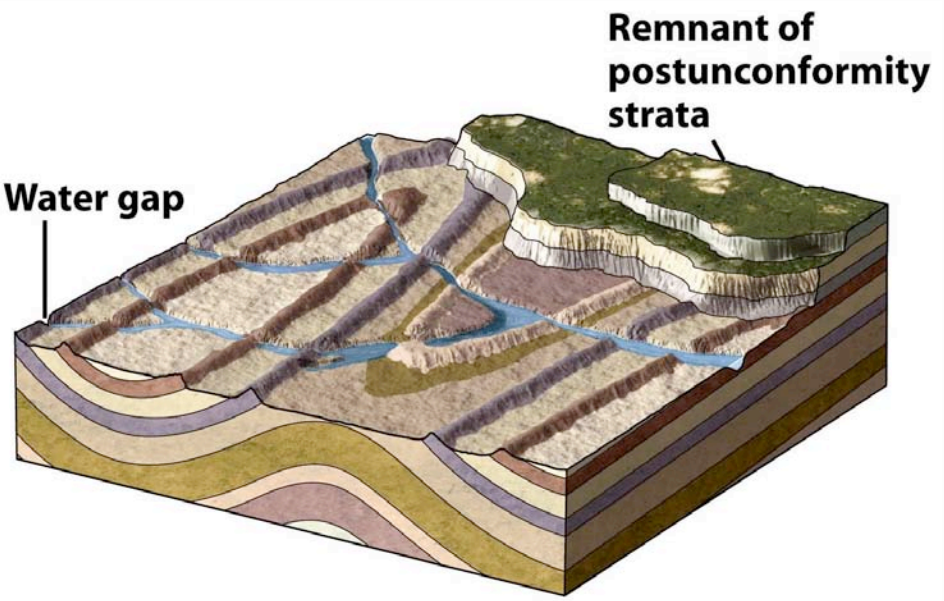
(d) Radial drainage

The topographic pattern streams take are not necessarily totally random. They are affected by rocks and their structures.

Drainage Evolution

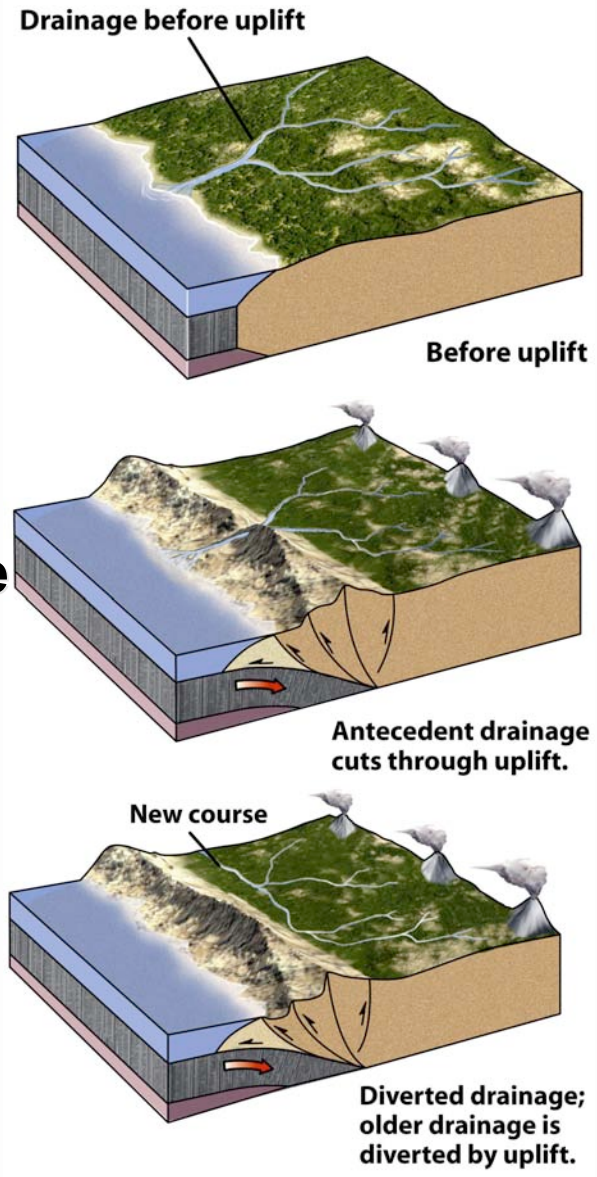
- **Superposed streams – Cross deformed terrain ignoring structure.**
  - **Streams initially develop in younger, flat strata.**
  - **The stream then chainsaws into underlying rocks.**
  - **Stream maintains its initial geometry.**



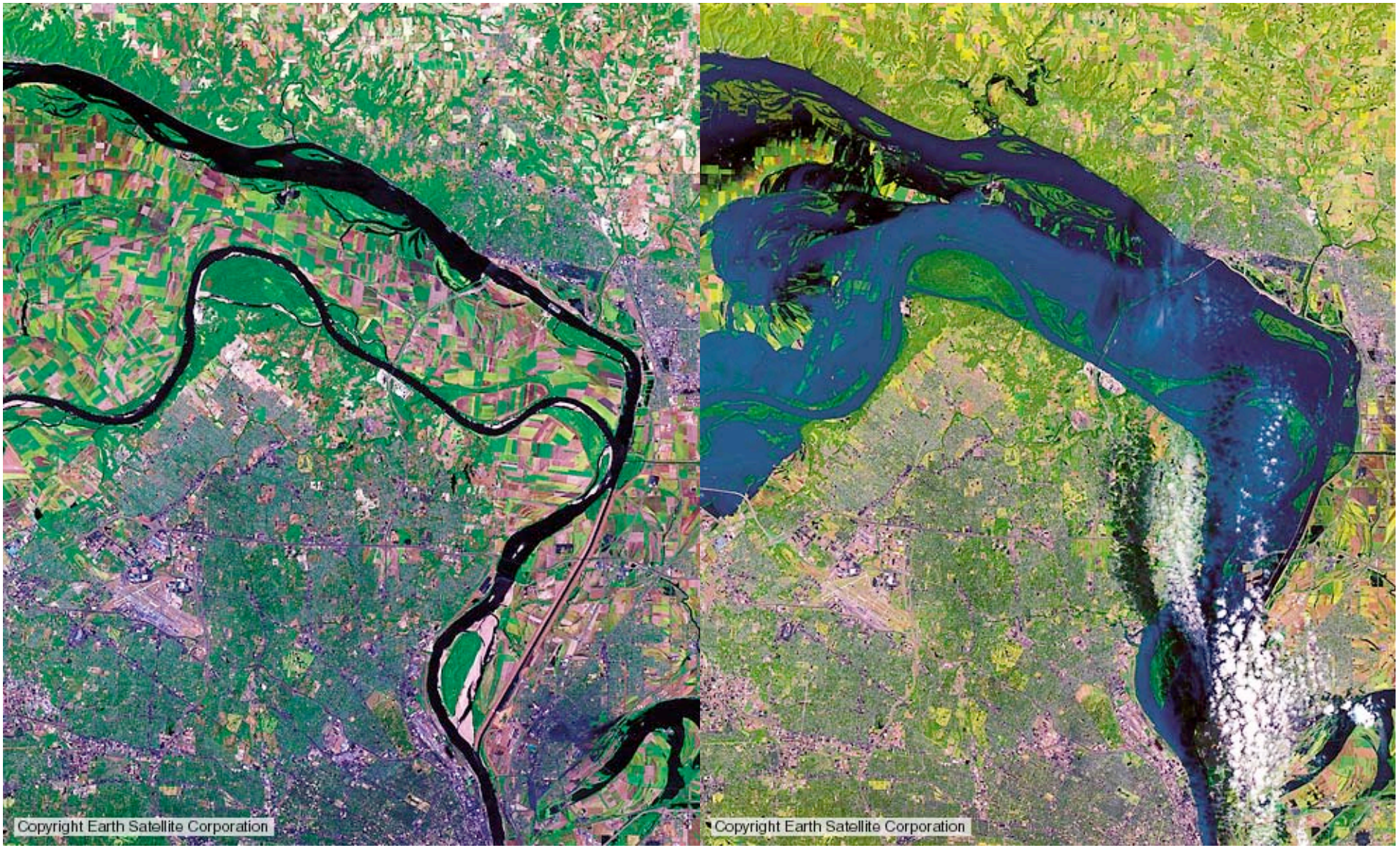


Drainage Evolution

- **Antecedent drainages.**
  - Tectonic uplift may raise ground beneath established streams.
  - If erosion keeps pace with uplift, the stream will cut through the uplift.
    - Called antecedent drainage.
  - If the rate of uplift exceeds erosion, the stream is diverted by the range.



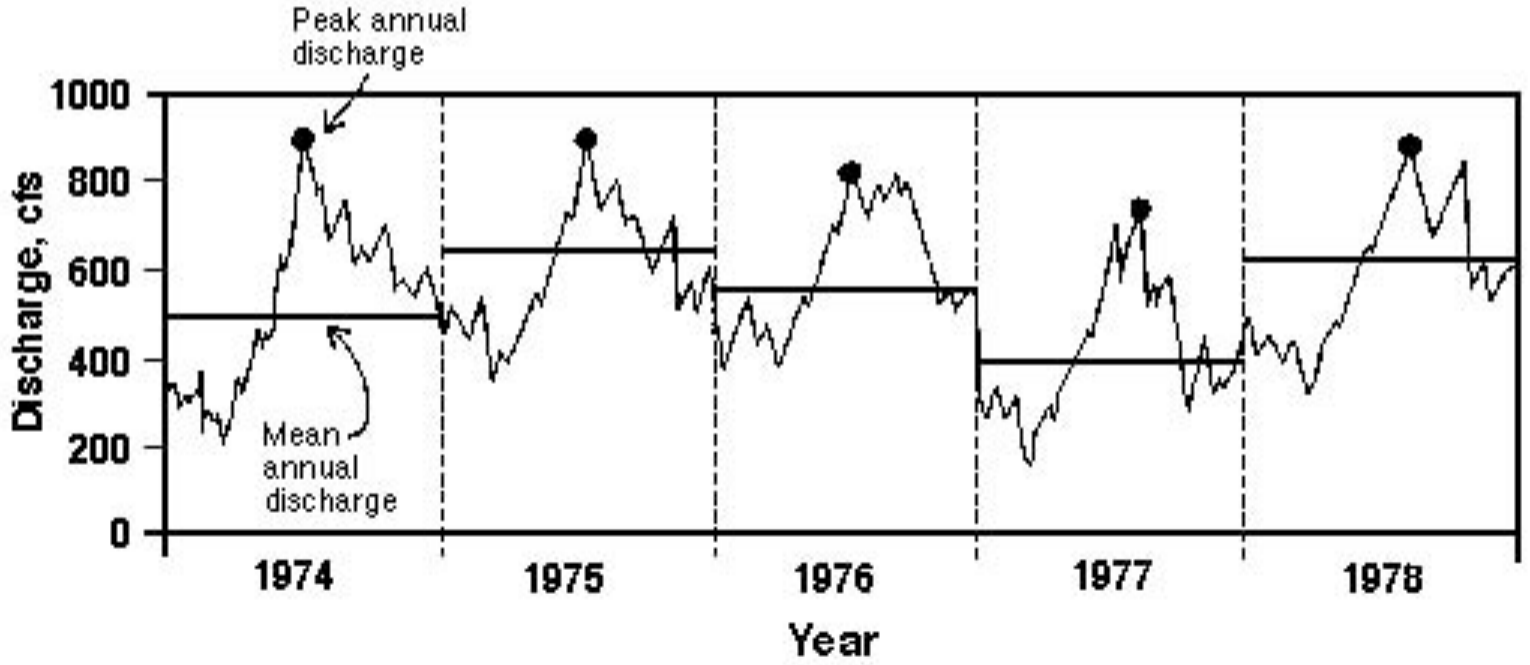
Mississippi Floodplain



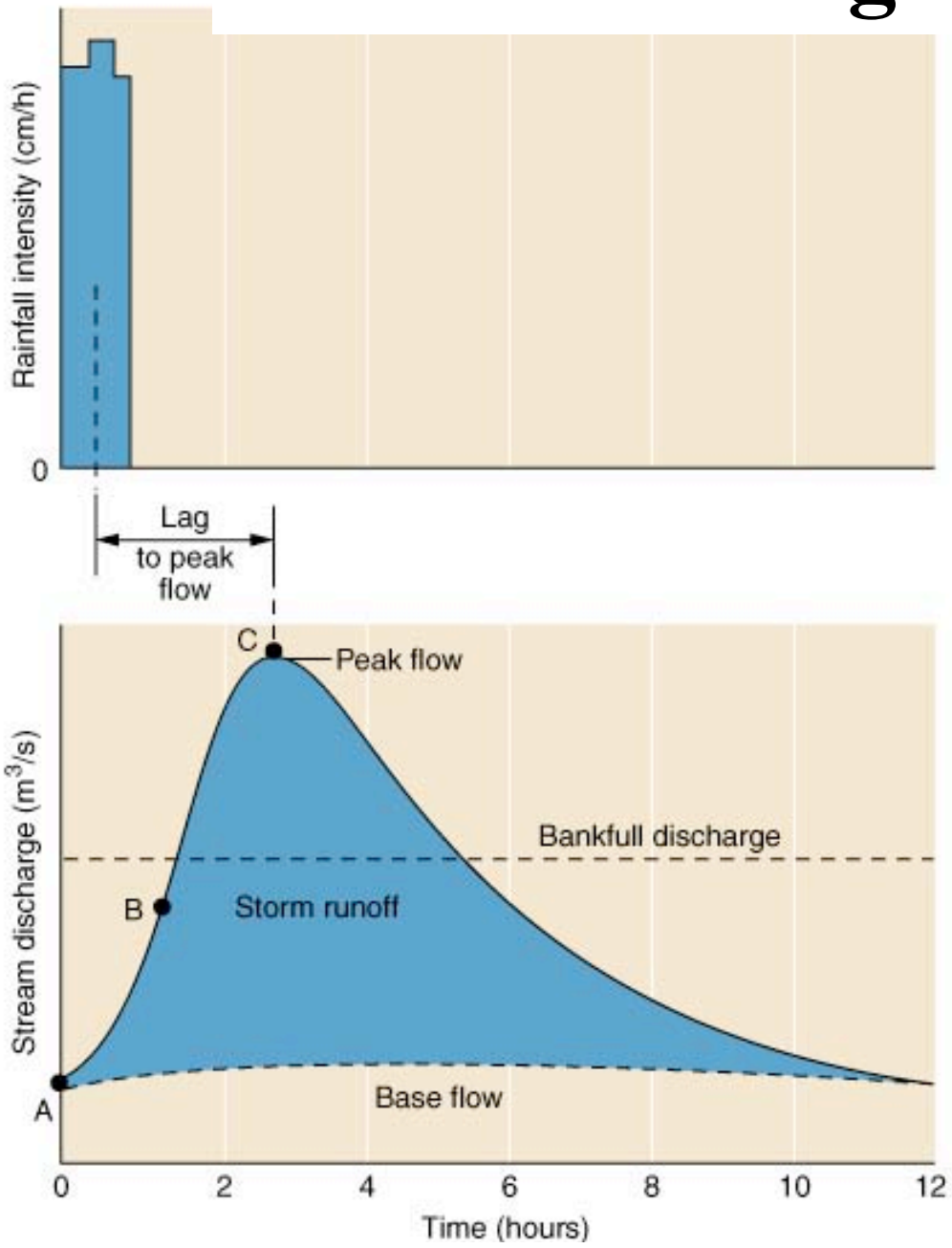
These are satellite images before and during Summer, 1993 floods of the Mississippi river north of St.Louis.

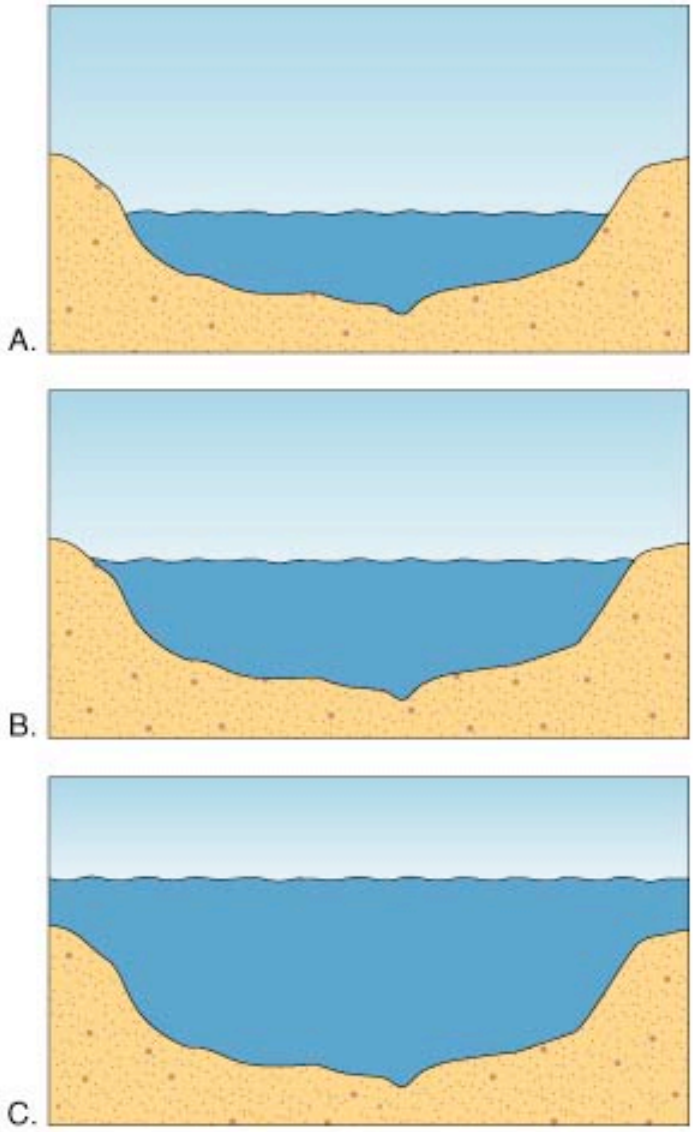
River Hydrograph discharge vs. time

Figure 4.15 Stream hydrograph showing the fluctuation of river discharge with time (heavy line) and the mean annual discharge for each of the years shown. (Freeze 1982)

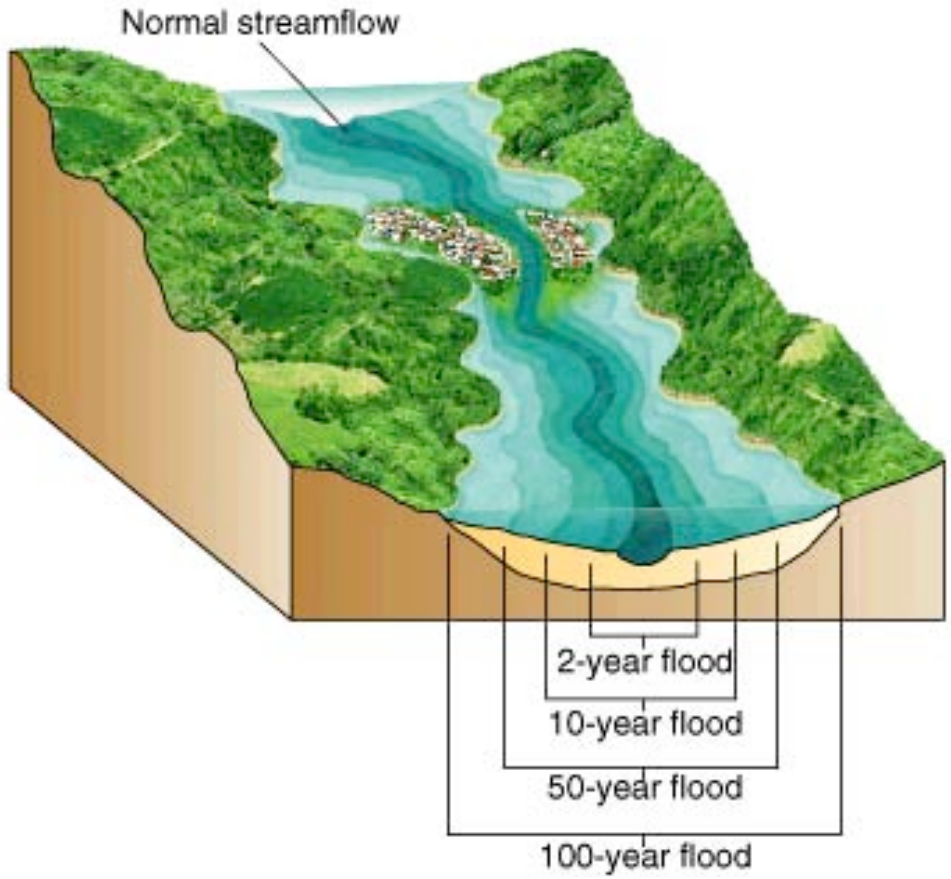


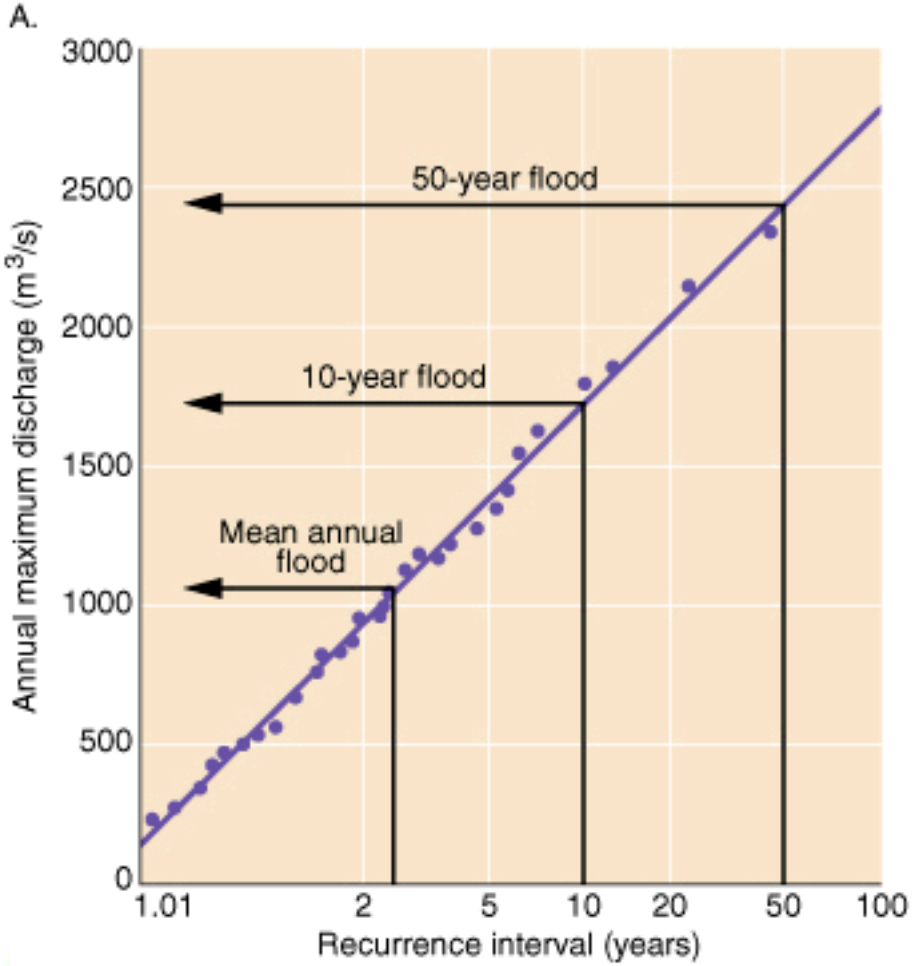
Flood Discharge after a storm



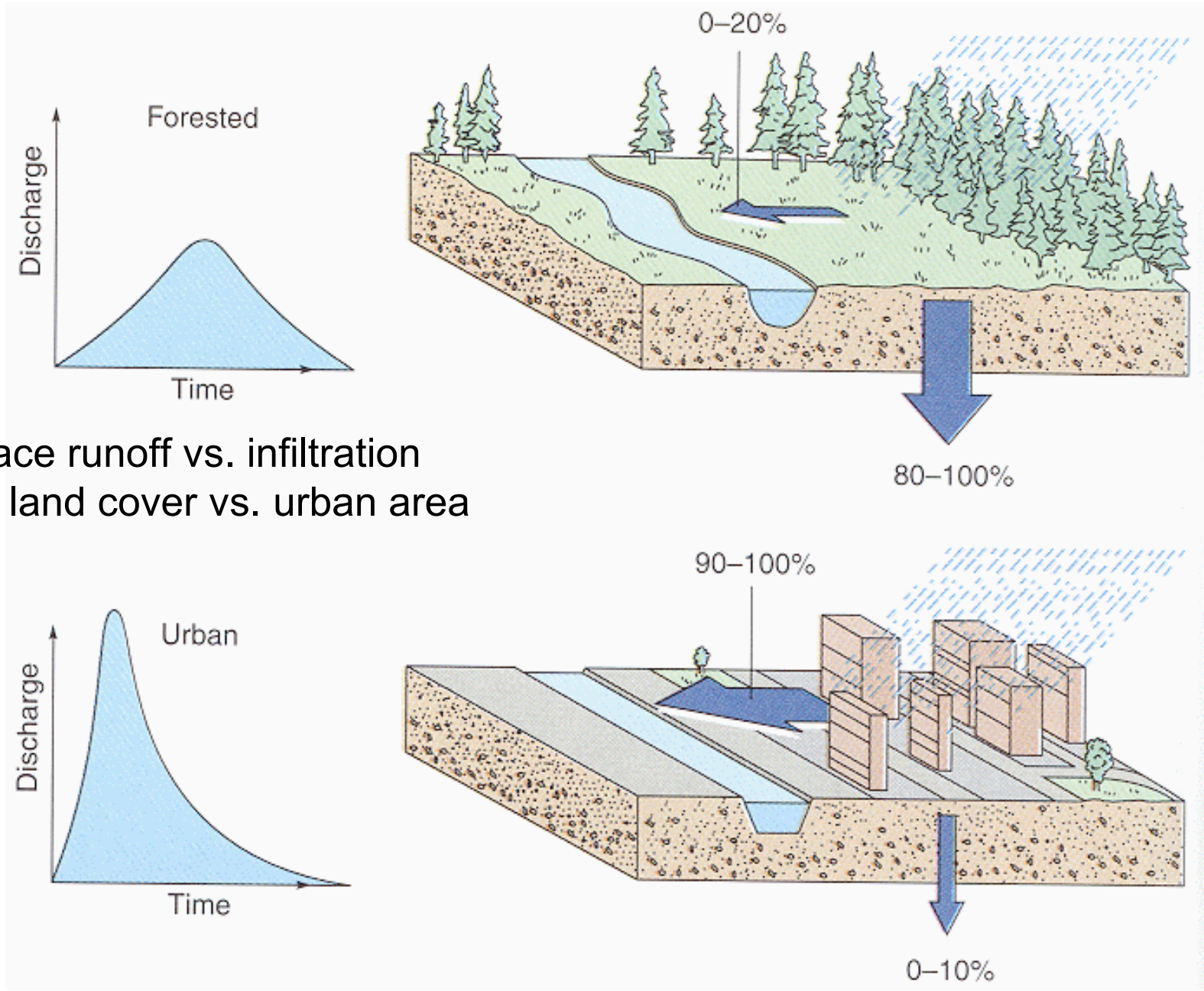


"Predicting" the frequency and magnitude of floods





Floods and Urbanization



surface runoff vs. infiltration
natural land cover vs. urban area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