Mountain Rivers

Gutta cavat lapidem

(Dripping water hollows out a stone)

*- Ovid,
Epistulae Ex Ponto,
Book 3, no. 10, 1. 5*

Mountain Rivers

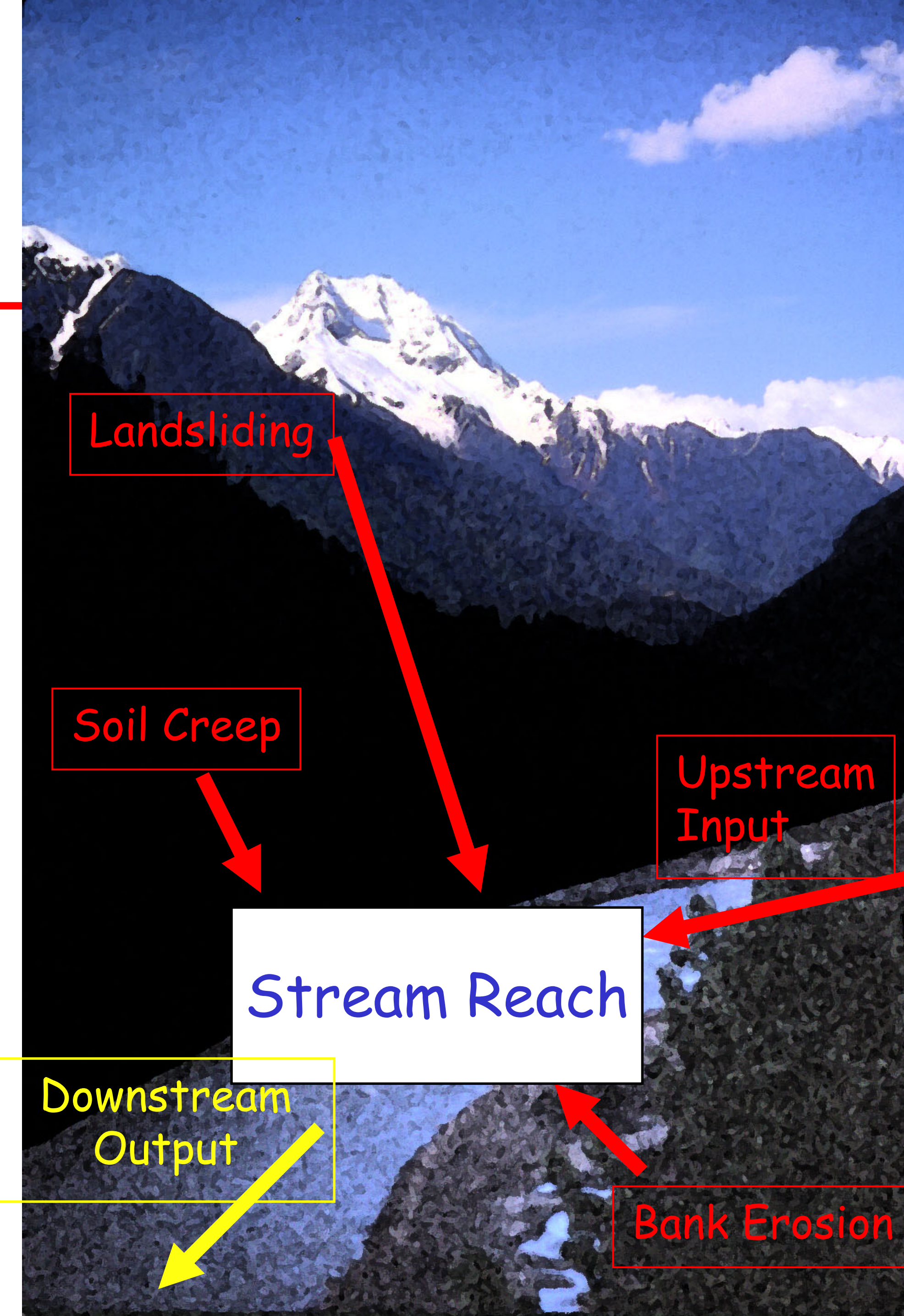
- Fixed channel boundaries (bedrock banks and bed)
- High transport capacity
- Low Storage
- Input ≈ Output

Sediment Budgets for Mountain Rivers

Little sediment storage implies that sediment inputs balanced by downstream sediment transport.

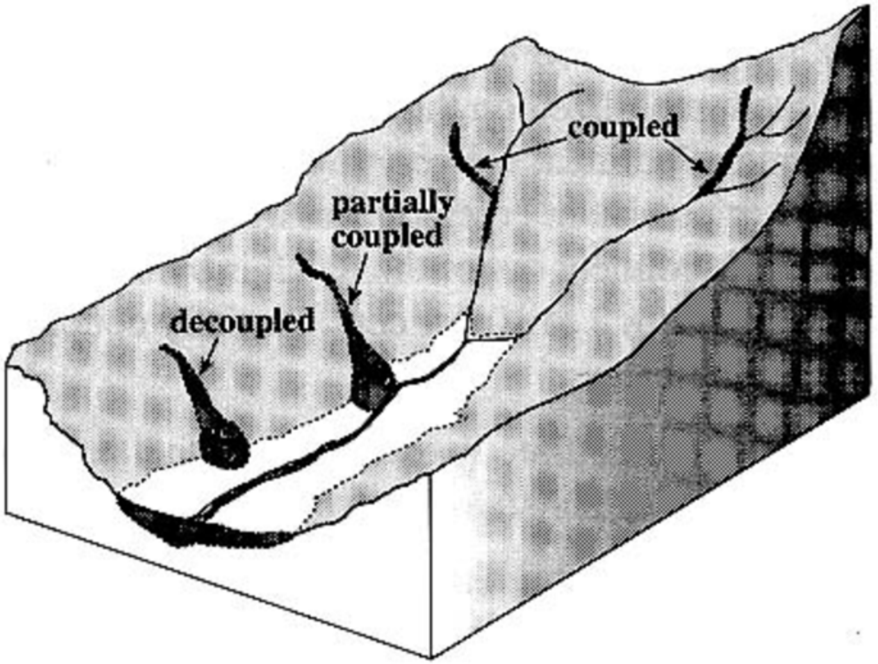
$$\text{Input} = \text{Output}$$

$$\Delta S = 0$$



Mountain Rivers

Strong hillslope-channel coupling in mountain streams means that sediment inputs can move downstream as a pulse.

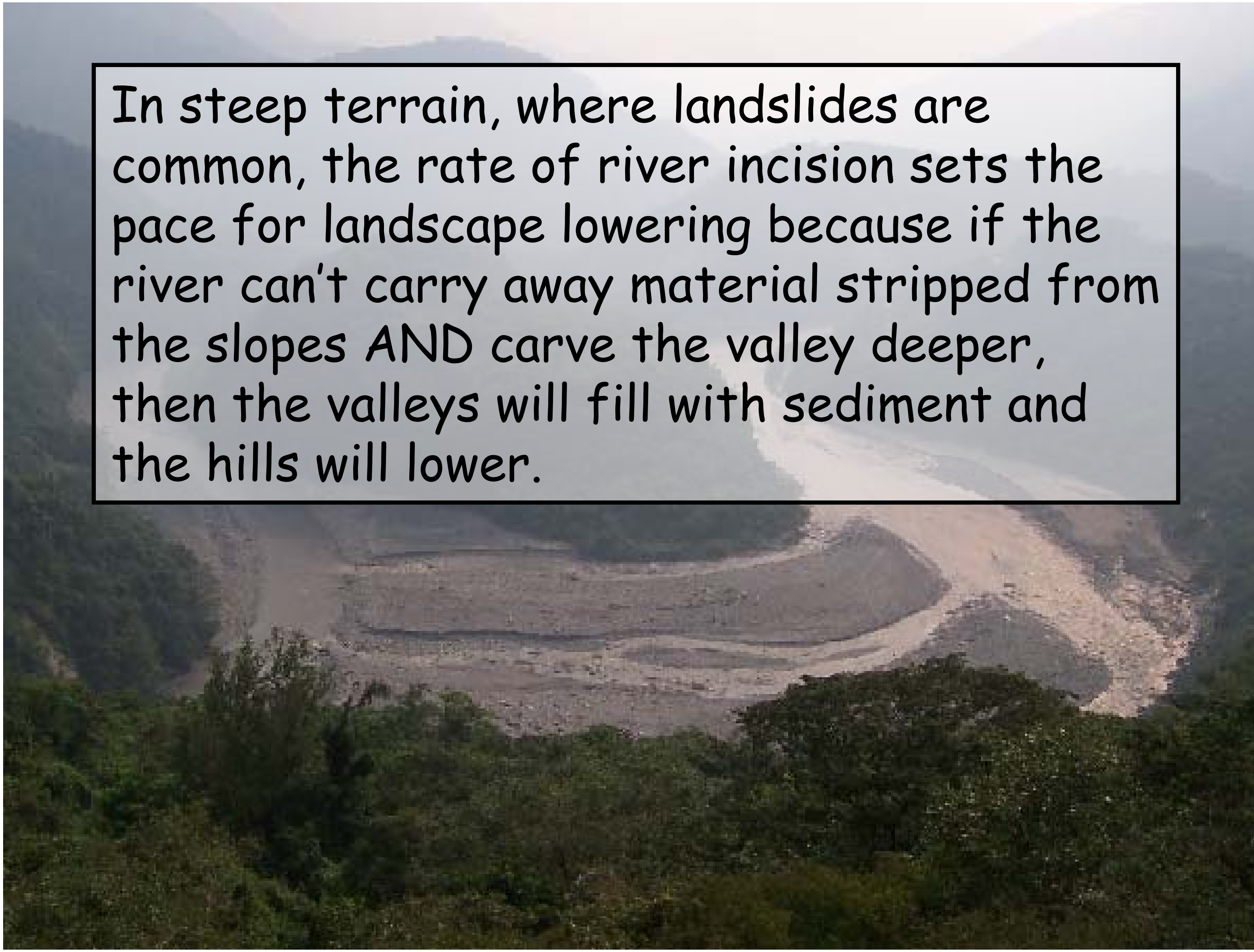


Taiwan

Taiwan

Taiwan

Taiwan

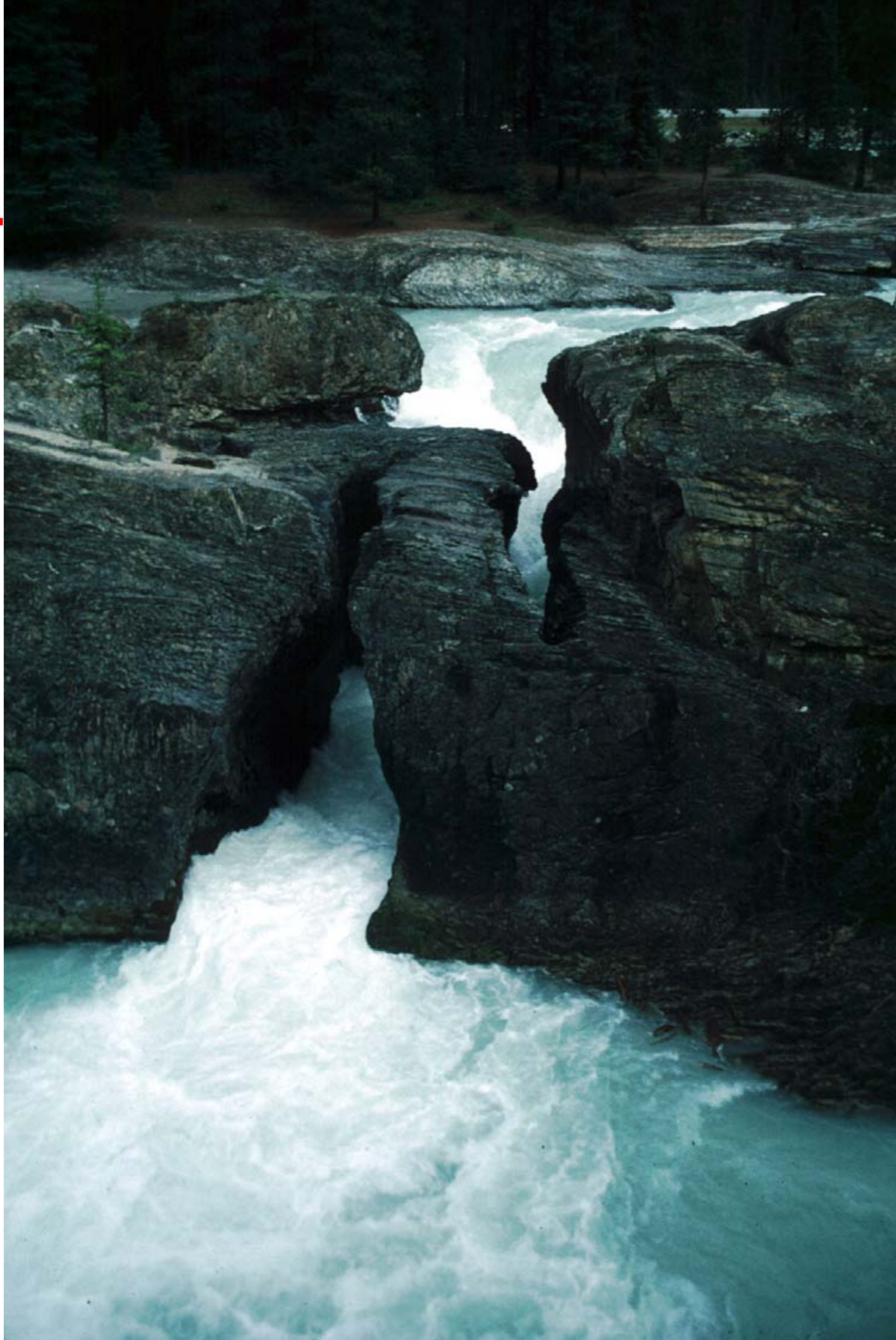


In steep terrain, where landslides are common, the rate of river incision sets the pace for landscape lowering because if the river can't carry away material stripped from the slopes AND carve the valley deeper, then the valleys will fill with sediment and the hills will lower.

Berkeley

Pacifica

Bedrock Channels



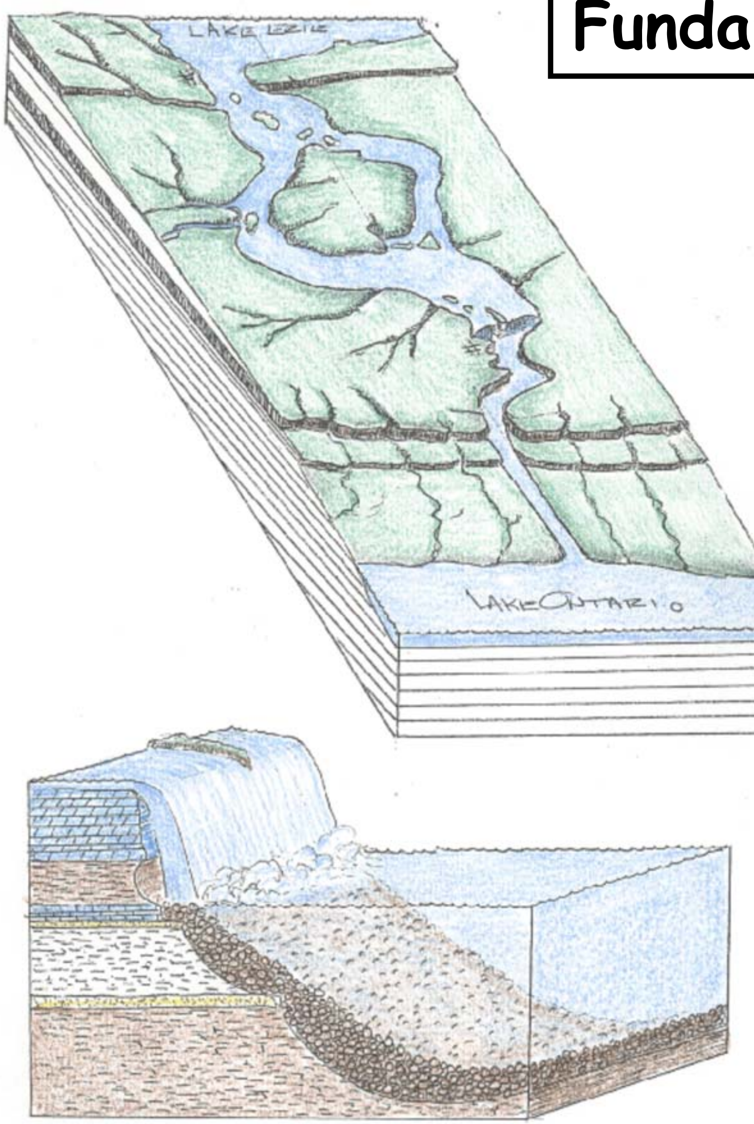
Channels floored by bedrock and lacking an alluvial bed cover.

Indicative of transport capacity well in excess of sediment supply.

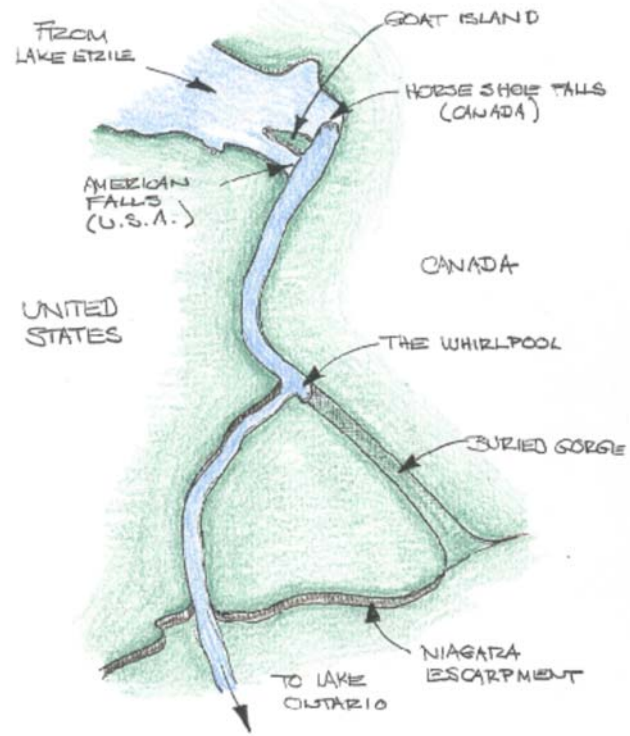
Waterfalls

Occur where barriers to down-cutting exist.
Usually only last as long as the barrier exists.

Fundamentally transient features!



THE GEOLOGY OF NIAGARA FALLS



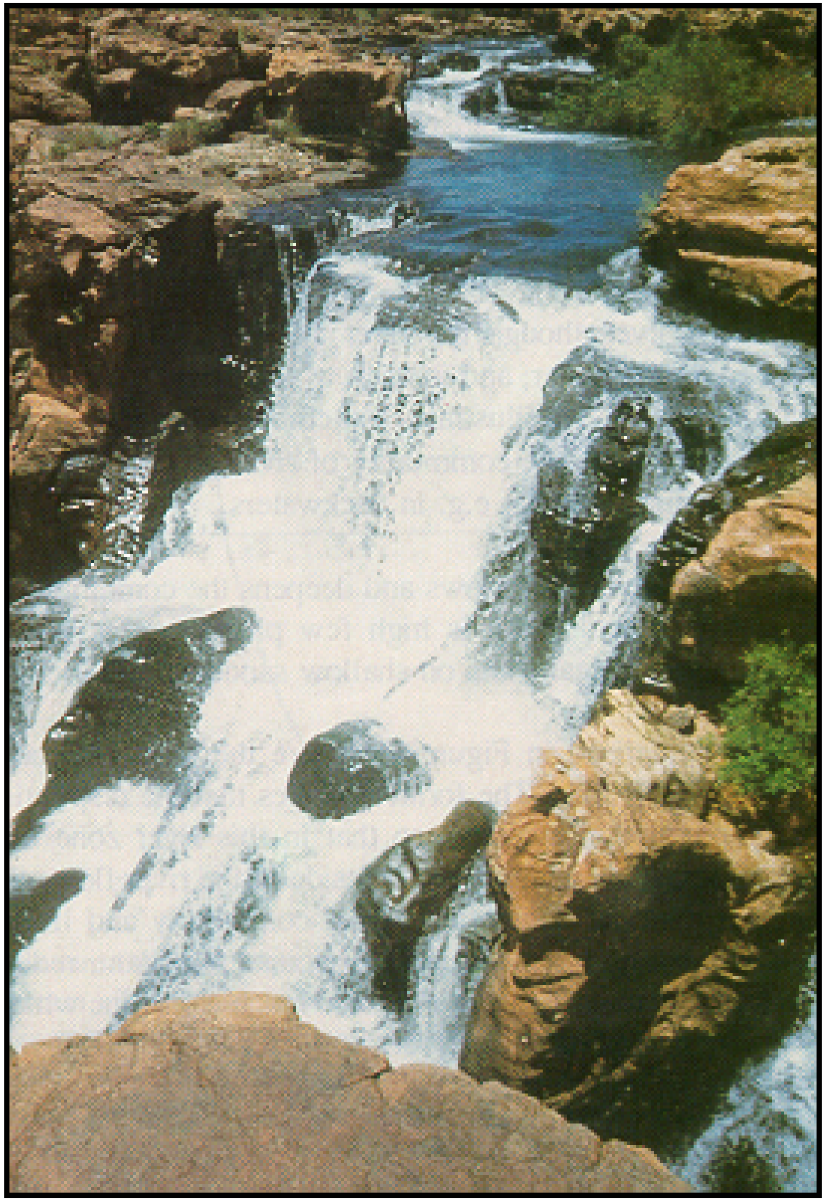
Waterfalls: "hanging valleys"

Comet Falls, Mt Rainier, Aug. 2001

Yosemite Falls

Waterfalls

Fine scale lithological contrasts such as from layers of hard and soft rock.



Base Level

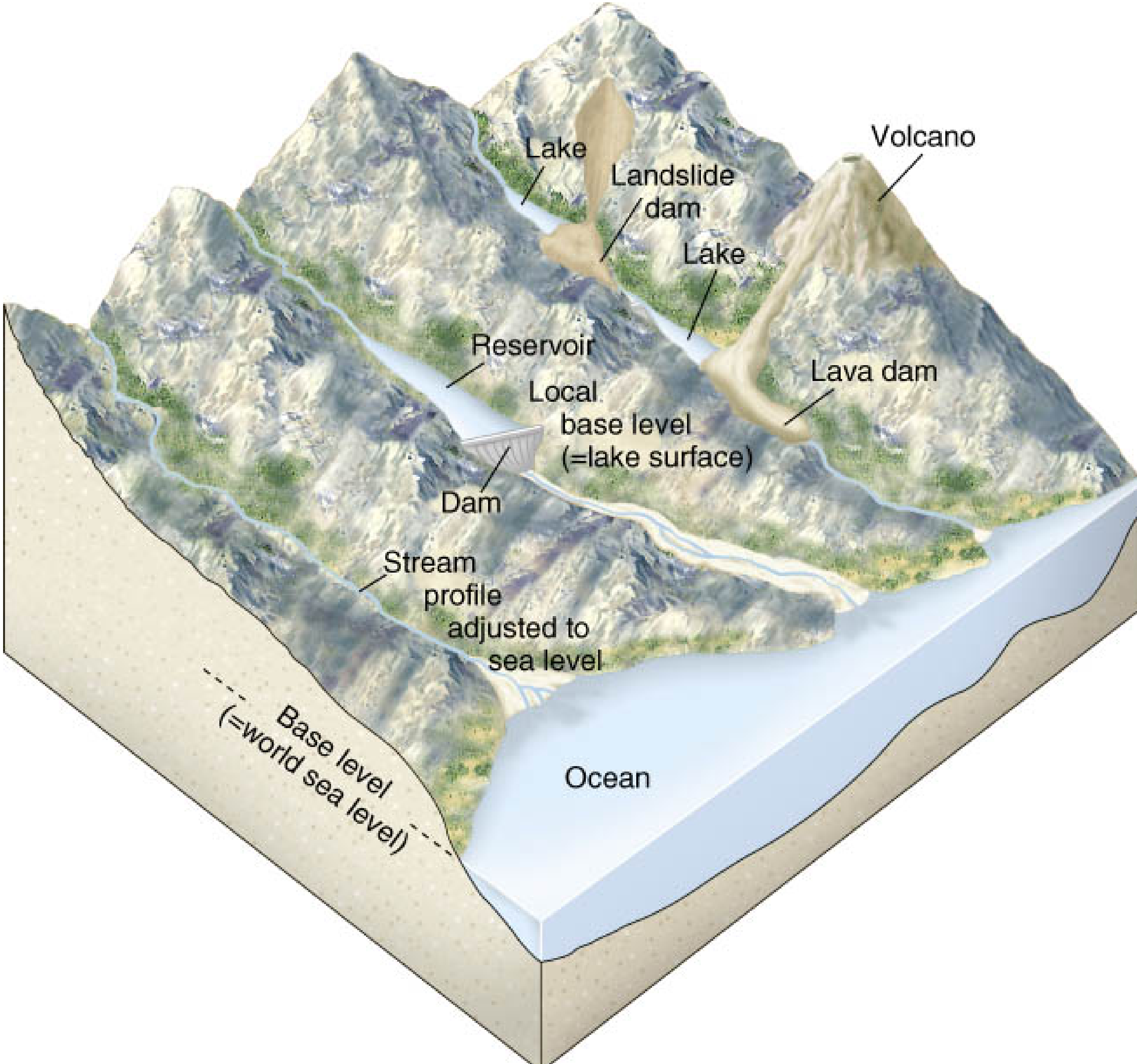
- The limiting level below which a stream cannot erode the land is called the base level of the stream.
- The base level for most streams is global sea level.

Base Level

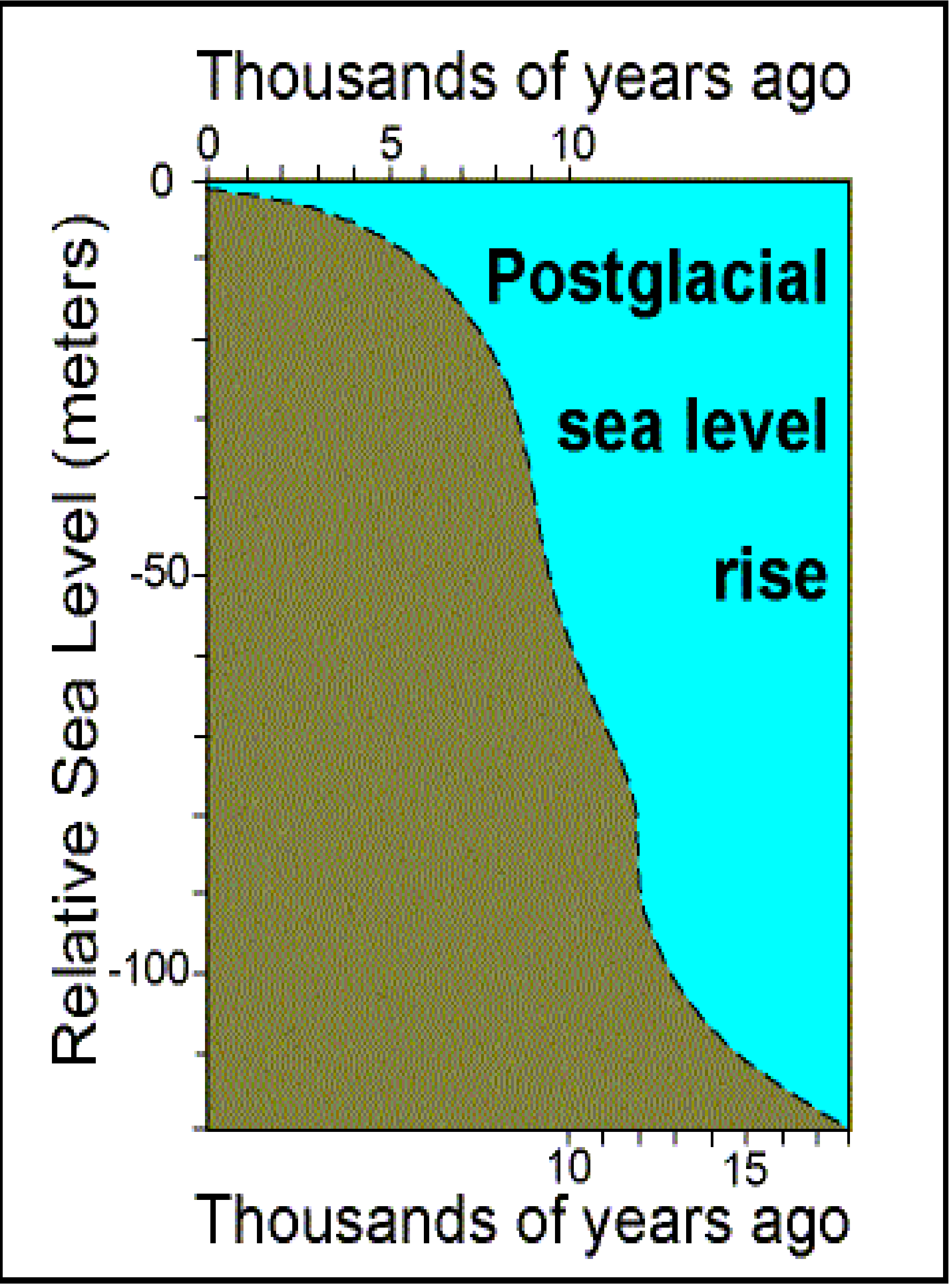
- Exceptions are streams that drain into closed interior basins having no outlet to the sea.

- Where the floor of a tectonically formed basin lies below sea level (for example, Death Valley, California), the base level coincides with the basin floor.

- When a stream flows into a lake, the surface of the lake acts as a local base level.



Volcano
Lake
Landslide dam
Lake
Reservoir
Lava dam
Local base level (=lake surface)
Dam
Stream profile adjusted to sea level
Base level (=world sea level)
Ocean



Holocene

Sea Level Changes

Primarily Cause ---

Glacial Melting

In The

Northern Hemisphere

Streams respond to changes in sea level.

Erode rapidly downward when sea level falls.

Deposit rapidly when sea level rises.

Bedrock channel erosion

- Streams erode rock and sediment over which if flows and are very effective in developing landscapes

- Streams erode rock and sediment in three main ways
    - Hydraulic action
    - Solution
    - Abrasion

Bedrock channel erosion

Hydraulic Action – the ability of flowing water to pick up and move rock and/or sediment

- Running water can flow into a fracture or joint, forcing a fragment loose and pushing it along the streambed
- Pressure of flowing water and swirling eddies lift the fragment or grain
- Hydraulic action is very effective at the base of rapids and waterfalls

Bedrock channel erosion

- Solution – chemical weathering (dissolution) of limestone over which a stream flows
  - Flowing water increases the dissolution rate and is effective in deepening a stream channel
  - Dissolution of a calcite cement from a sandstone may allow the grains to be set free by hydraulic action
- Abrasion – the grinding away of the stream channel by friction and impact with grains and fragments carried by the stream

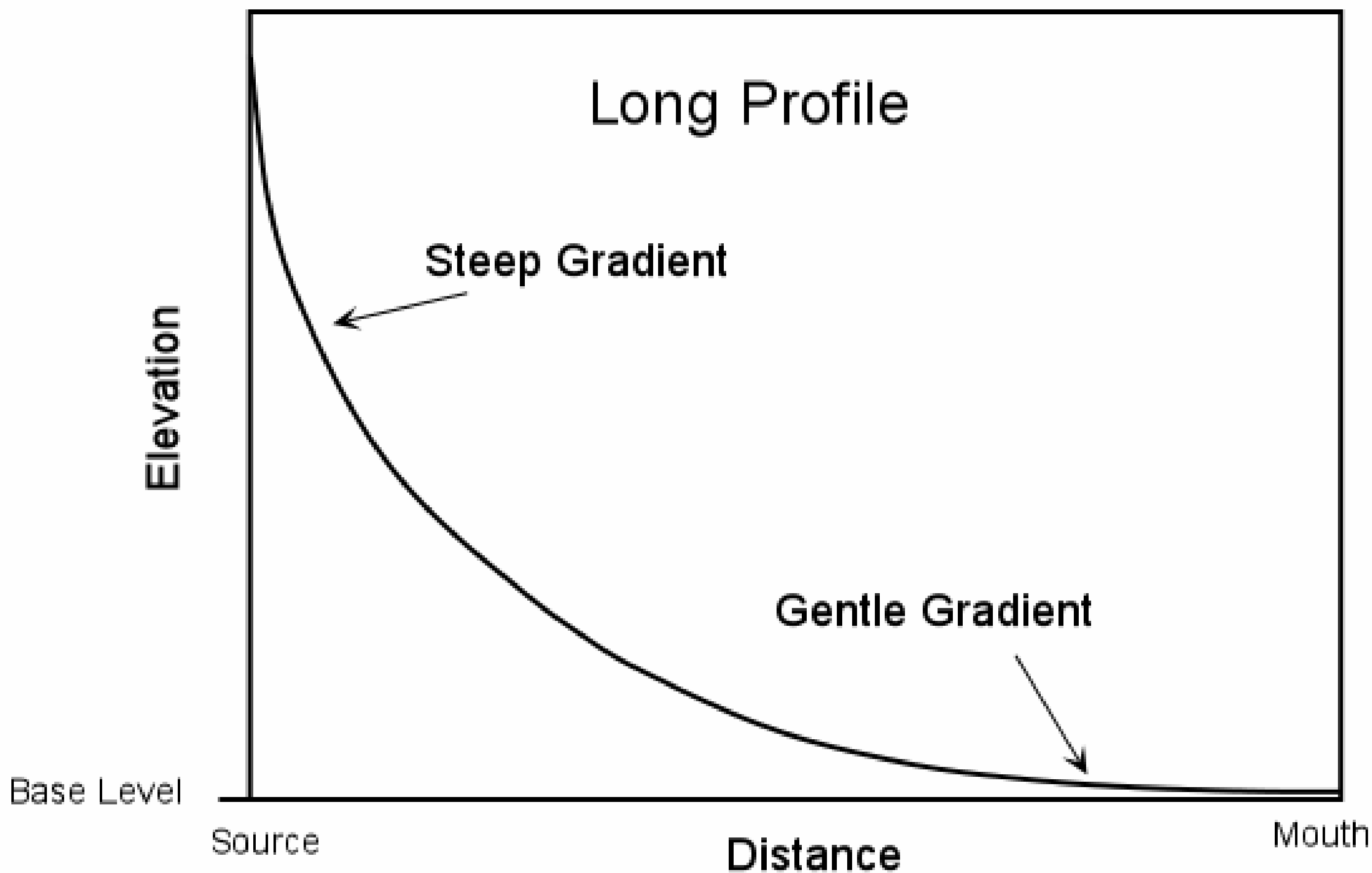
Graded Rivers

Graded rivers are those which maintain a balance between erosion and uplift and/or deposition.

Graded Rivers

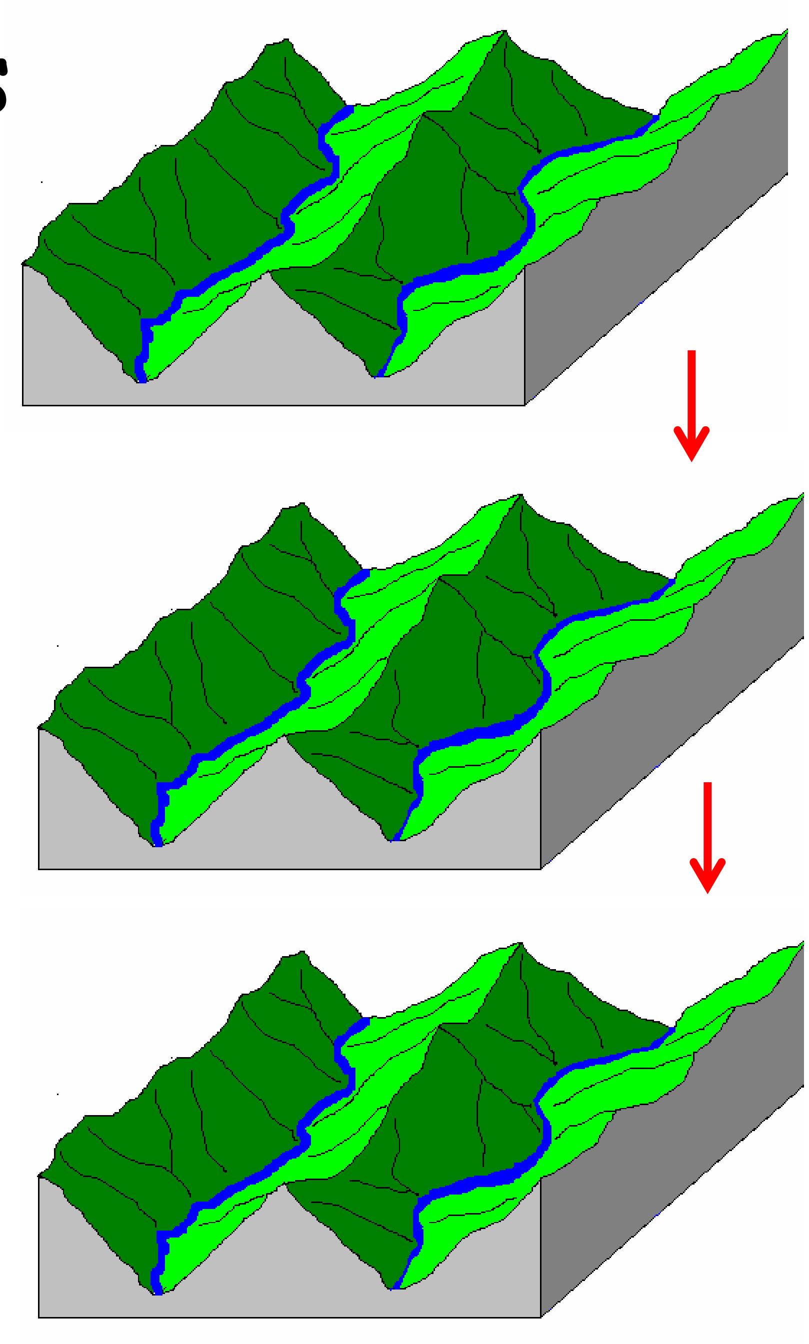
Steady state river profiles are concave up because of the trade off between greater discharge and lower slope as drainage area increases downtream.

Graded Rivers



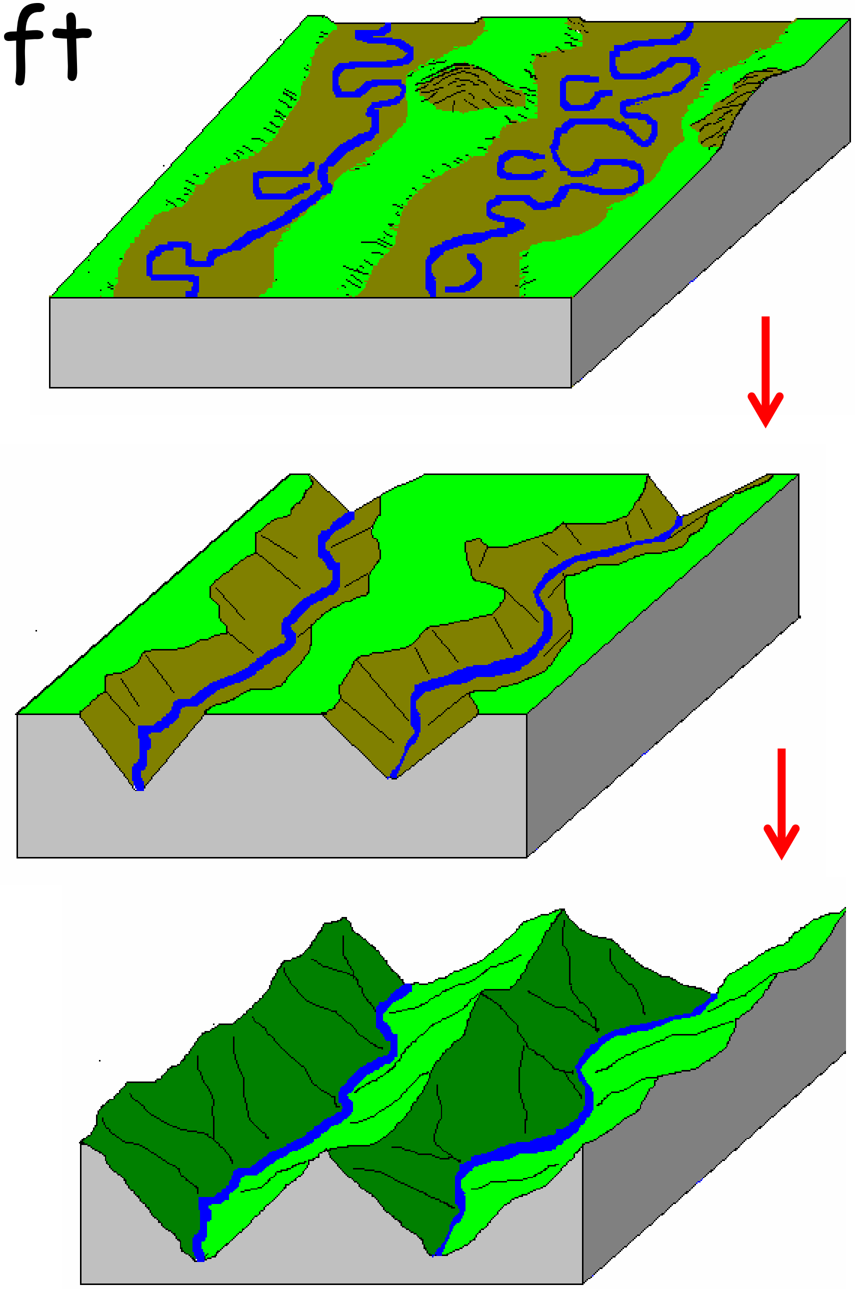
Steady-state channels

When erosion rates balance uplift rates topography can achieve a steady state, despite active erosion.



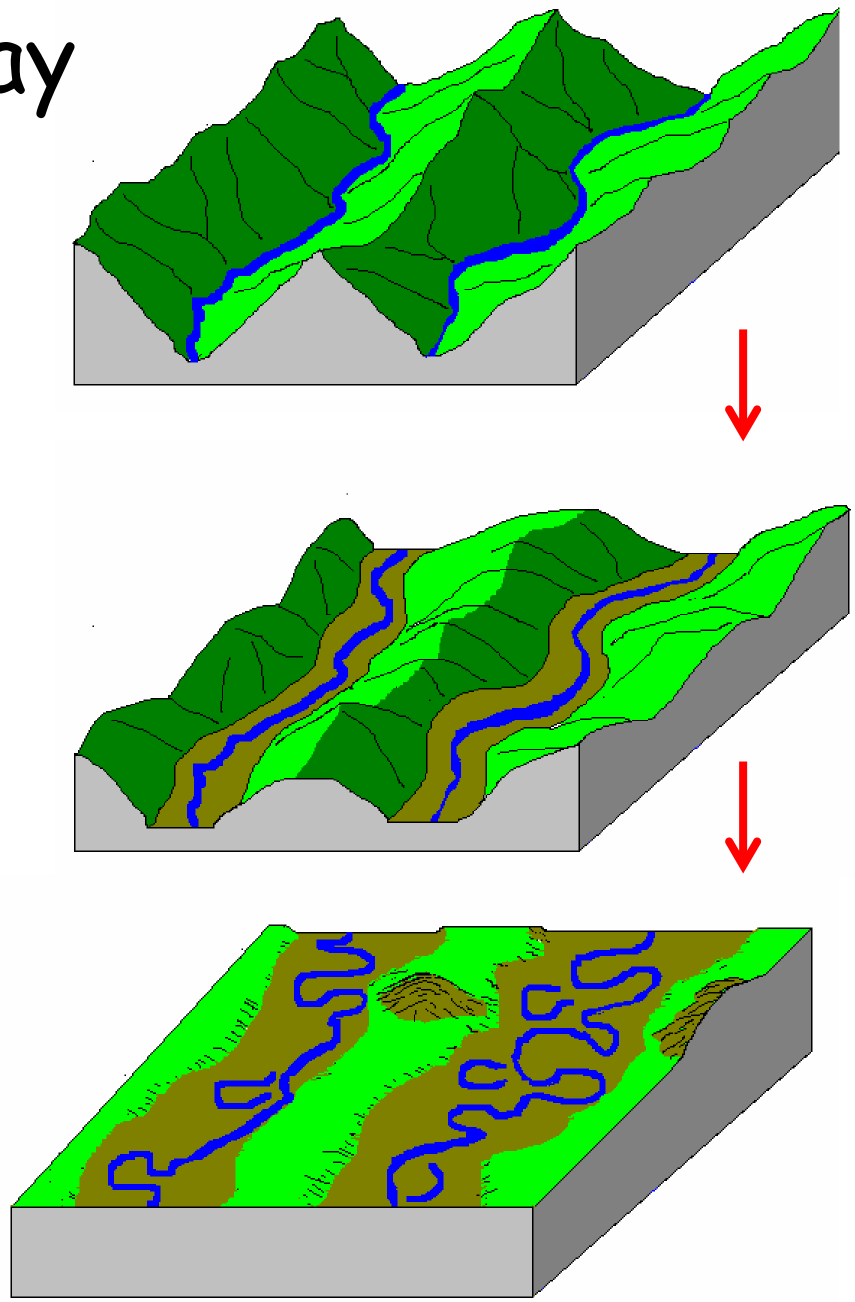
Mountain range uplift

When uplift rates exceed erosion rates topography rises, rivers incise into the rising topography and eventually sculpt mountains.

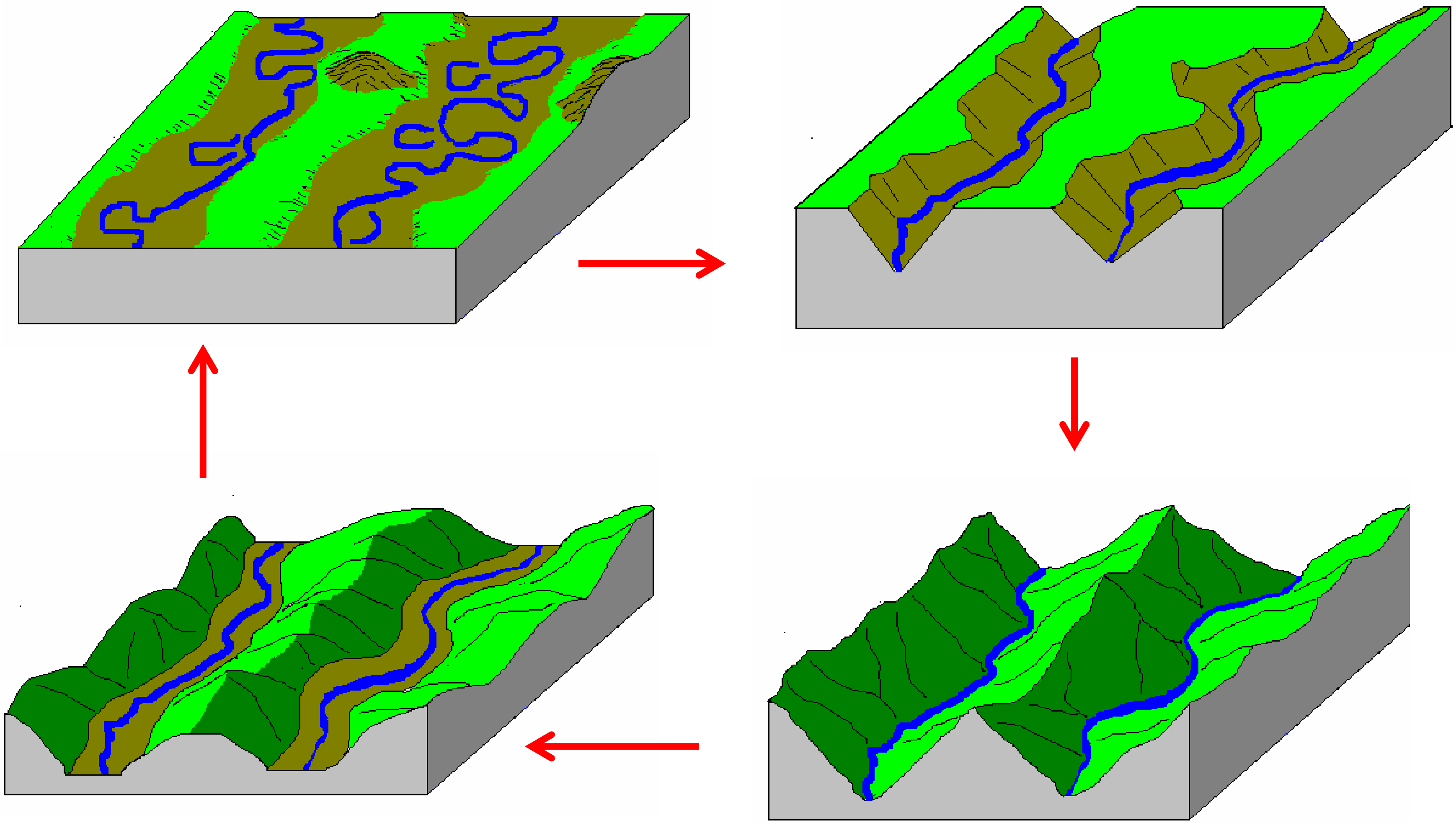


Mountain range decay

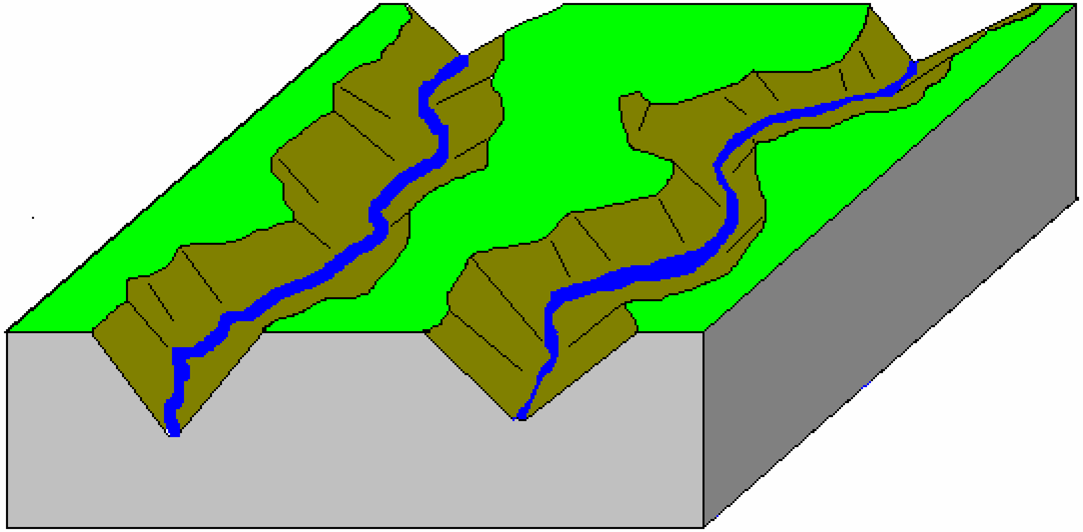
When erosion rates exceed uplift rates rivers wear down mountainous topography and eventually re-create low-gradient depositional plains.



Physiographic Cycle

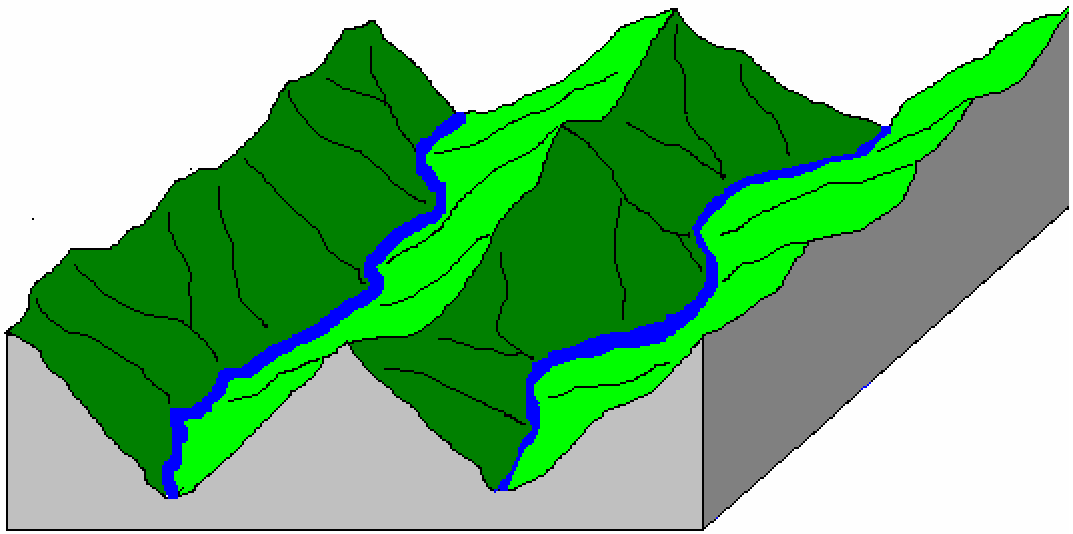


Youth



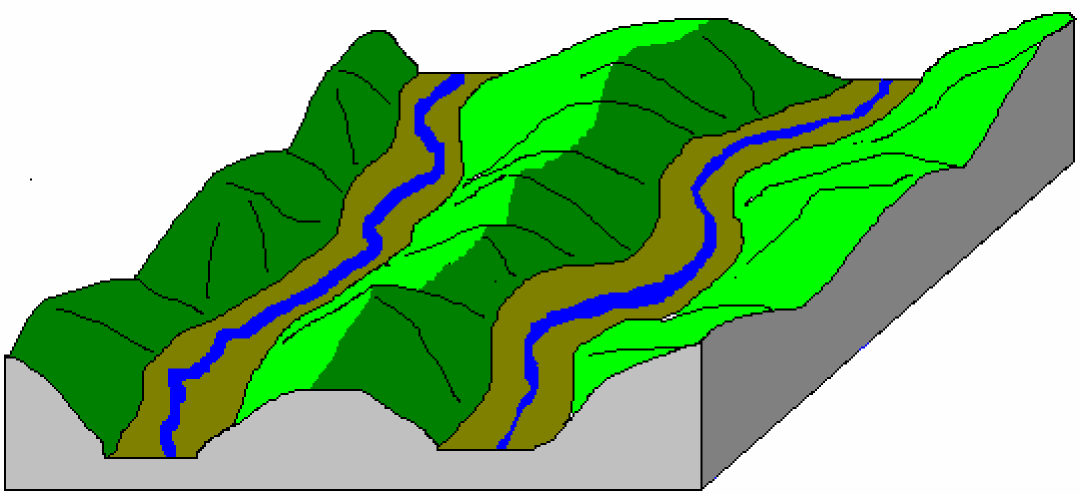
- V-Shaped Valley
- Rapids
- Waterfalls
- No Flood Plain
- Drainage Divides Broad and Flat, Undissected by Erosion
- Valley Being Deepened
- General Agreement on this stage, lots of examples

Maturity



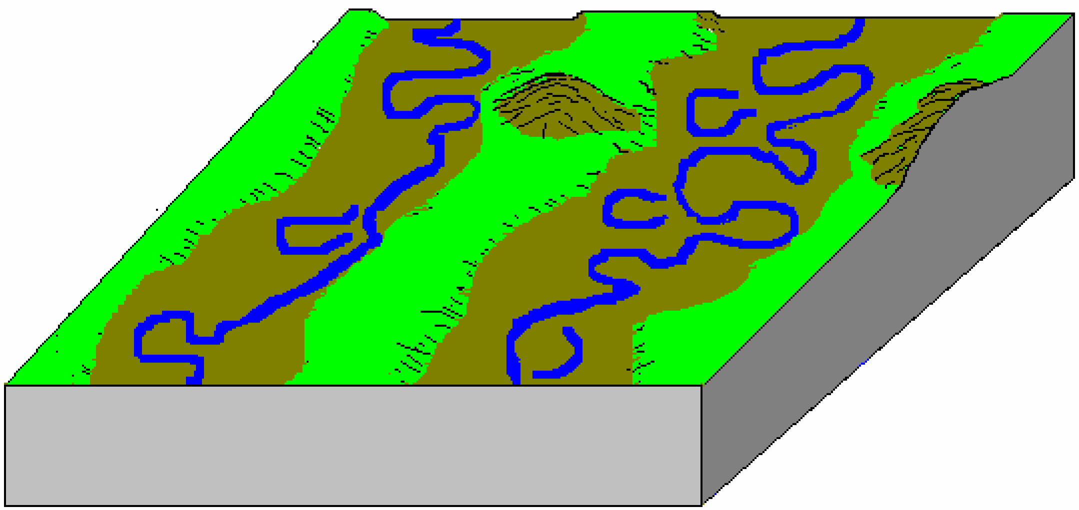
- V-Shaped Valley
- Beginnings of Flood Plain
- Sand and Gravel Bars
- Sharp Divides
- Relief Reaches Maximum
- Valleys stop deepening
- General Agreement on this stage, lots of examples

Maturity (Late)



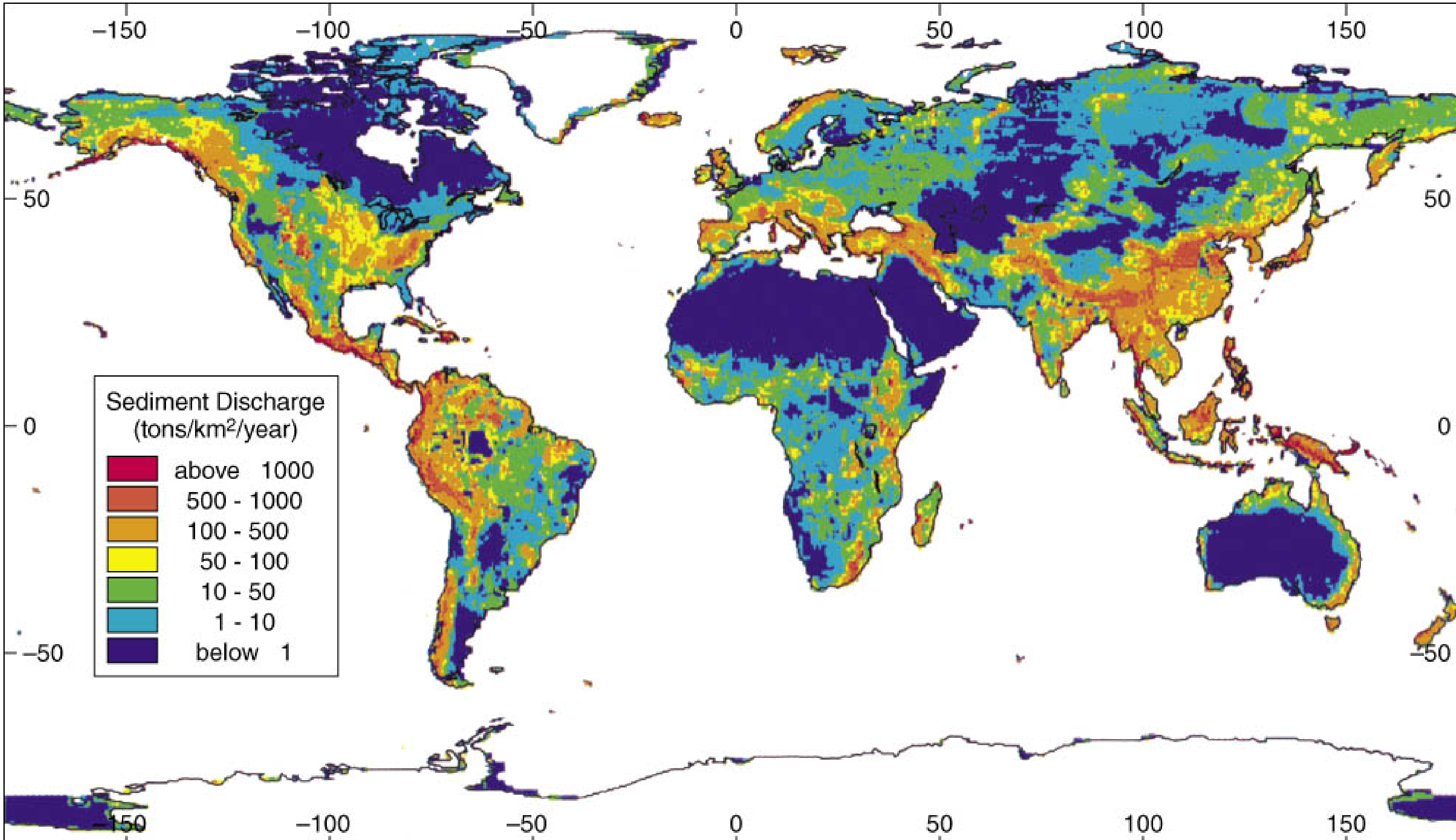
- Valley has flat bottom
- Narrow Flood Plain
- Divides begin to round off
- Relief diminishes
- Sediment builds up, flood plain widens
- River begins to meander
- Many geologists believe slopes stay steep but simply retreat.

Old Age



- Land worn to nearly flat surface (peneplain)
- Resistant rocks remain as erosional remnants (monadnocks)
- Rivers meander across extremely wide, flat flood plains

Global Sediment Yield



Range of 1 m per million years to 1 m per year

Sediment Yield

- In southern Alaska and the southern Andes, large active glaciers contribute to high sediment yields.

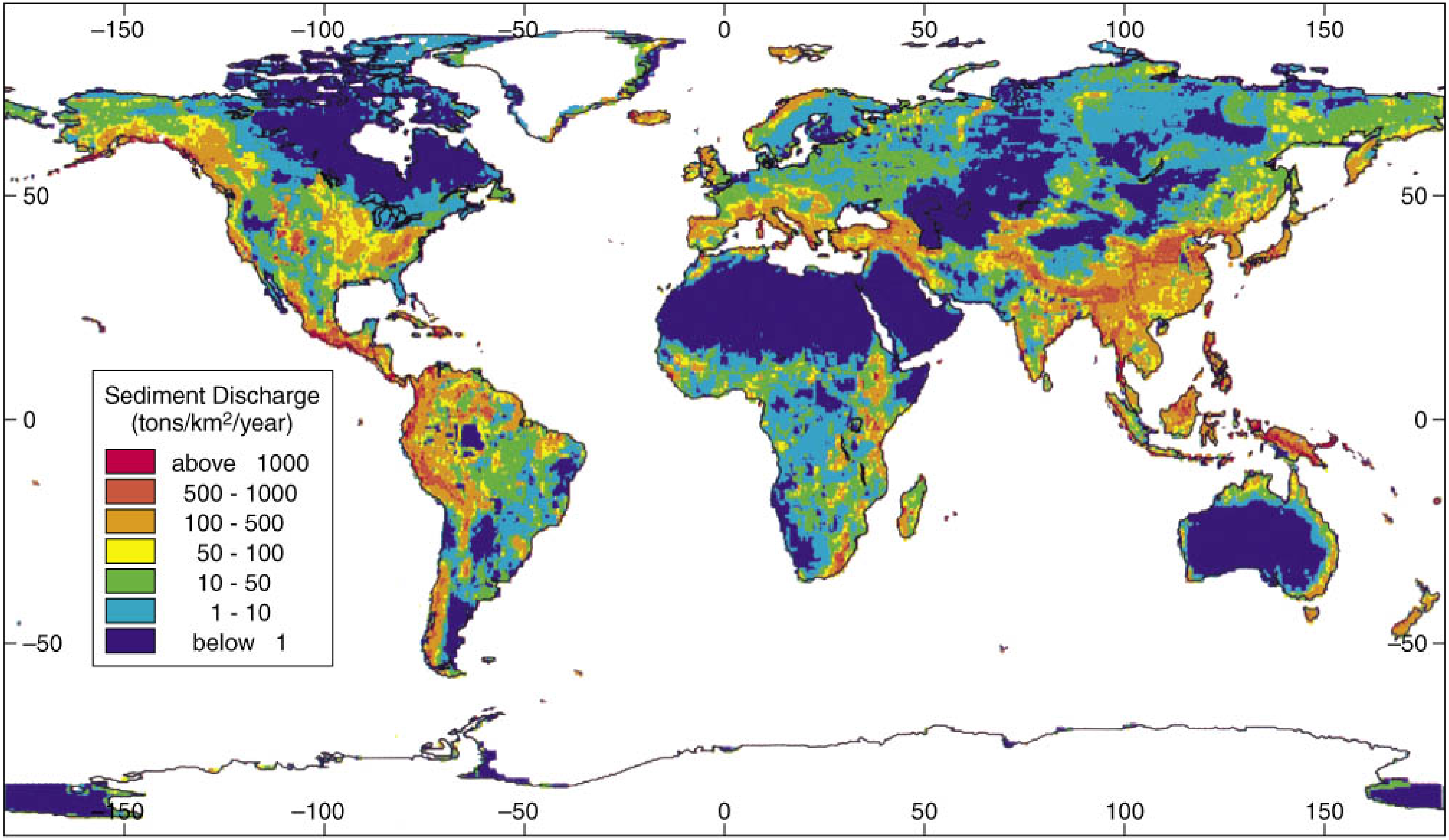
- The clearing of forests, cultivation of lands, damming of streams, construction of cities, and numerous other human activities also affect erosion rates and sediment yields.

Sediment Yield

- In arid regions, reduced precipitation limits vegetation, making the land vulnerable to erosion.
  - Areas receiving abundant precipitation may actually experience less erosion than some relatively dry regions,
  - Fields measurements suggest that some of the greatest local sediment yields are from desert landscapes.

- Monsoon regions of southeastern Asia receive abundant precipitation that generates high runoff.

Modern sediment yield is >10 long-term (geological) rate.



Dams

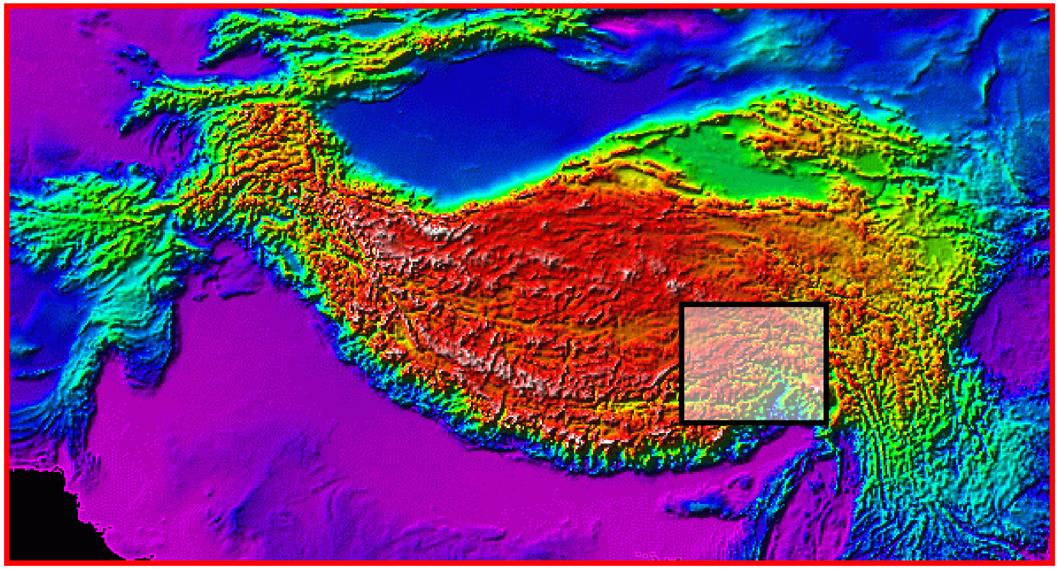
- Both natural and artificial dams built across a stream create a reservoir that traps nearly all the sediment that the stream formerly carried to the ocean.

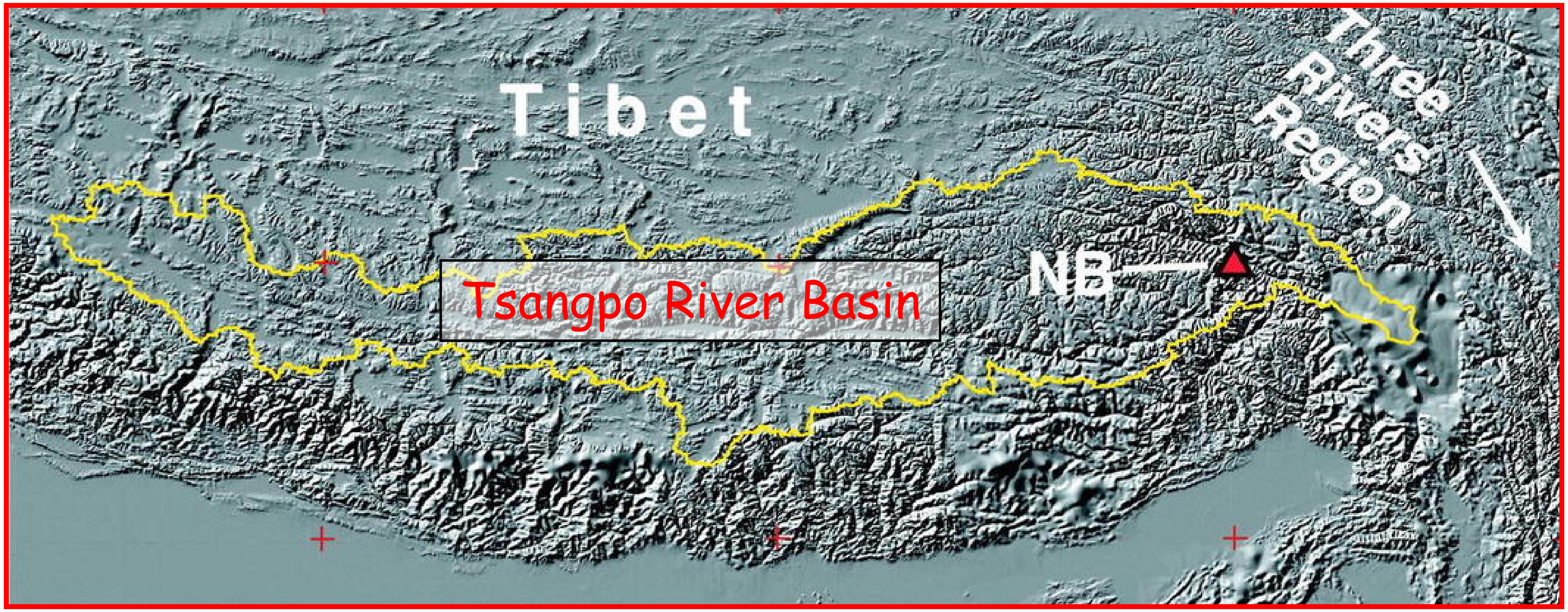
- Globally, dams have reduced the sediment load that reaches the oceans by half.

Natural Dams

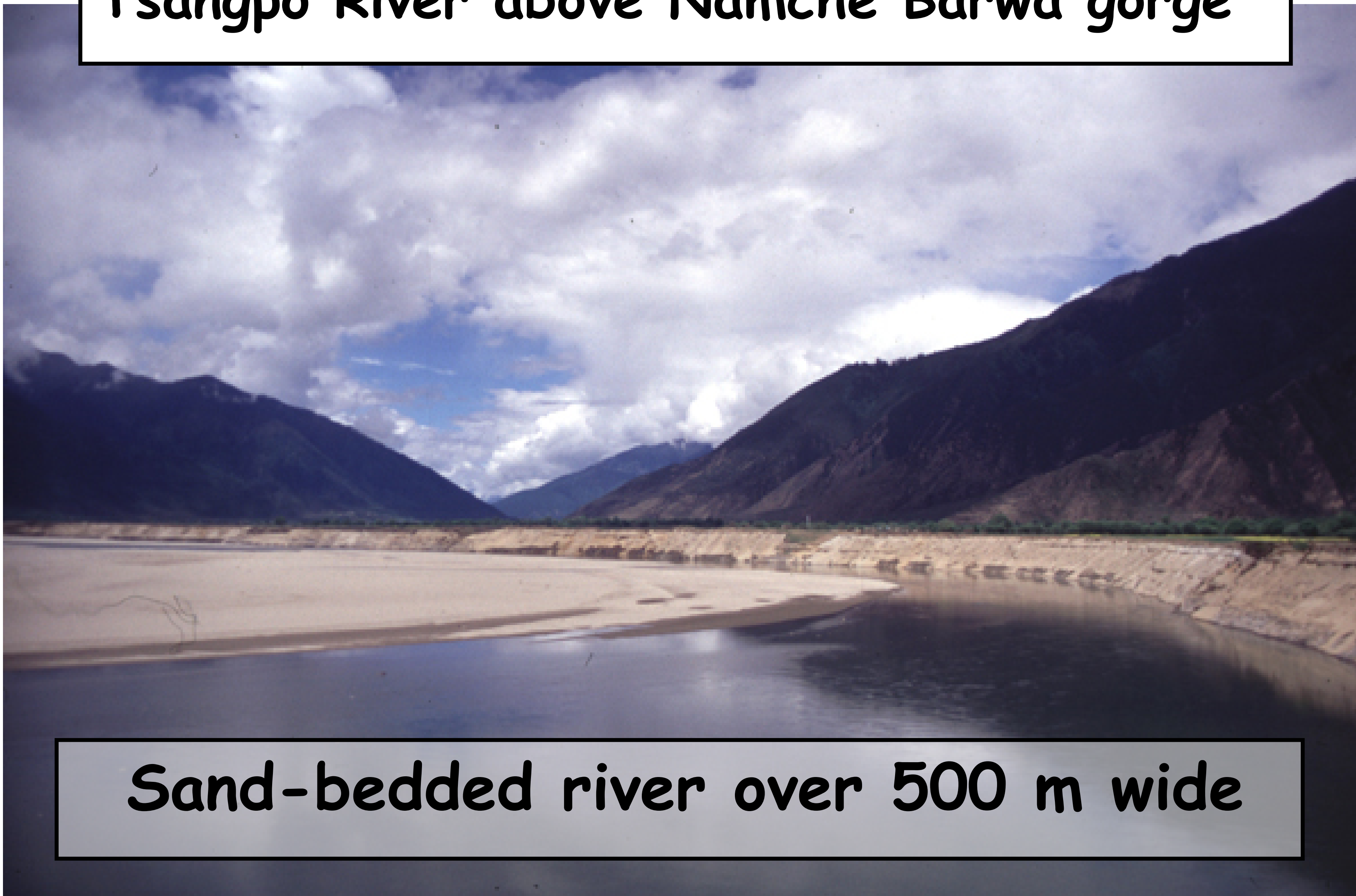
- The courses of many streams are interrupted by lakes that have formed behind natural dams consisting of:
  - Landslide sediments.
  - Glacial deposits.
  - Glacier ice.
  - Lava flows.
  -
- Such a dam acts as a local base level and creates an irregularity in a stream's long profile.

Natural glacier dams on the Tsangpo River, eastern Tibet

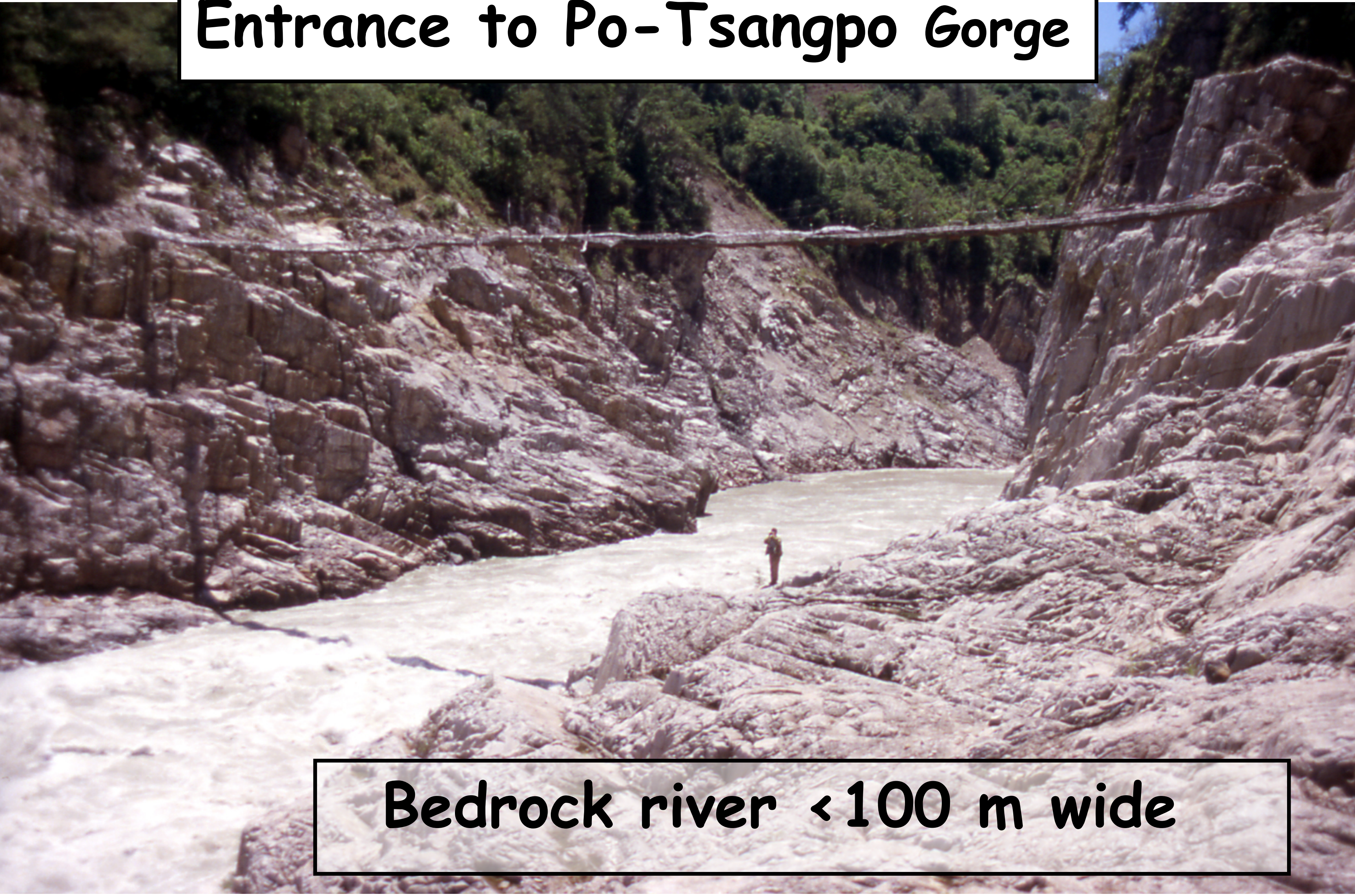




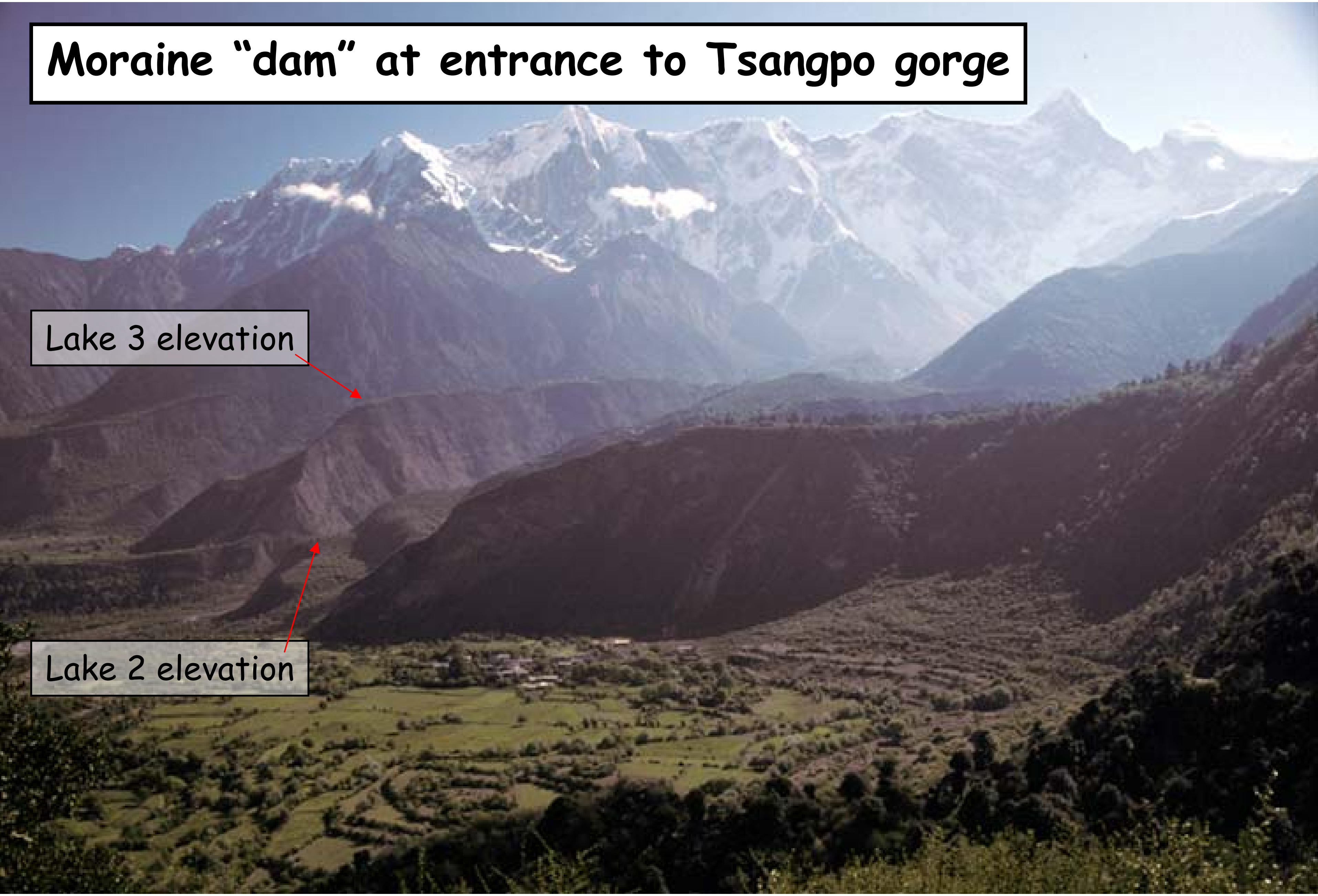
Tsangpo River above Namche Barwa gorge



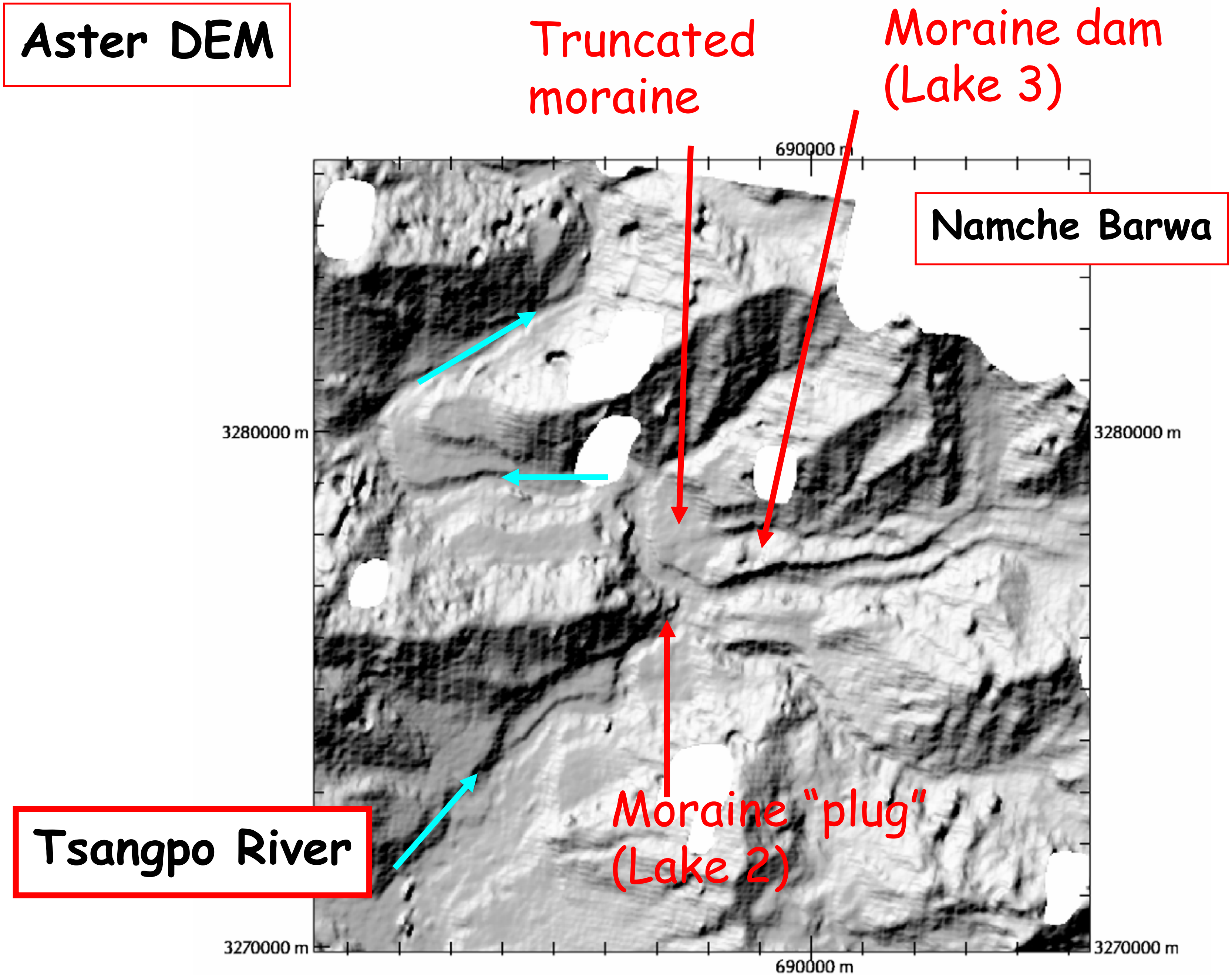
Entrance to Po-Tsangpo Gorge

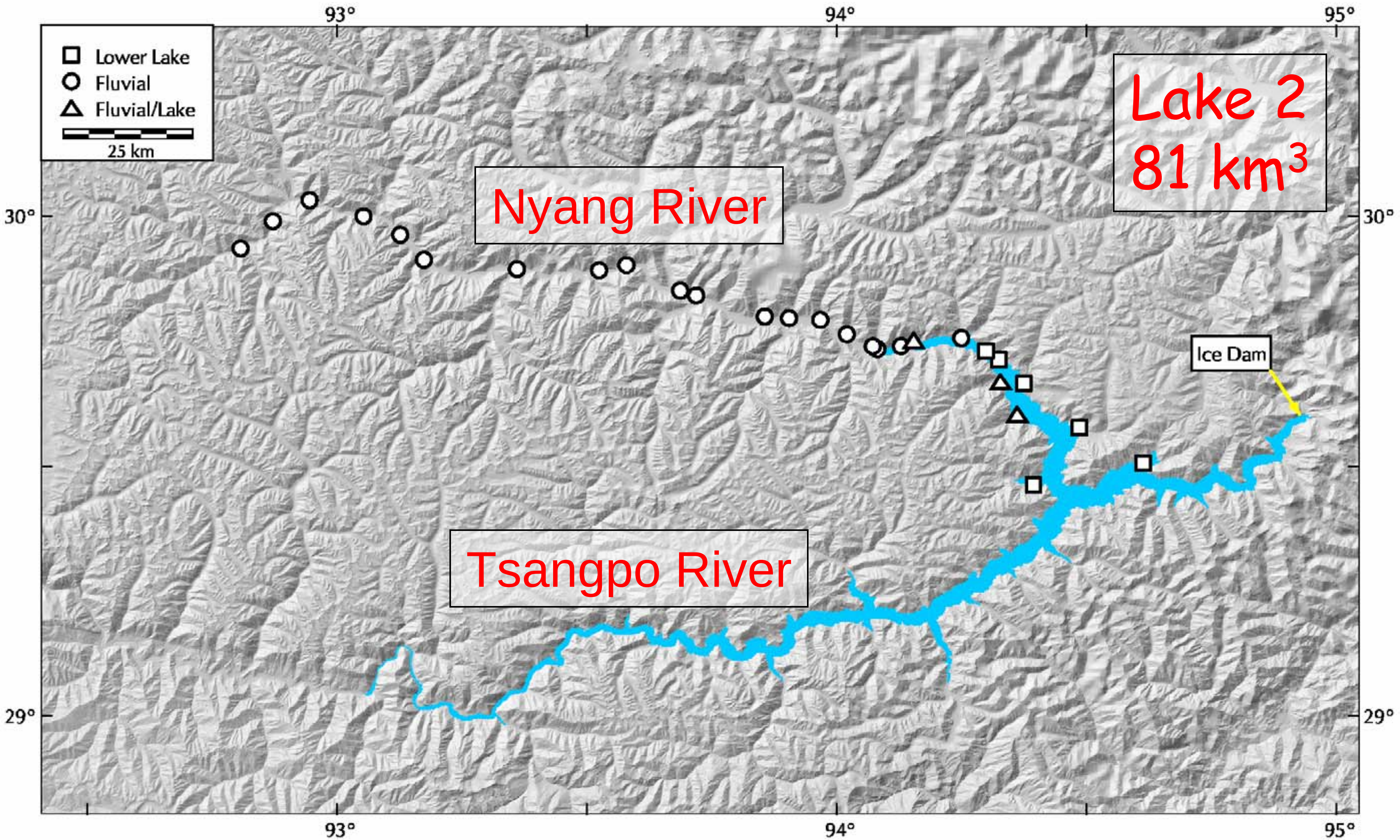


Moraine “dam” at entrance to Tsangpo gorge

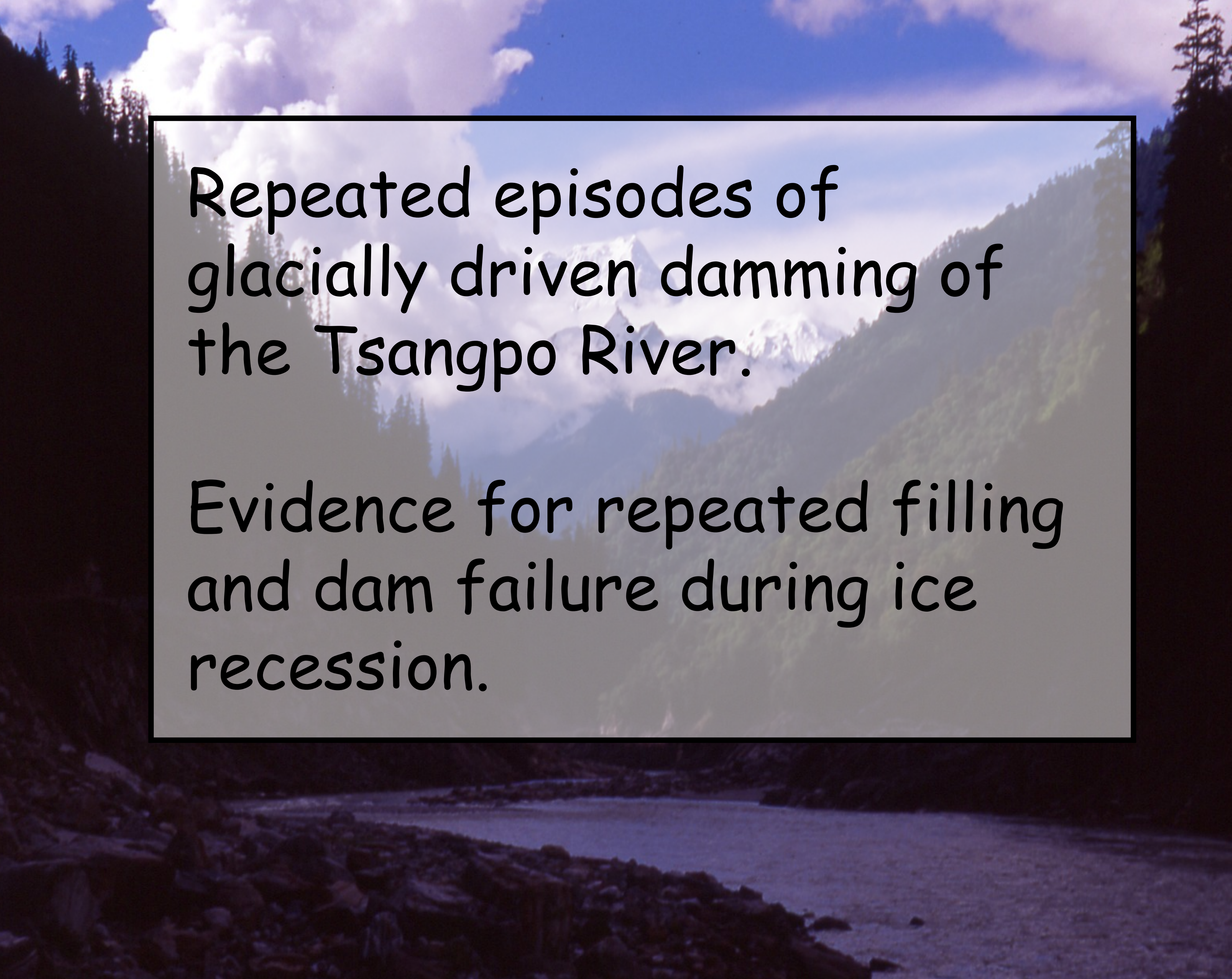


Moraine "plug" at entrance to Tsangpo gorge


Aster DEM
Truncated moraine
Moraine dam (Lake 3)
Namche Barwa
690000 m
3280000 m
3280000 m
Moraine "plug" (Lake 2)
Tsangpo River
3270000 m
3270000 m
690000 m

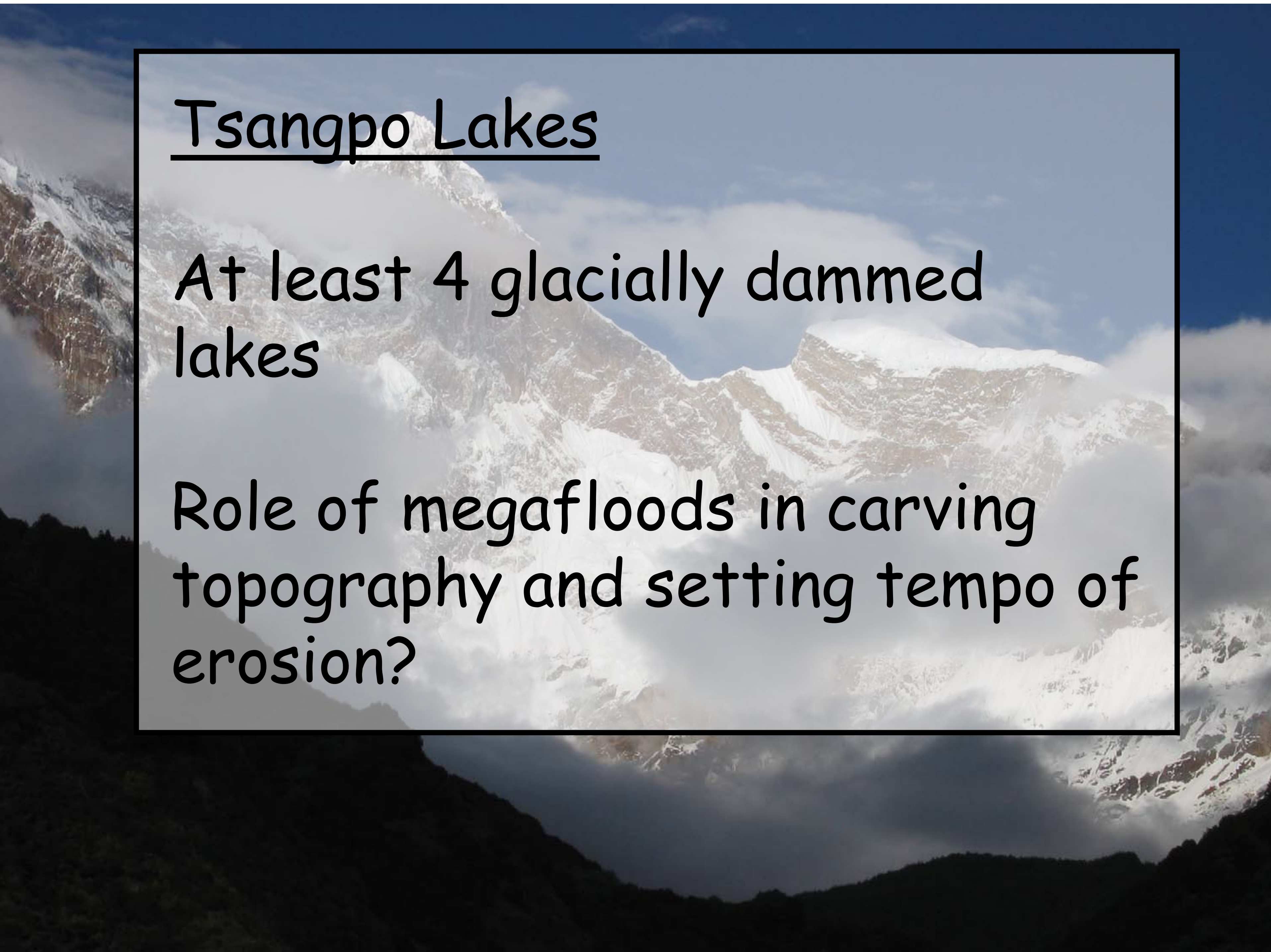

Lower Lake
Fluvial
Fluvial/Lake
25 km
93°
94°
95°
30°
29°
Lake 2
81 km^3
Nyang River
Tsangpo River
Ice Dam

Delta terrace from tributary



Repeated episodes of glacially driven damming of the Tsangpo River.

Evidence for repeated filling and dam failure during ice recession.



Tsangpo Lakes

At least 4 glacially dammed lakes

Role of megafloods in carving topography and setting tempo of erosion?

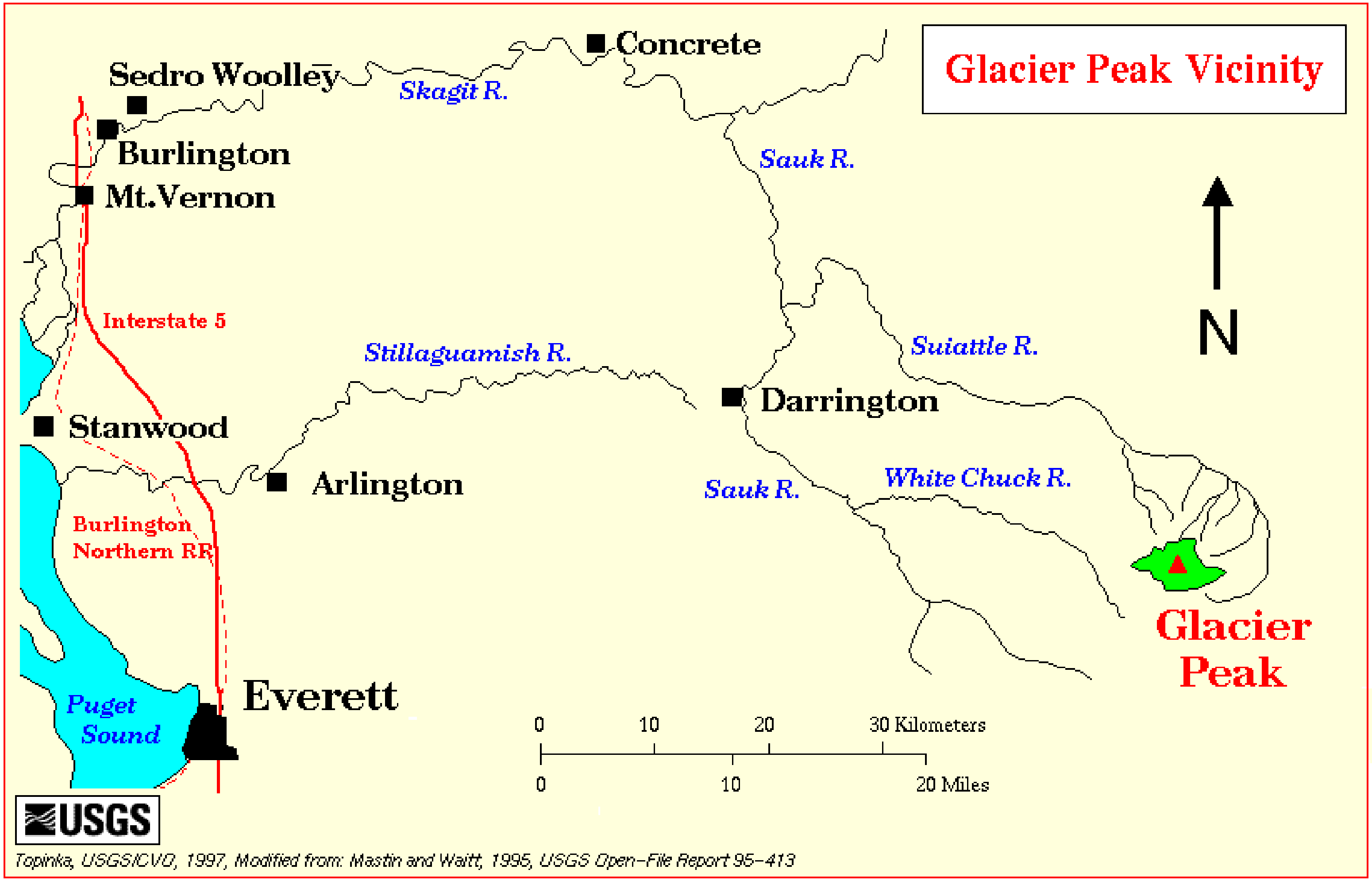
In the late 8th century, Padmasambhava brought Buddhism to Tibet. Locals tell of how he defeated the demon of the lake, thereby draining it and raising the valley's farmland from its waters.

Artificial Dams

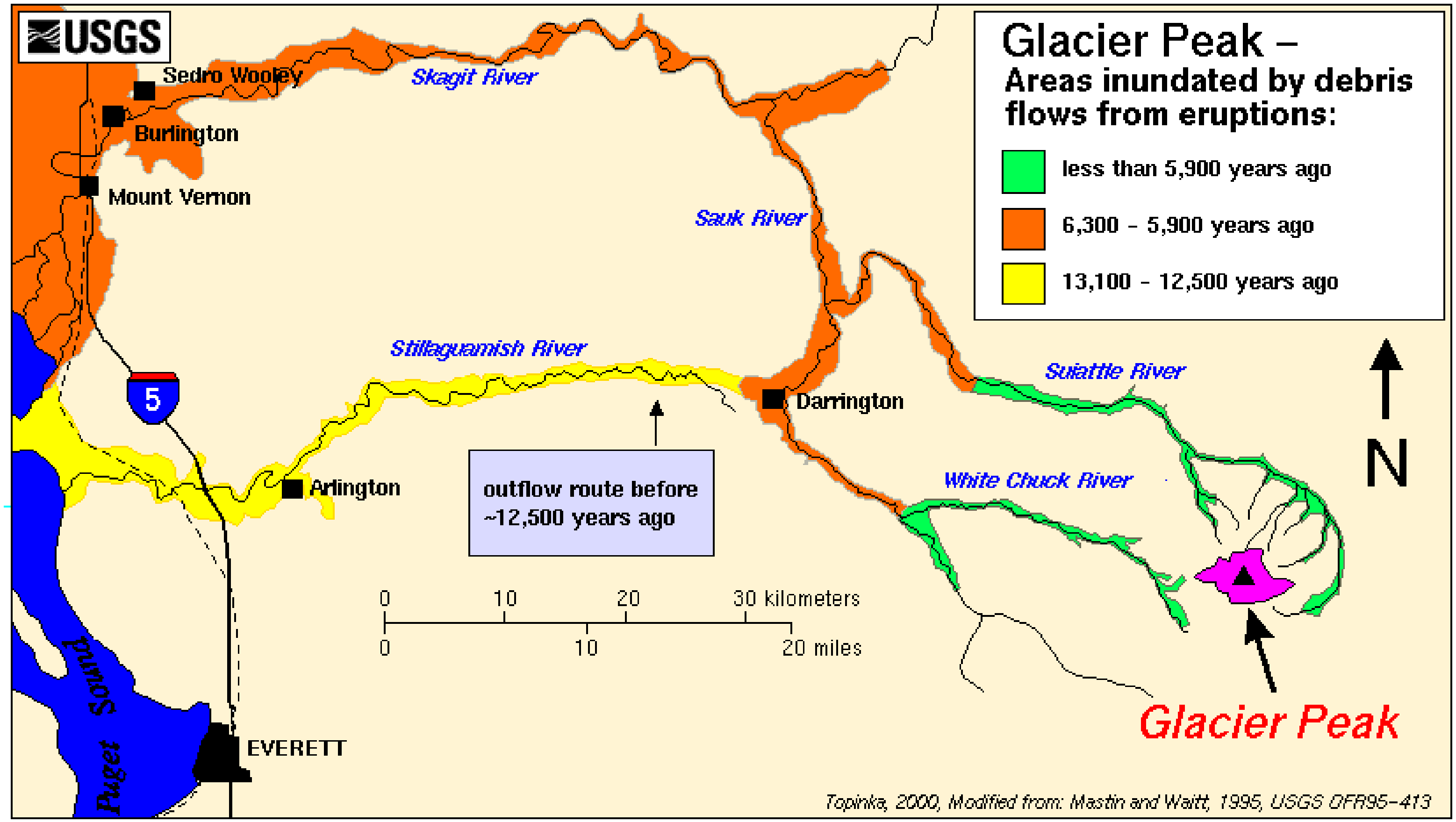
- Large artificial dams also disrupt the normal flow of water in a stream.

  - They are being constructed in ever-increasing numbers for:
    - Water storage.
    - Flood control.
    - Hydroelectric power.

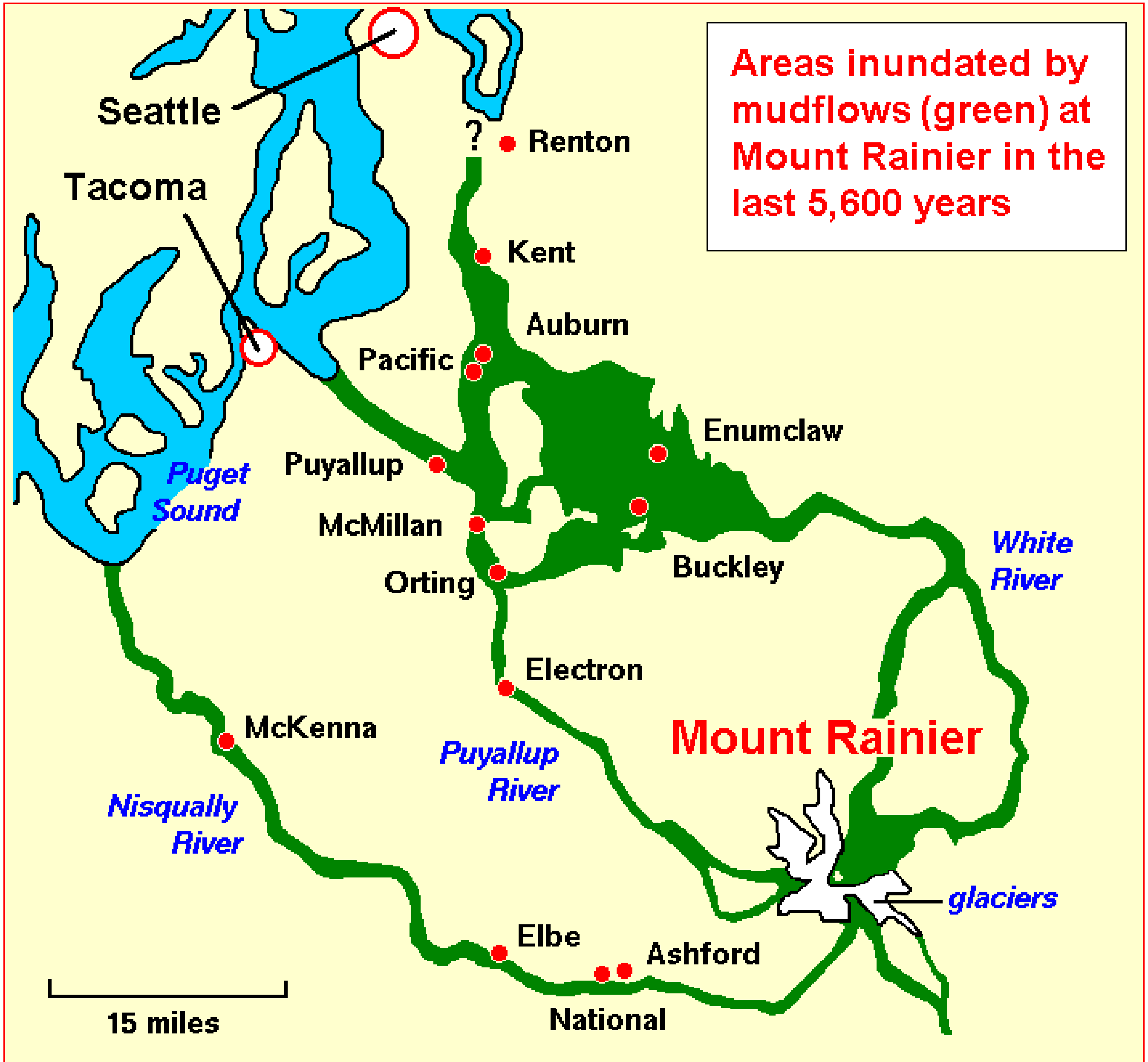
1976 Teton Dam, ID



Glacier Peak Vicinity
Concrete
Sedro Woolley
Skagit R.
Burlington
Sauk R.
Mt.Vernon
Interstate 5
Stillaguamish R.
Suiattle R.
N
Darrington
Stanwood
Arlington
Sauk R.
White Chuck R.
Burlington
Northern RR
Glacier
Peak
Everett
Puget
Sound
0
10
20
30 Kilometers
0
10
20 Miles
USGS
Topinka, USGS/CVO, 1997, Modified from: Mastin and Waitt, 1995, USGS Open-File Report 95-413

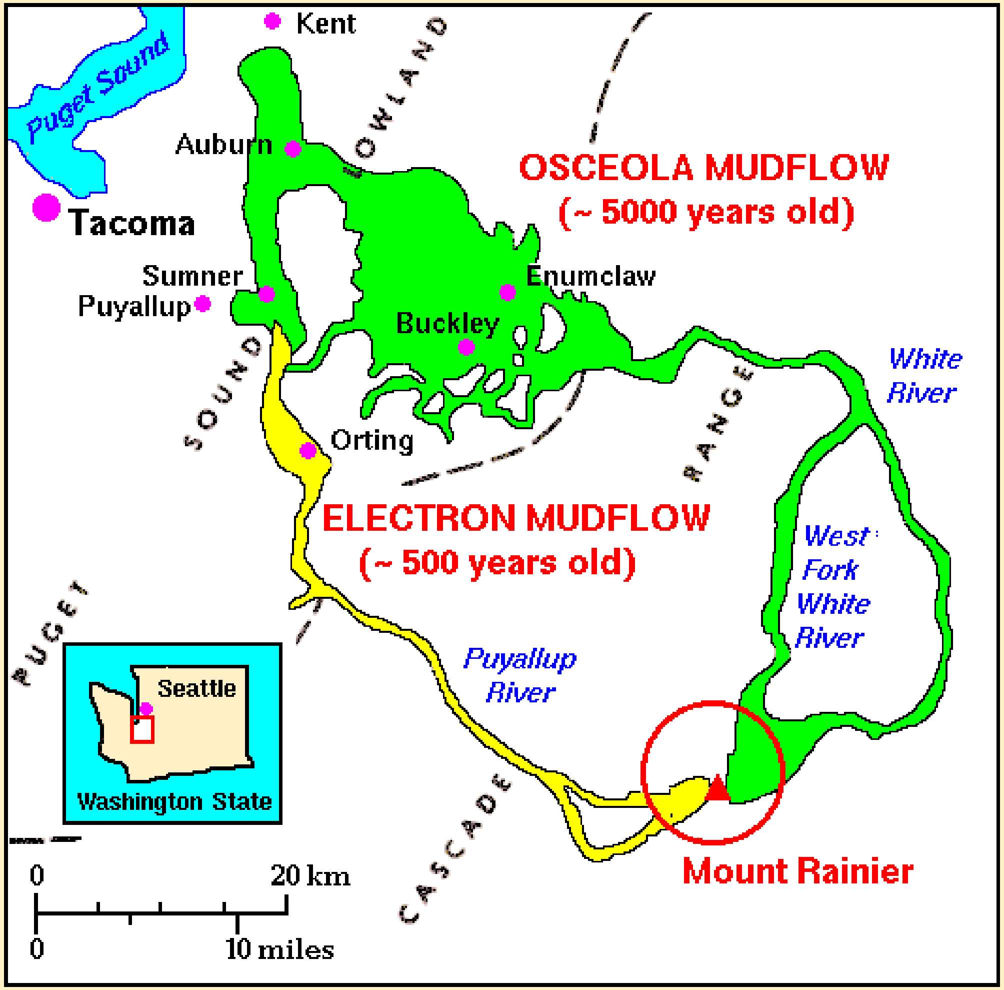


USGS
Glacier Peak –
Areas inundated by debris flows from eruptions:
less than 5,900 years ago
6,300 - 5,900 years ago
13,100 - 12,500 years ago
Sedro Wooley
Burlington
Mount Vernon
Skagit River
Sauk River
Stillaguamish River
Suiattle River
White Chuck River
Darrington
Arlington
5
outflow route before ~12,500 years ago
0 10 20 30 kilometers
0 10 20 miles
N
Glacier Peak
Puget Sound
EVERETT
Topinka, 2000, Modified from: Mastin and Waitt, 1995, USGS OFR95-413



USGS Topinka, USGS/CVO, 2001; Modified from: Sisson, 1995, USGS Open-File Report 95-642

Extent of Two Holocene Mudflows from Mount Rainier



Topinka, USGS/CVO, 1997, Modified from: Crandell, et.al., 1979


When will that volcano blow again, anyway?