mountain rivers

fixed channel boundaries
(bedrock banks and bed)

high transport capacity

low storage

input ≈ output

strong interaction between
streams & hillslopes

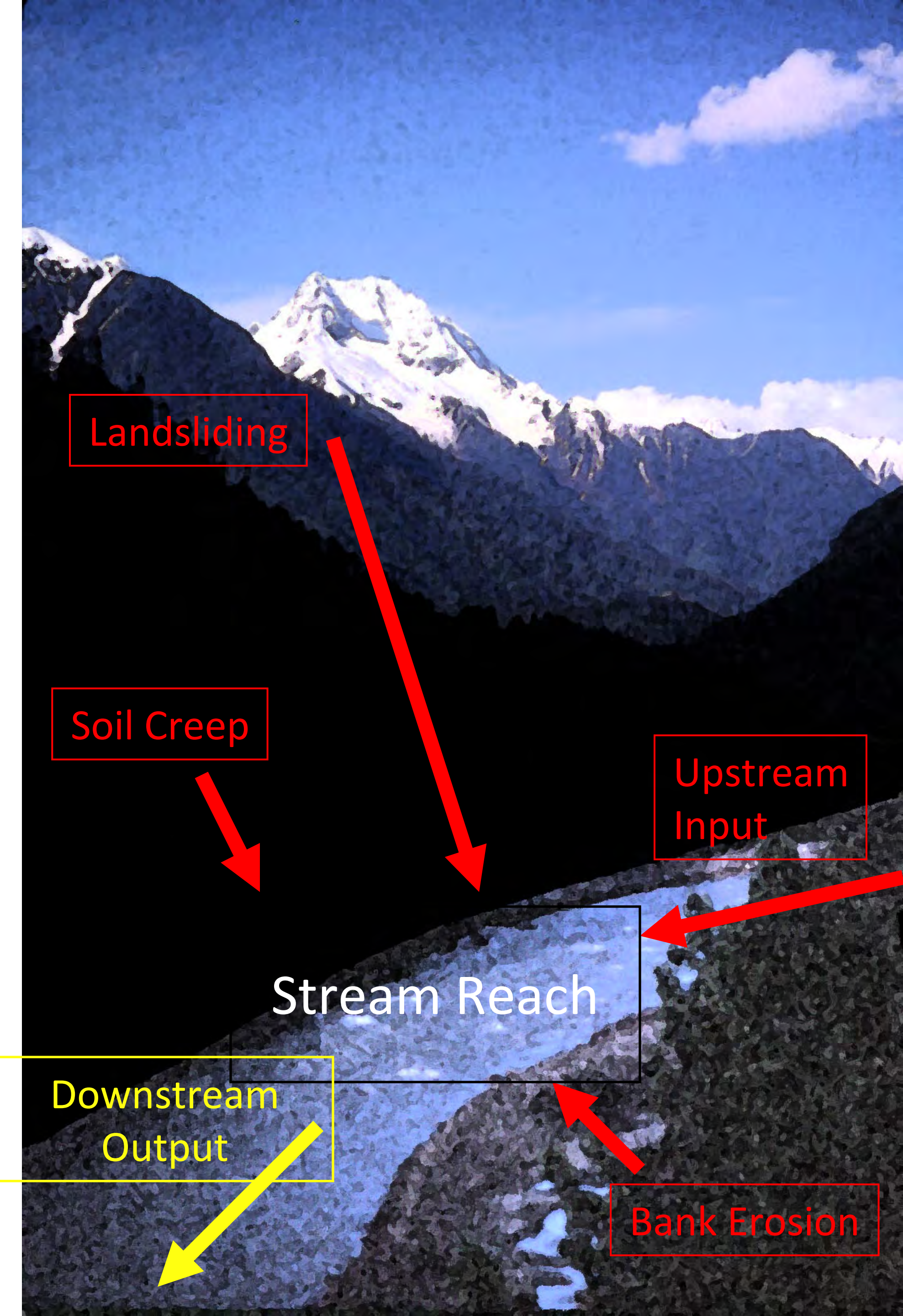
Sediment Budgets for Mountain Rivers

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

Input = Output

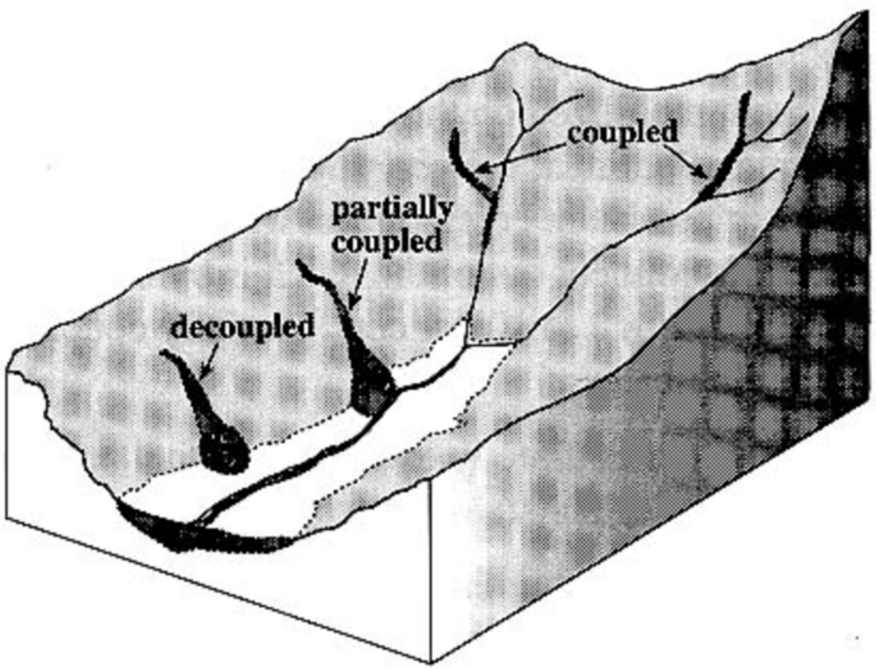
$\Delta S = 0$

* erosion of bed can be very important in mountains



Mountain Rivers

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

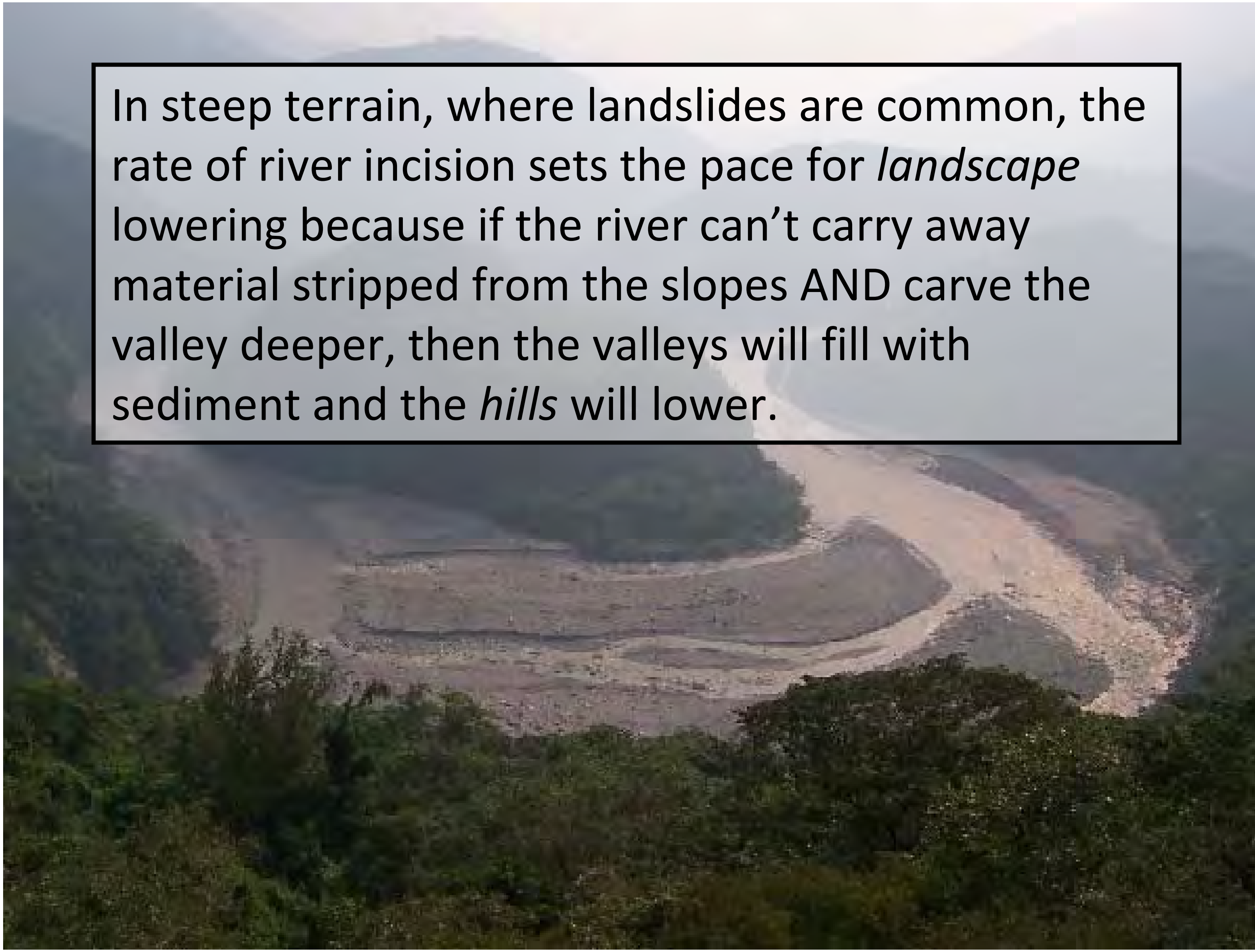


Taiwan

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.

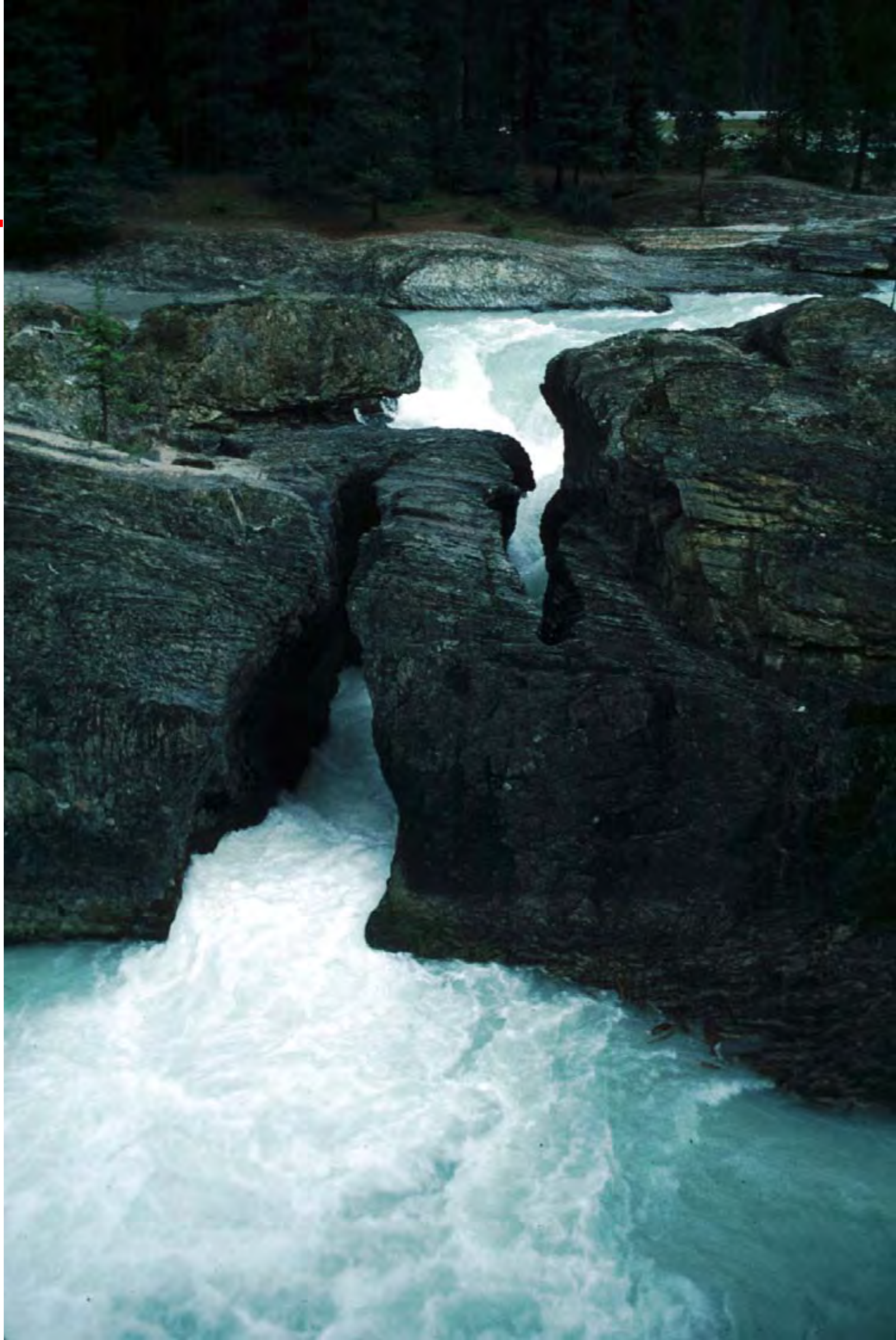
Berkeley

Pacifica

Bedrock Channels

Channels floored by bedrock and lacking an alluvial bed cover.

Indicative of transport capacity well in excess of sediment supply.

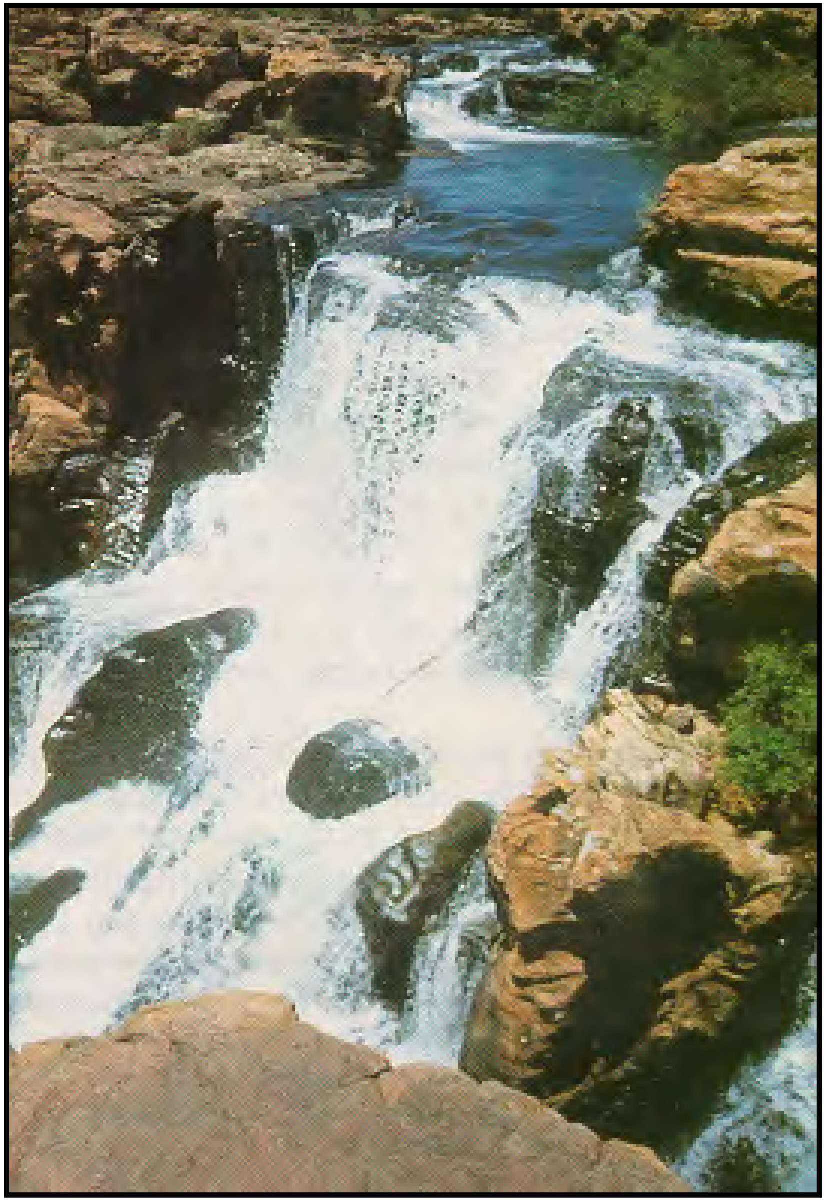


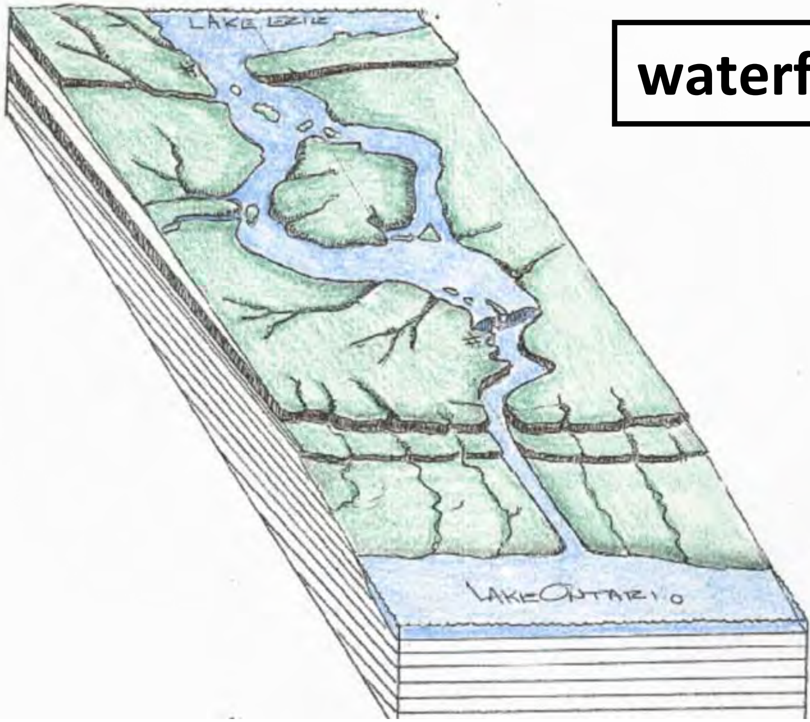
Waterfalls

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

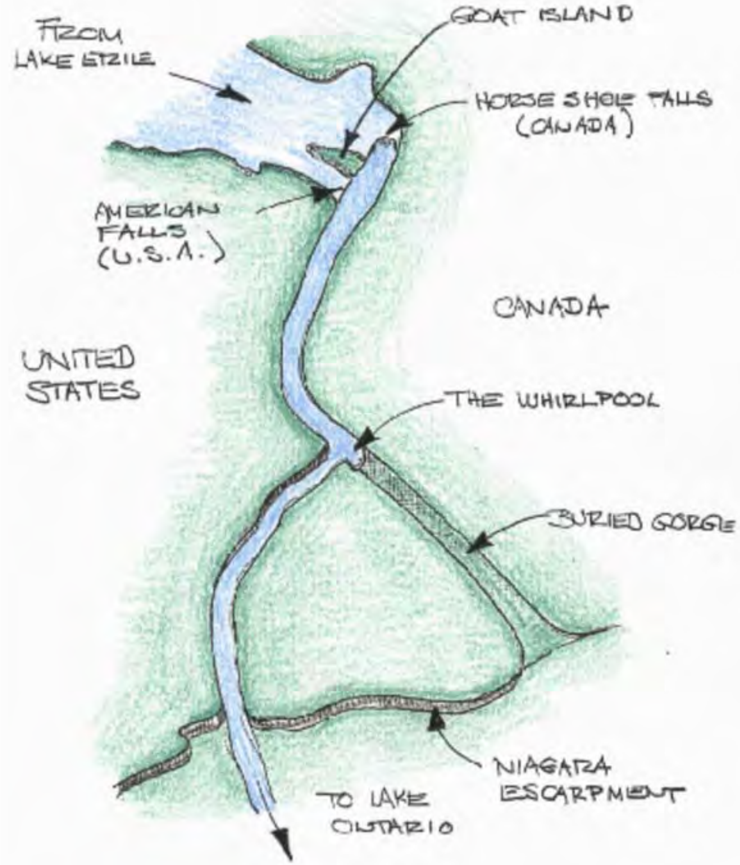
Waterfalls

often associated with lithological contrasts such as from layers of hard and soft rock

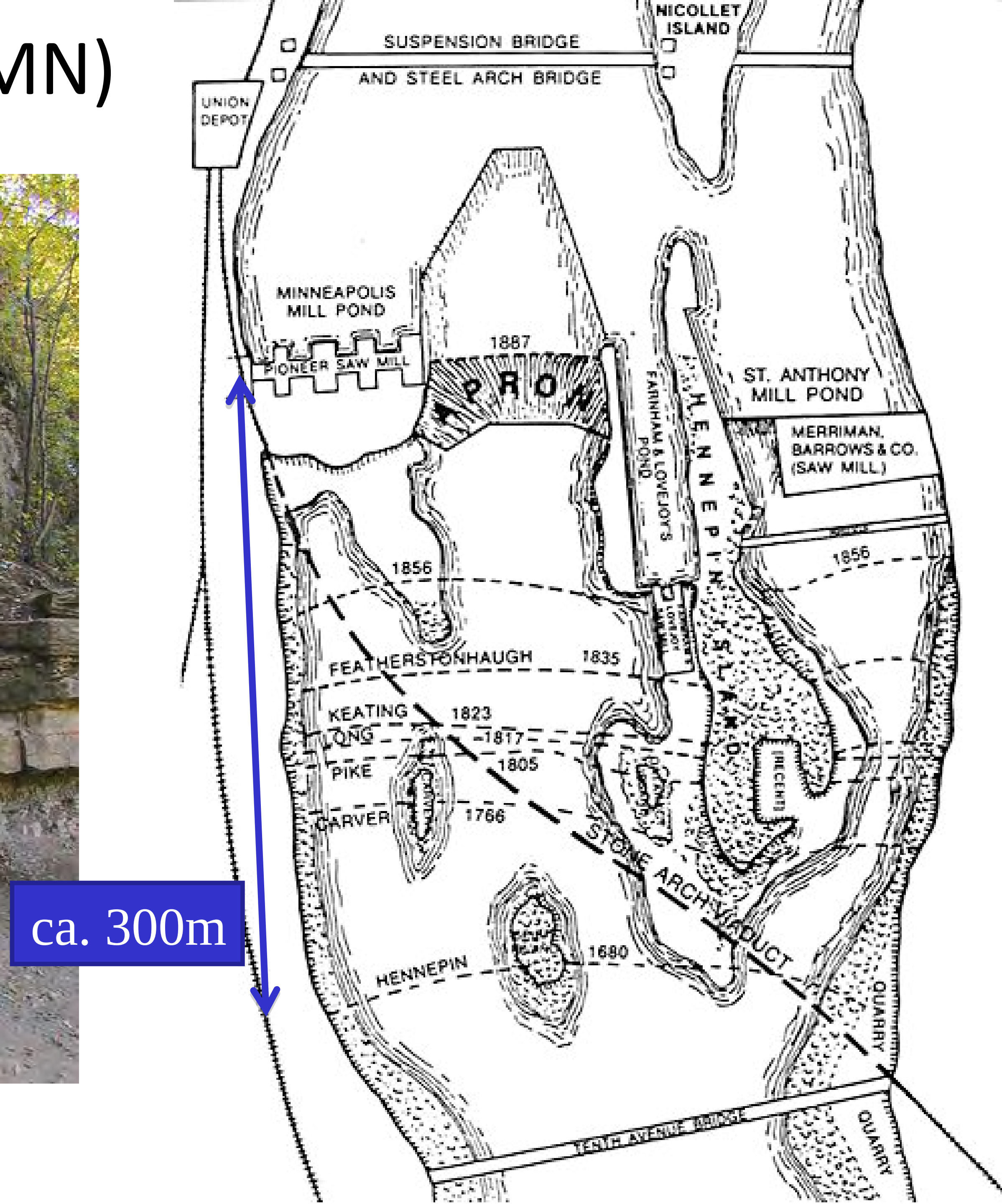




waterfalls are transient features!



st. anthony falls (MN)



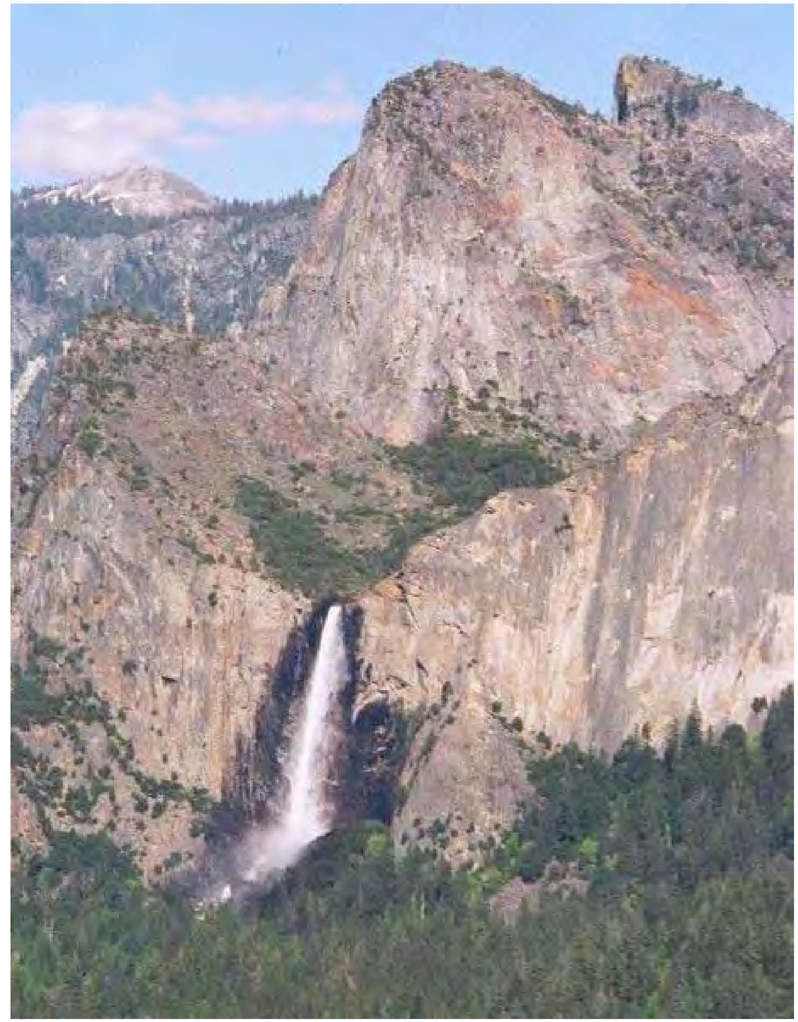
timing of glacial retreat (N.H.Winchell)

$$\frac{\text{distance to original escarpment}}{\text{rate of SAF retreat}} = \text{time since glaciers}$$

managing the retreat…

Waterfalls: “hanging valleys”

Comet Falls, Mt Rainier,
Aug. 2001



Bridal Veil Falls

bedrock channel erosion

streams are extremely effective rock erosion agents via three main mechanisms:

- **hydraulic action**
- **solution**
- **abrasion**

hydraulic action:

- pressure of flowing water & swirling turbulence *physically move* rock fragments & sediment grains
- pressure & turbulence can *wedge open* pre-existing weaknesses (fractures or joints)
- particularly effective at waterfalls & rapids (steep)

bedrock channel erosion

solution:

chemical weathering (dissolution) of bedrock

most prevalent in limestone (why?)

flowing water increases dissolution rates & deepens streams

dissolution of calcite sandstone cement can produce large volumes of sediment

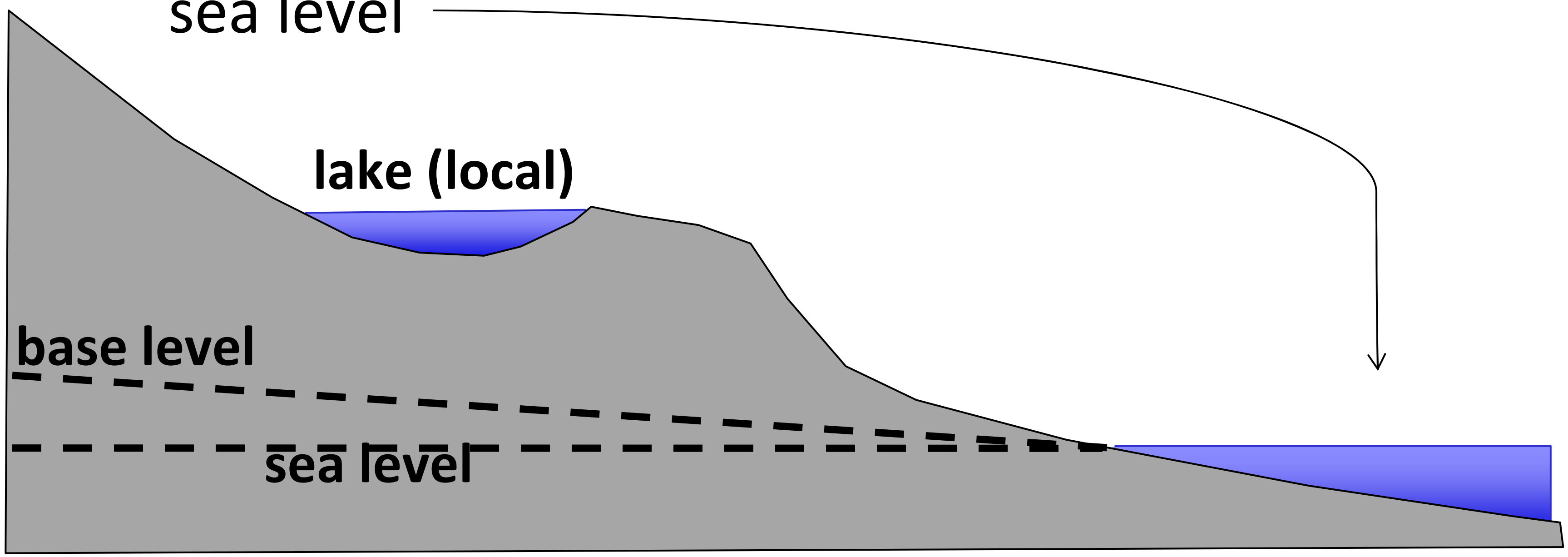
abrasion:

grinding away of bedrock via friction & impact of rock fragments & sediment grains carried by the stream

Base Level

The limiting level below which a stream cannot erode the land is called the base level of the stream.

The *ultimate* base level for most streams is global sea level

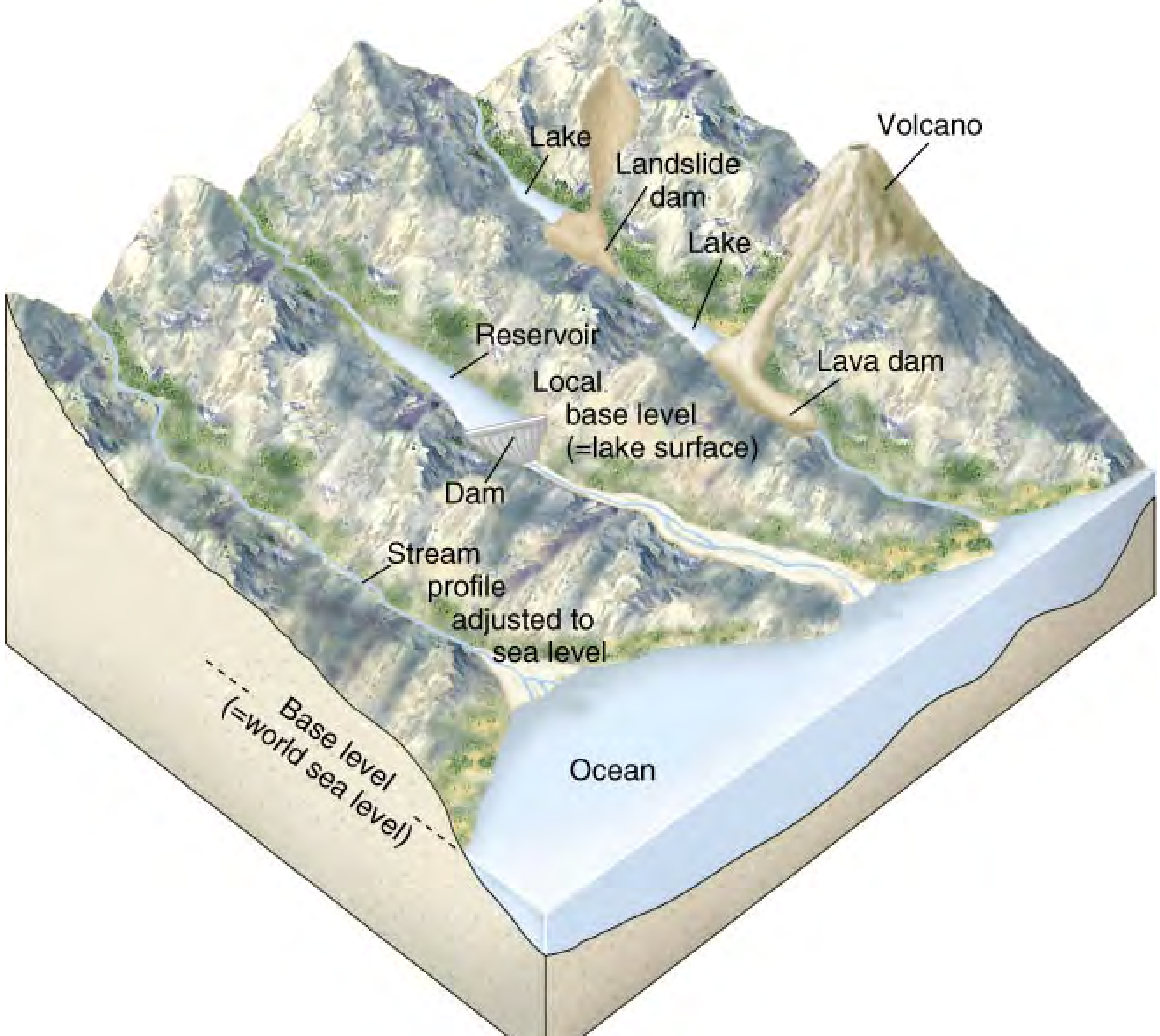


Base Level

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

sea level changes

Holocene sl rise due to glacial melting

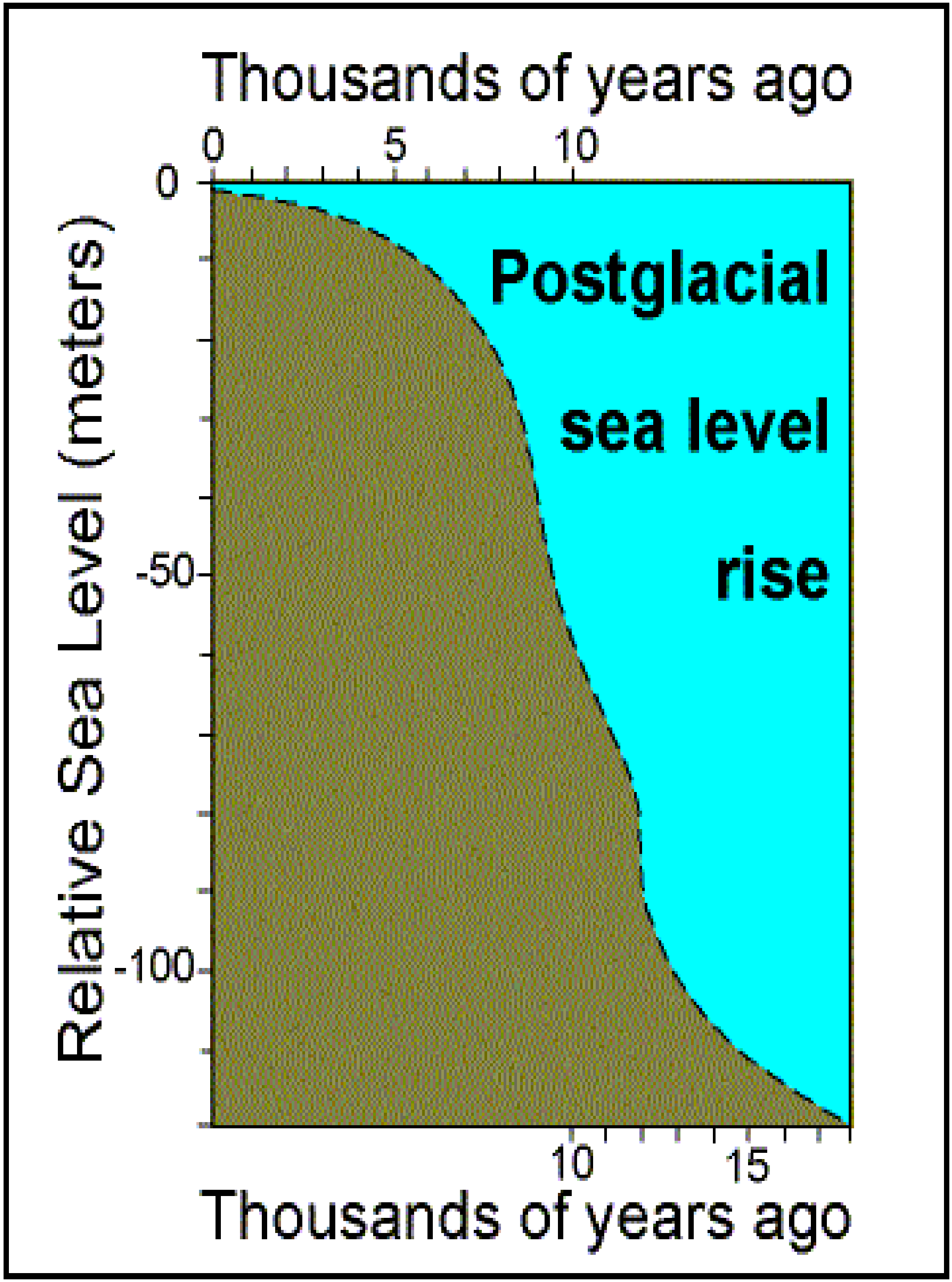
what happens in streams when base level changes?

goes down?

erosion! new lower level to which they can incise

goes up?

sedimentation! there is an ocean in the way



‘graded’ rivers (or streams)

maintain balance between erosion & deposition

input = output (what rivers would like to do)

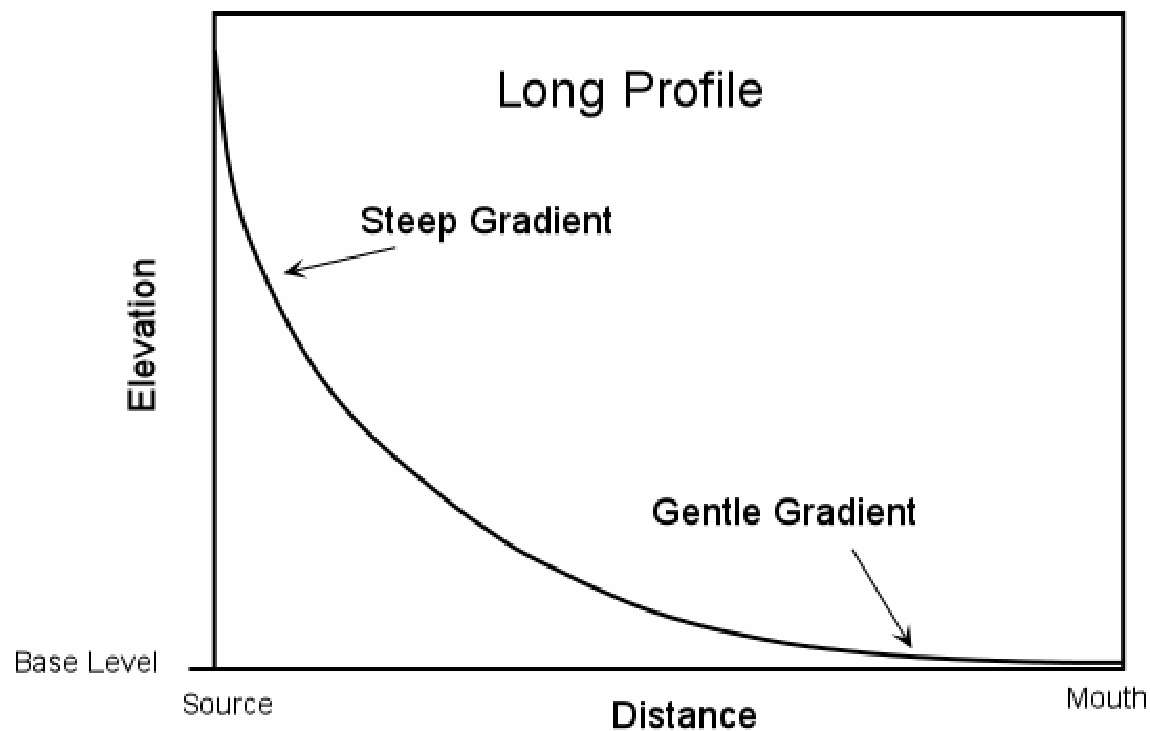
river profiles (source to base level) are ‘concave up’

represents balance between increasing discharge and lower slopes to maintain equilibrium

higher discharges can carry more sediment…

BUT, river systems typically do not supply enough…

SO, rivers need (create) lower slopes…



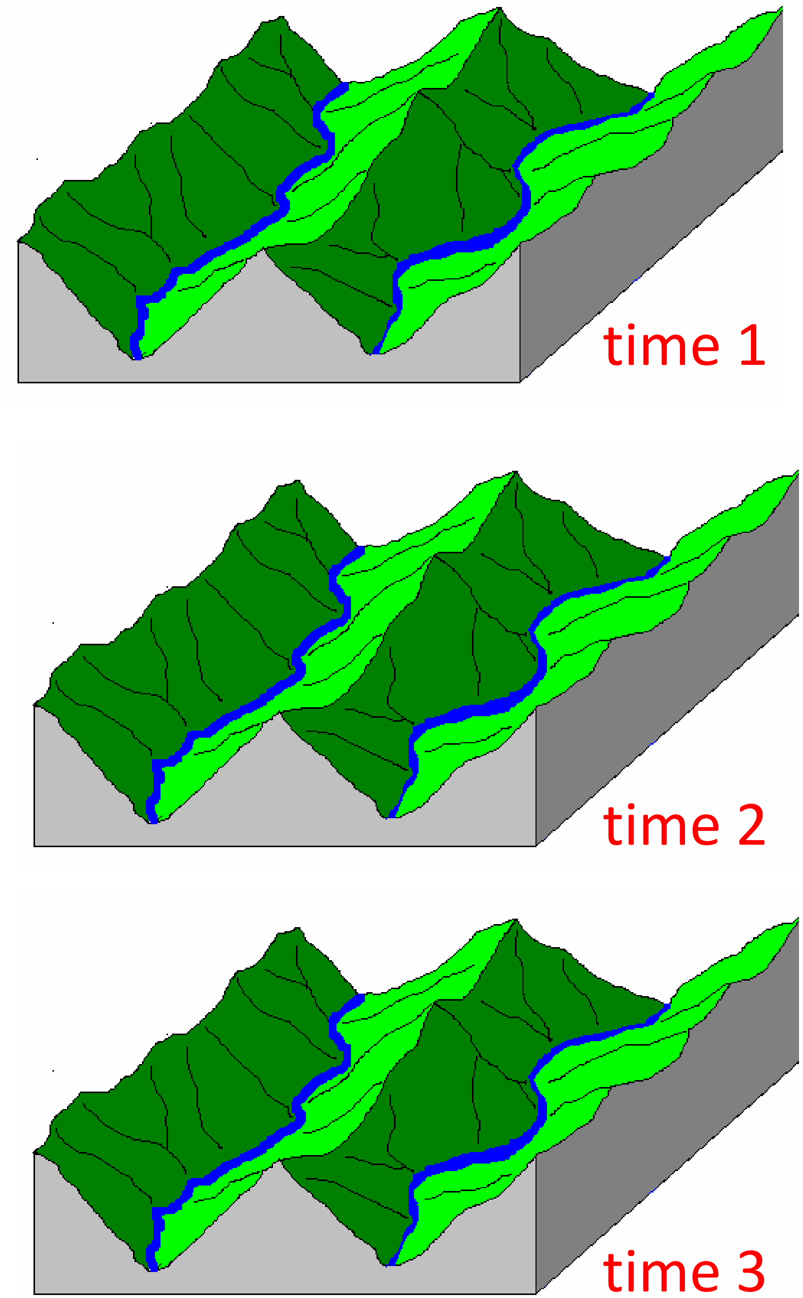
Steady-state channels

in many mountain ranges, rocks are being actively ‘uplifted’ by tectonic forces

when erosion rates balance uplift rates topography* can achieve a *steady state*, despite active erosion

*topography:

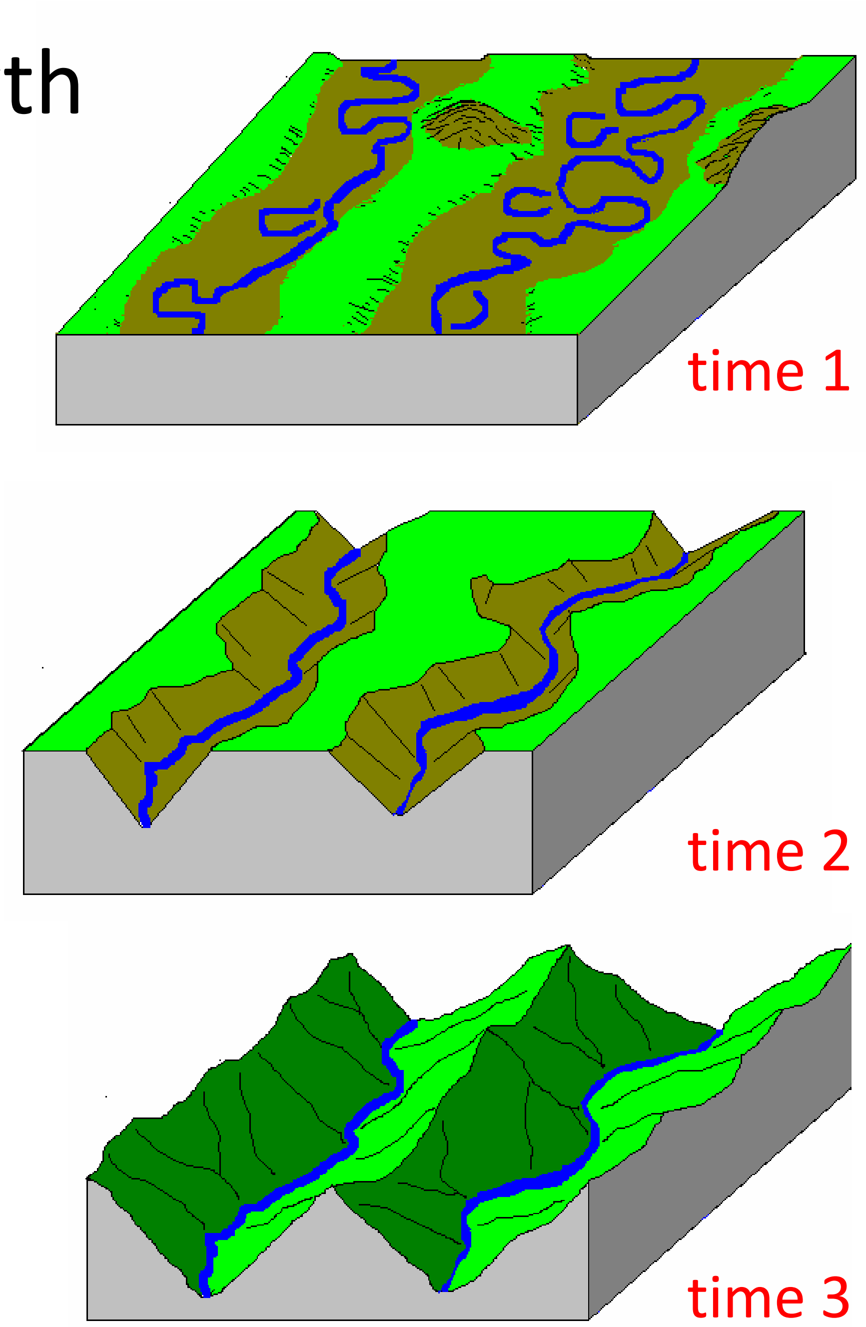
- relief
- steepness
- drainage basin morphology



Mountain range growth

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

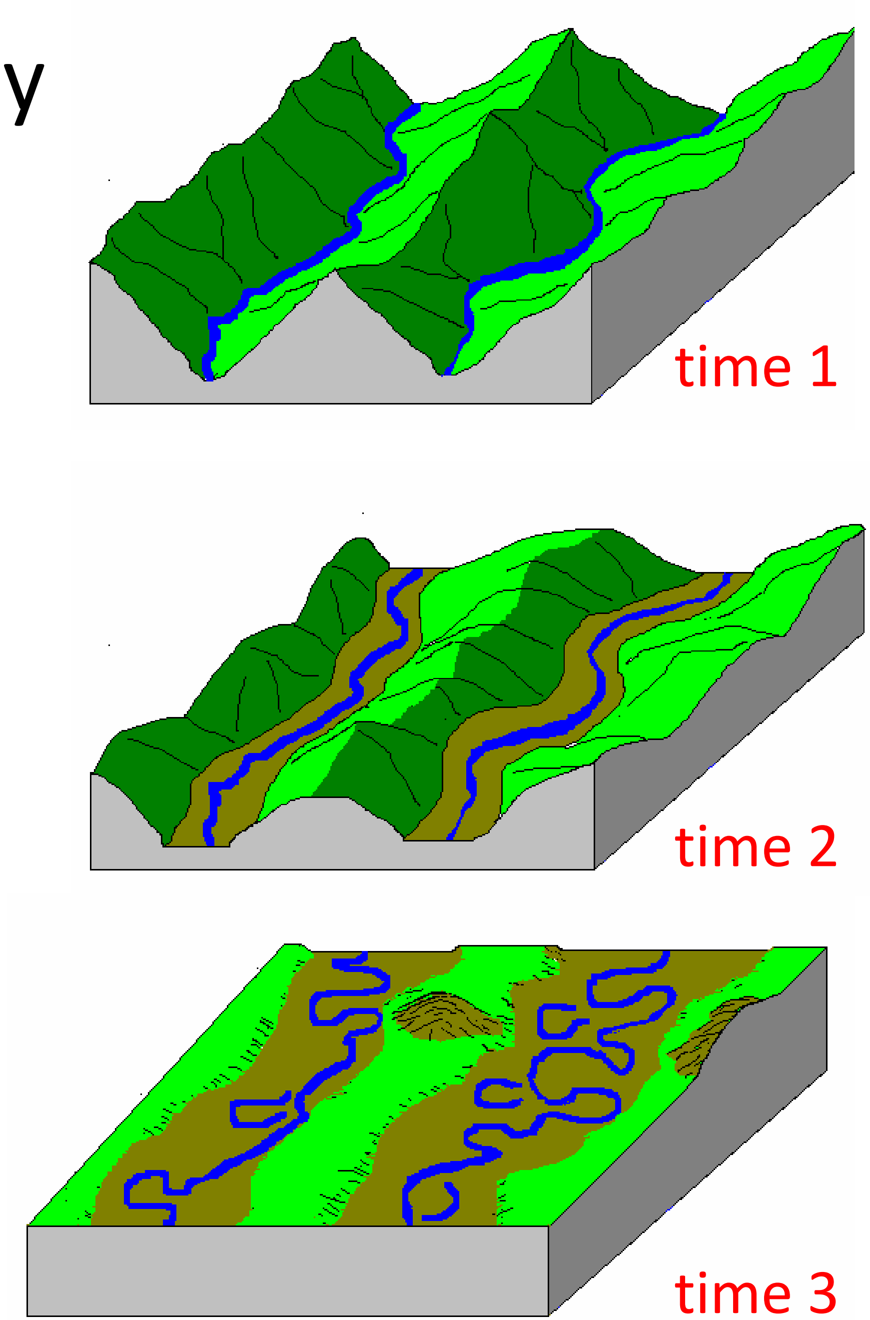
increasing relief, steepness



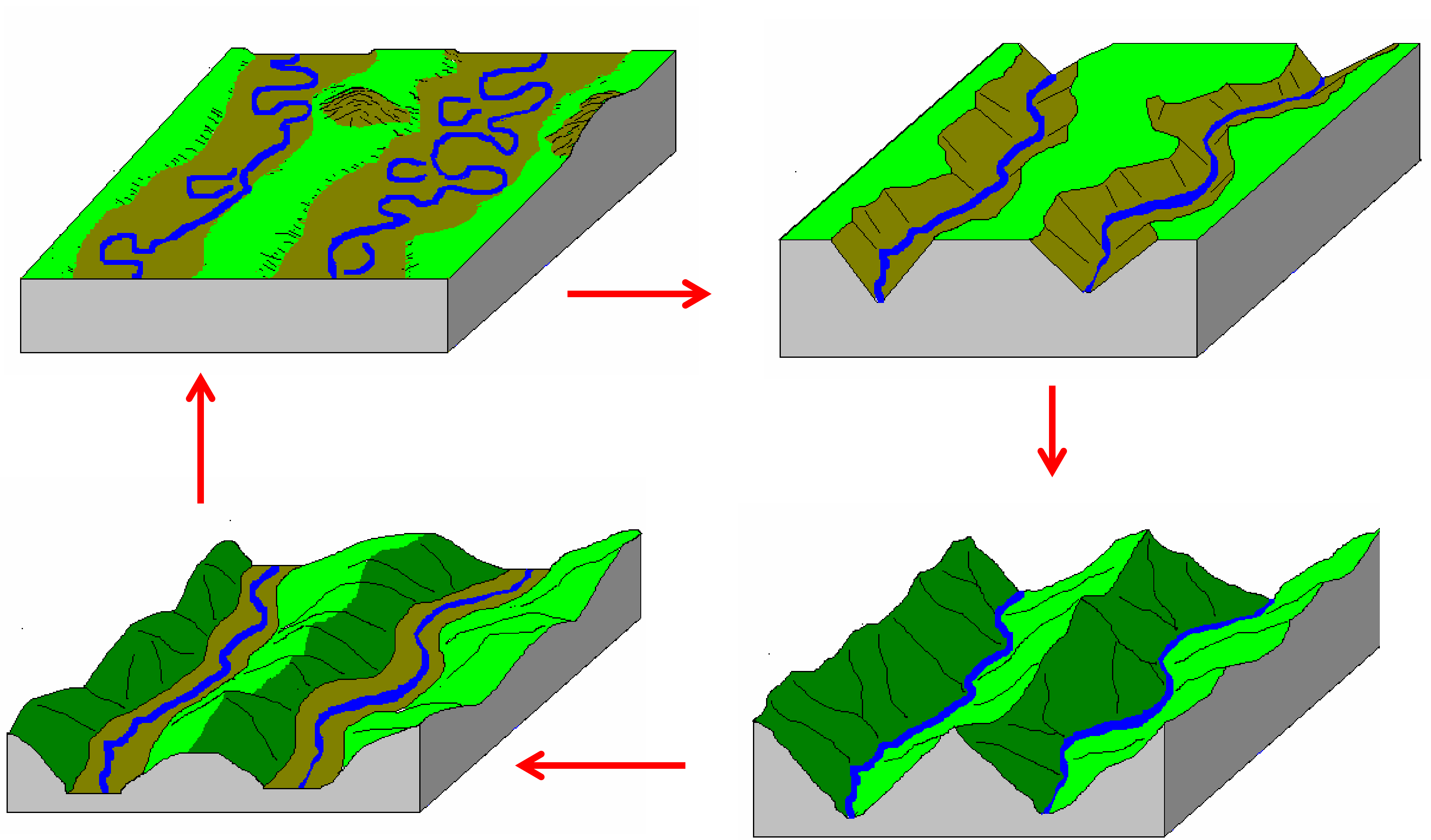
Mountain range decay

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

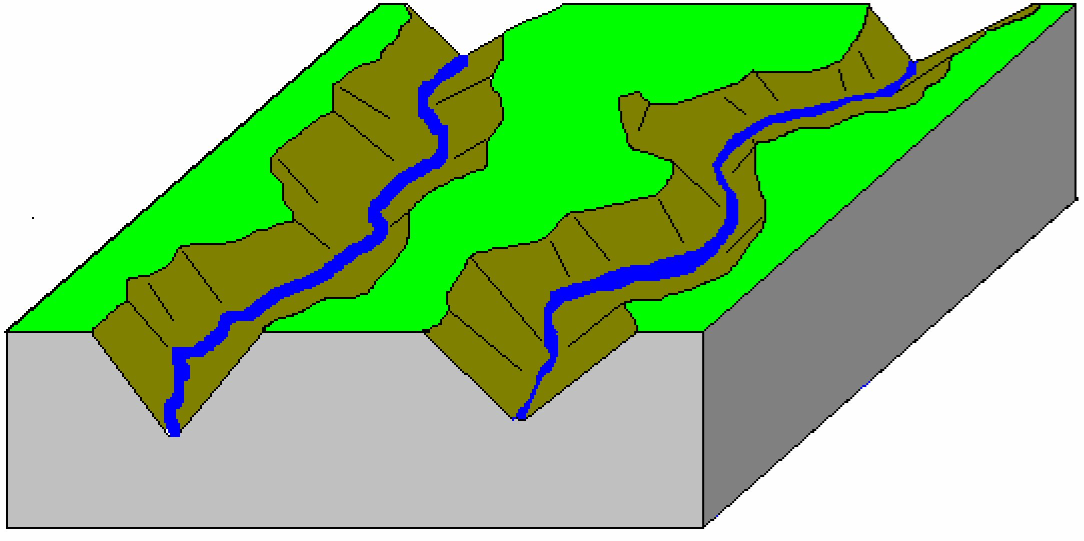
decreasing relief, steepness



Physiographic Cycle



young valleys



V-Shaped

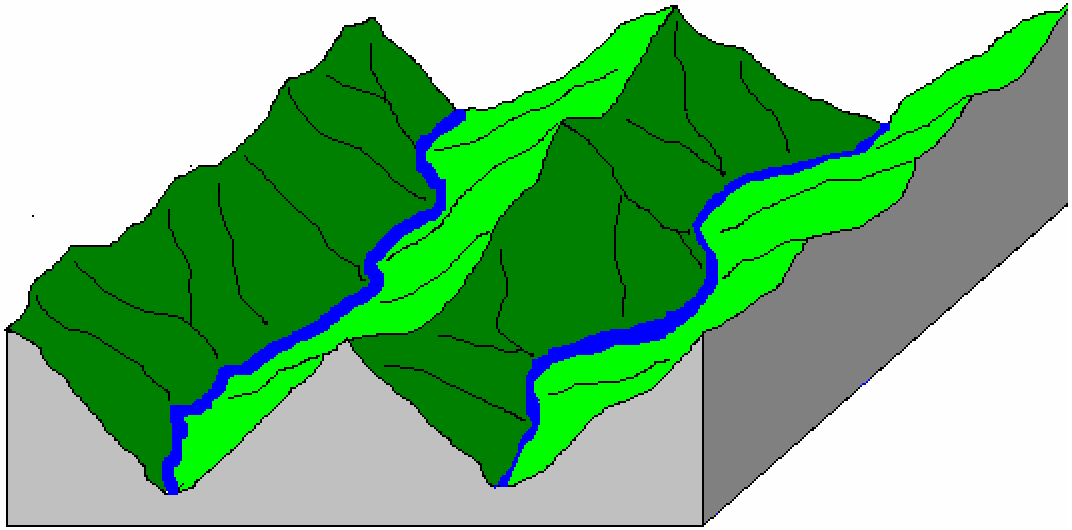
rapids & waterfalls

no flood plain

drainage divides broad
and flat—untouched
by erosion

valley actively deepening

mature valleys



continued V-shaped valley

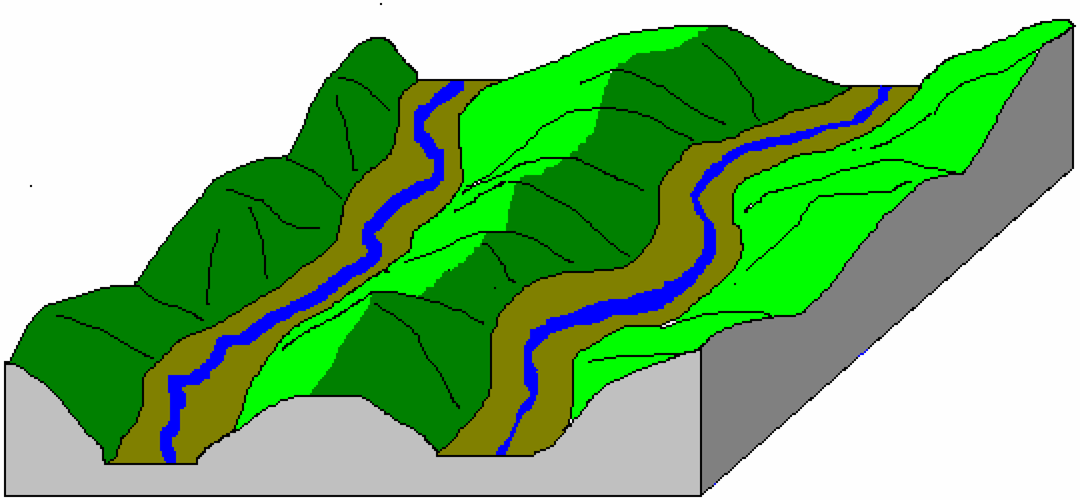
beginnings of flood plain

sand and gravel bars

sharp drainage divides

relief reaches maximum—
valleys stop deepening

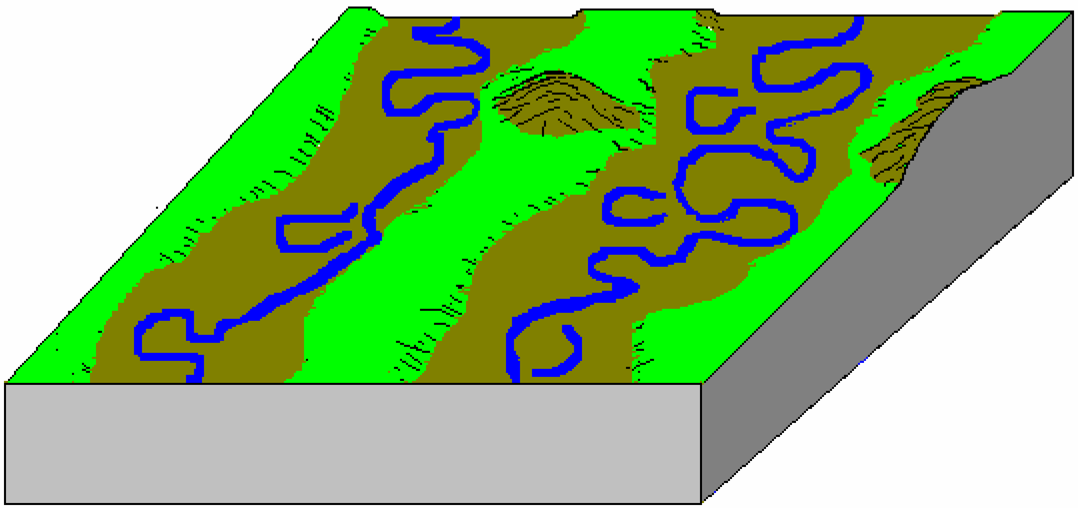
maturity (late)



- valley has flat bottom (due to sediment deposition)
- narrow flood plain
- divides begin to round off
- relief diminishes
- river begins to meander

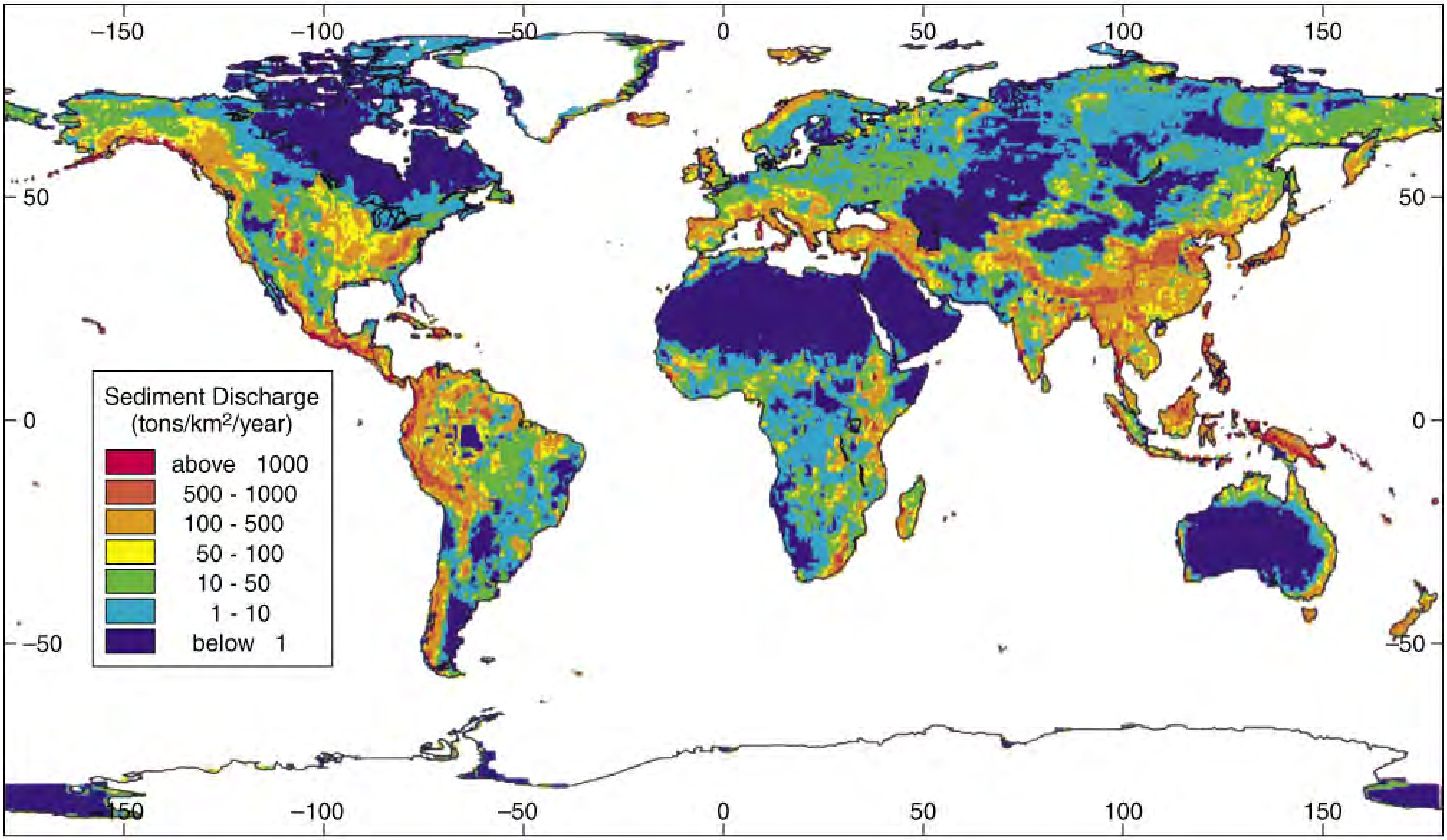
many geologists believe slopes stay steep but simply retreat

old age



- land worn to nearly flat surface (peneplain)
- resistant rocks remain as erosional remnants
- rivers meander across extremely wide, flat flood plains

Global Sediment Yield



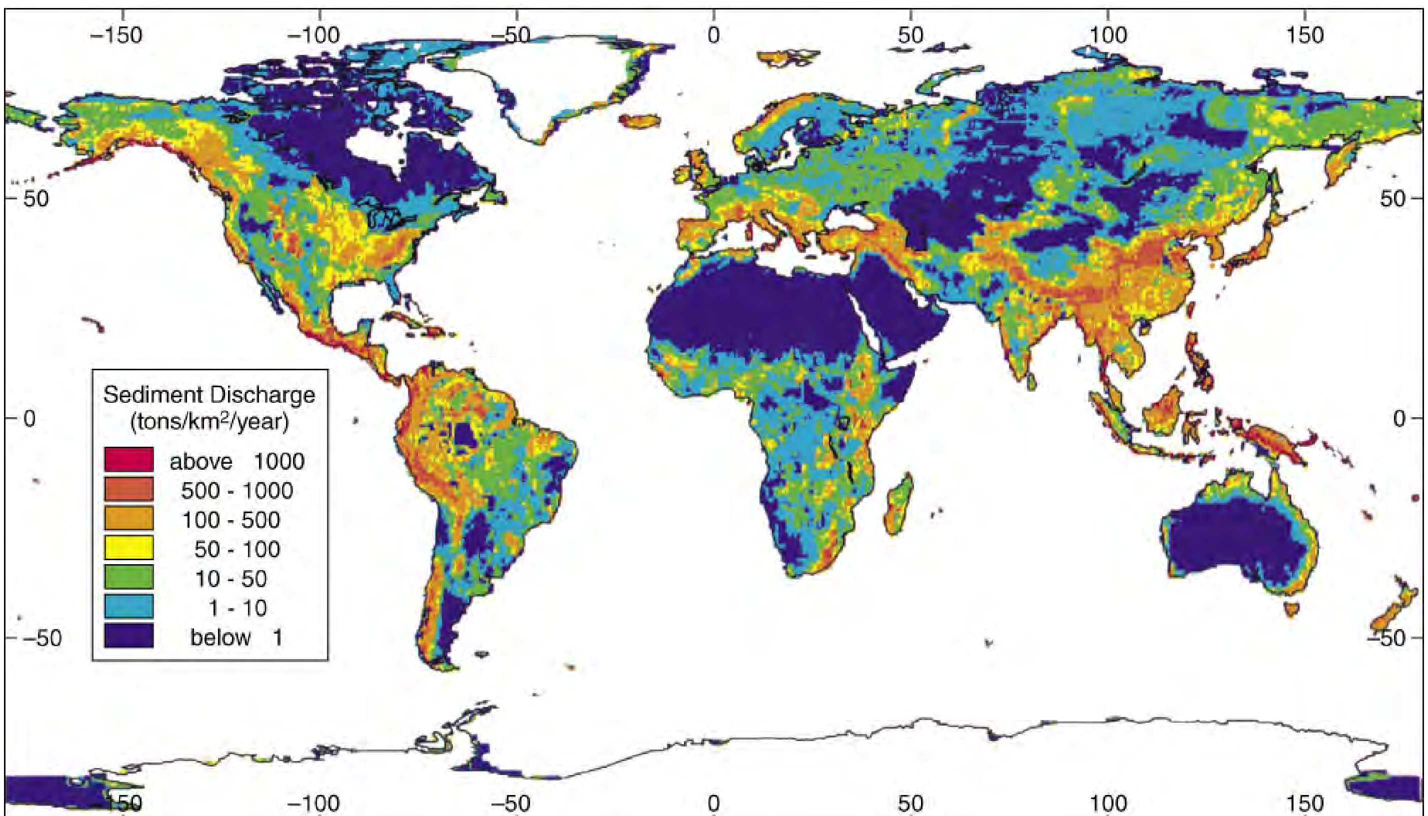
Range of 1 m per million years to 1 m per year

Sediment Yield – fun facts

southern Alaska and the southern Andes, large active glaciers

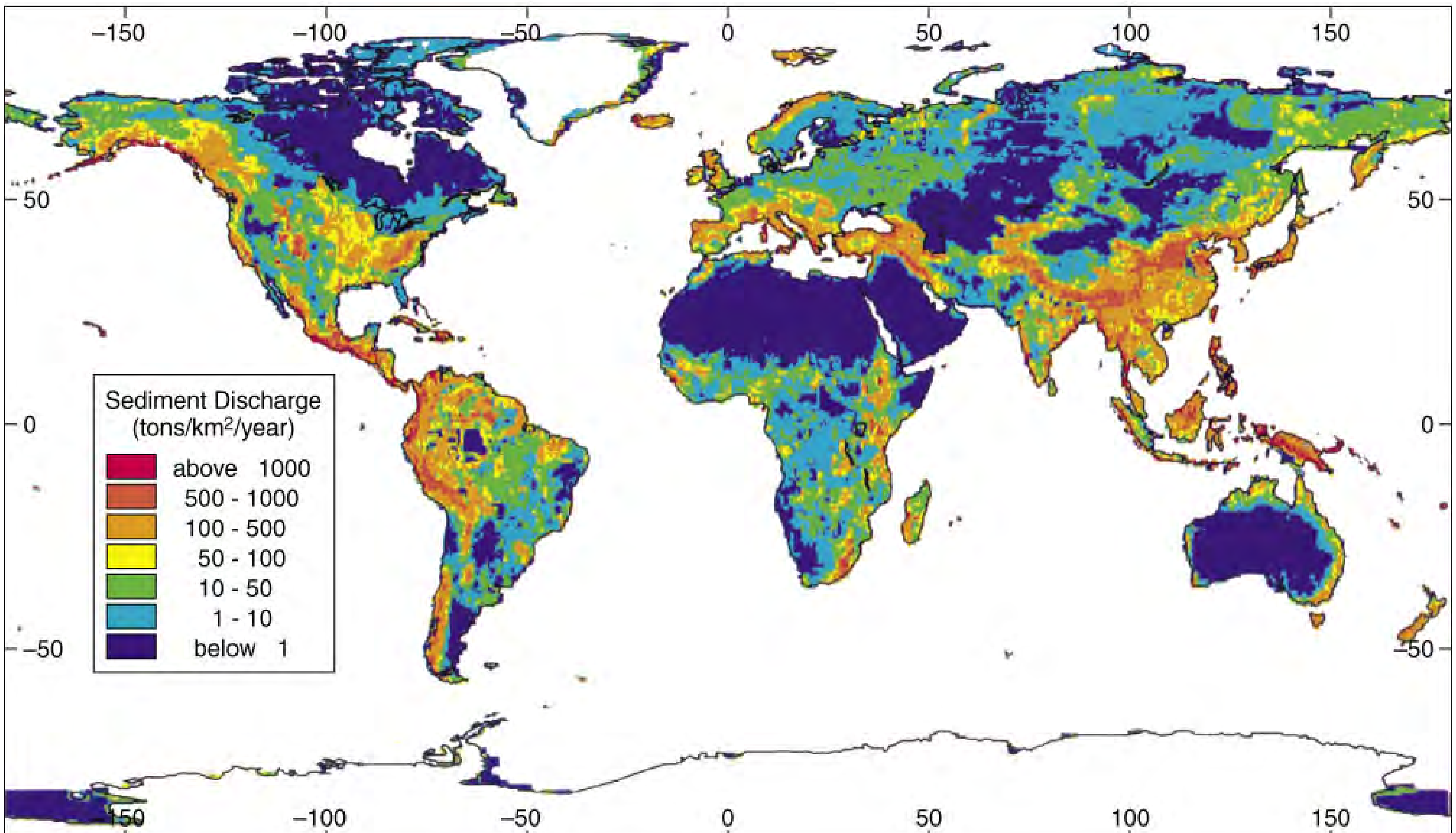
In arid regions, reduced precipitation limits vegetation, making the land vulnerable to erosion

but, need precip to move substantial amounts…

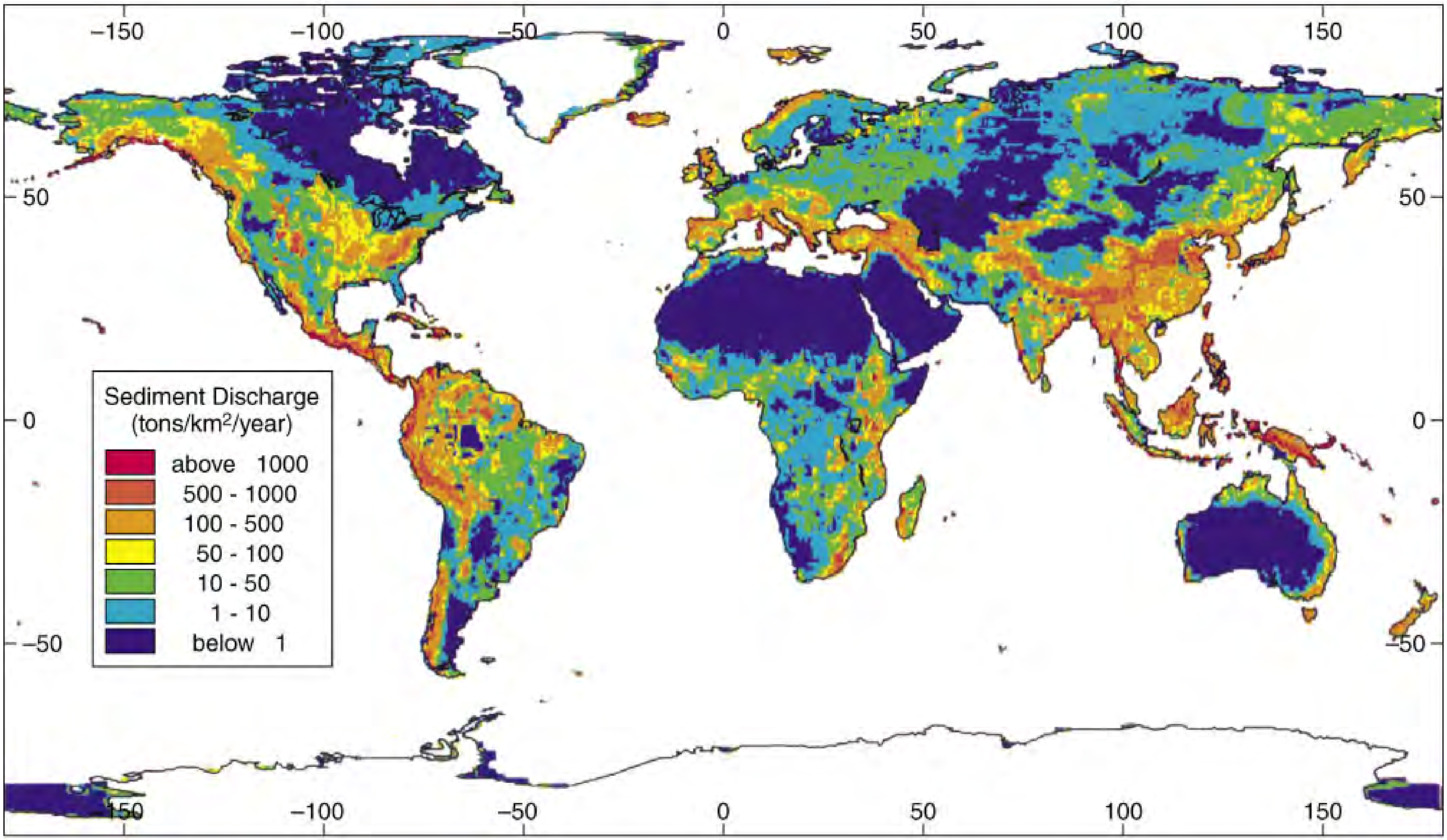


Sediment Yield

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



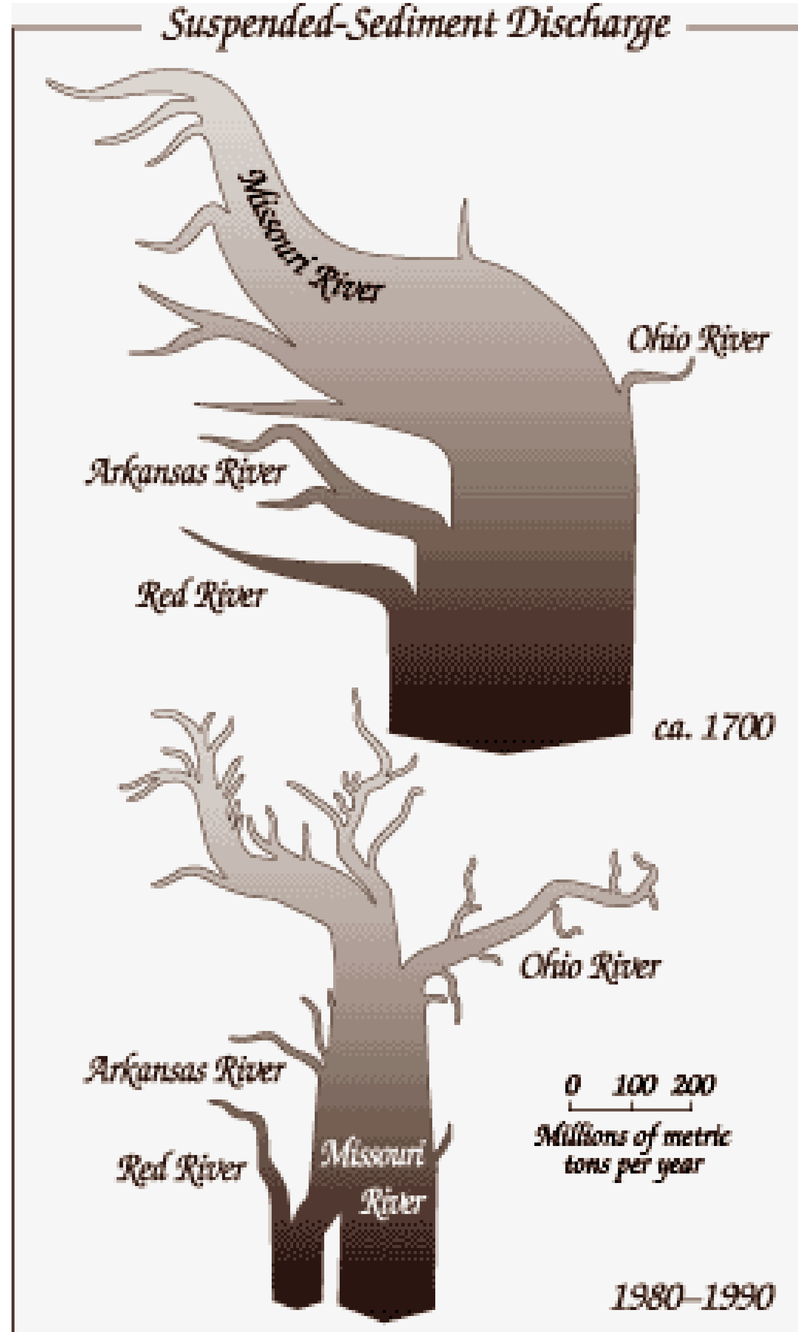
Modern sediment yield is >10 long-term (geological) rate



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

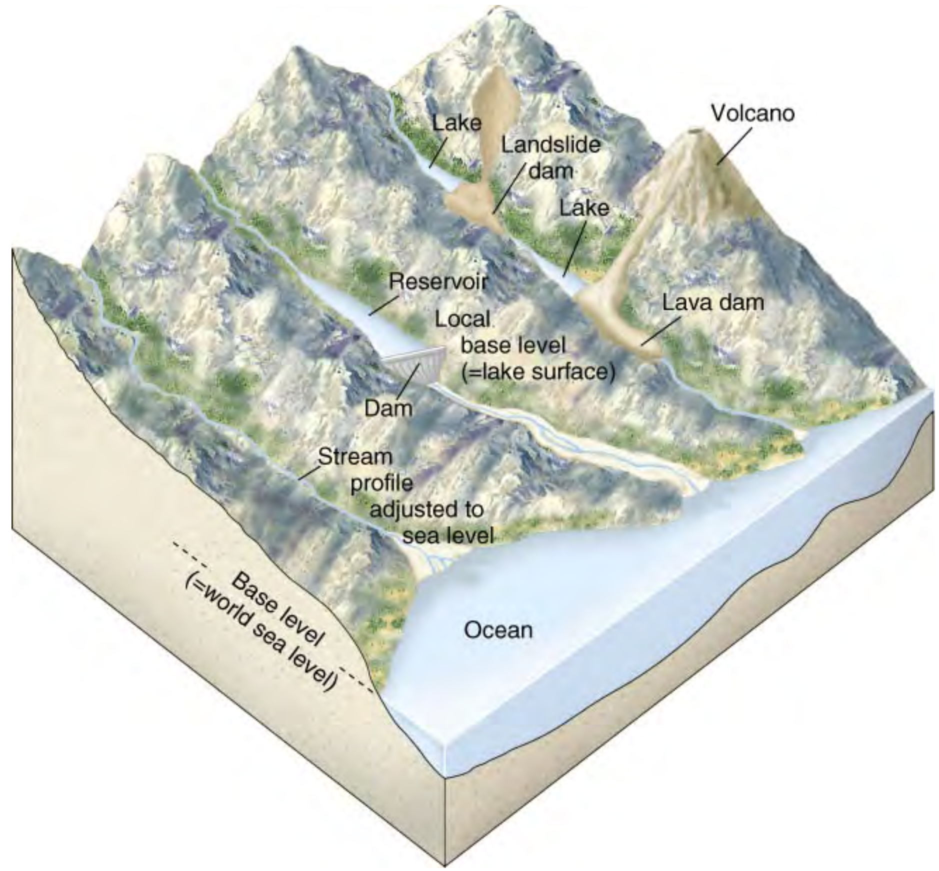
Globally, anthropogenic dams have reduced the sediment load that reaches the oceans by half



Natural Dams

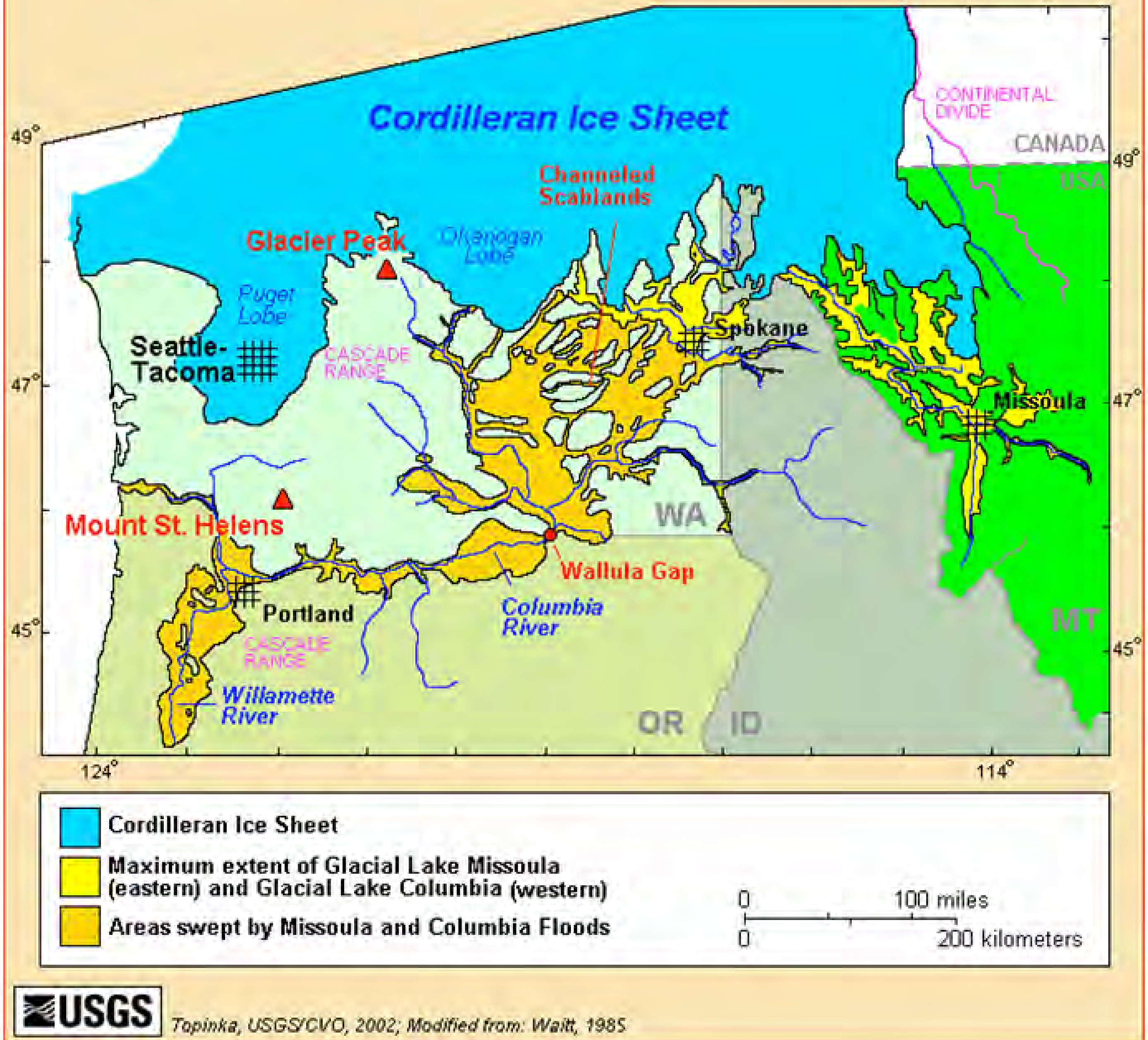
The courses of many streams are interrupted by lakes that have formed behind natural dams consisting of:

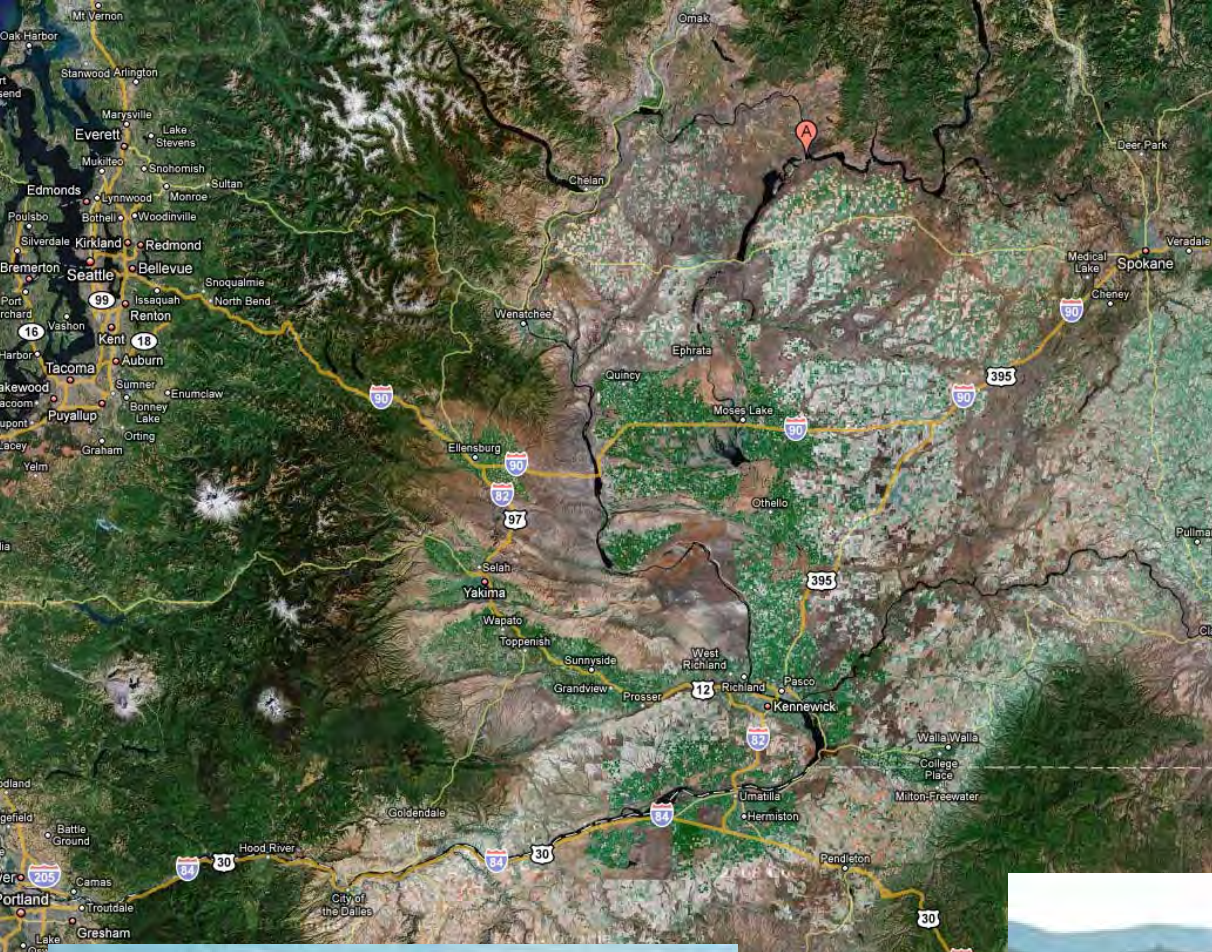
- landslide sediments
- glacial deposits
- glacier ice
- lava flows



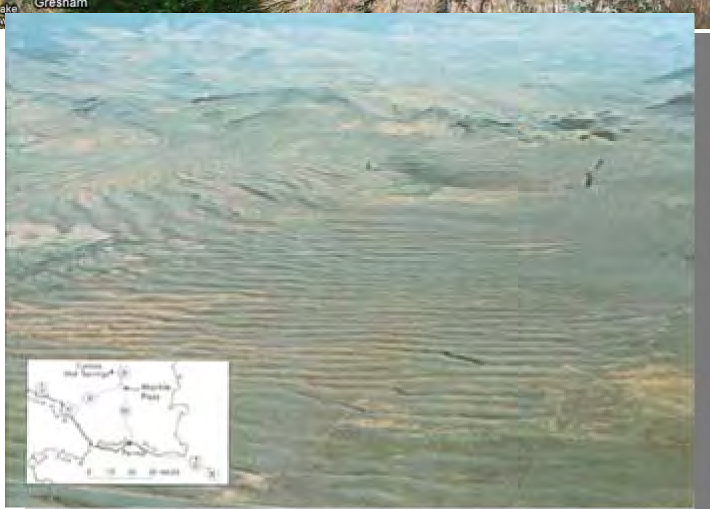
act as a local base level and create irregularities in streams' long profiles

Pacific Northwest and the "Missoula Floods"

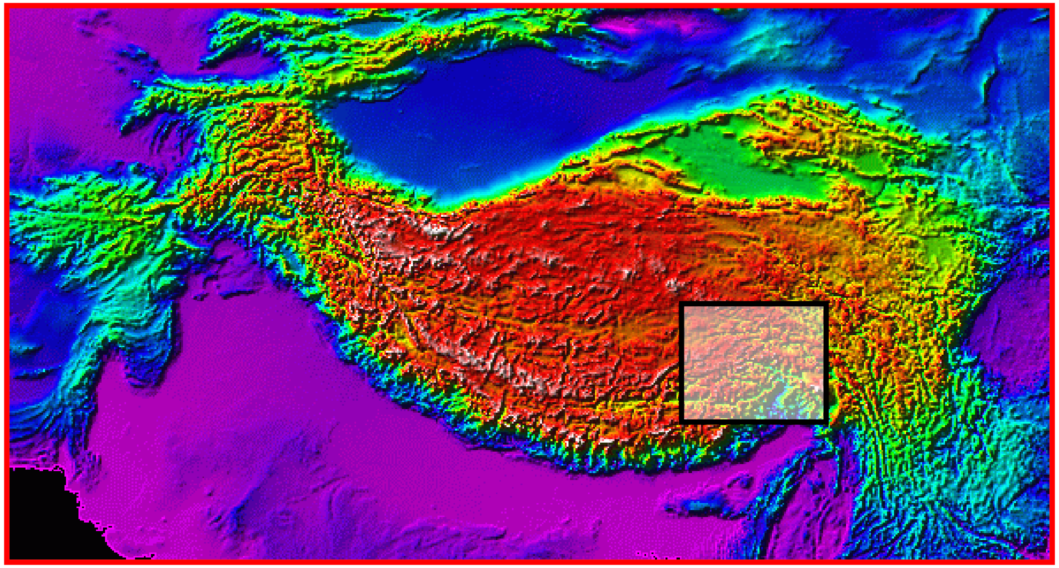


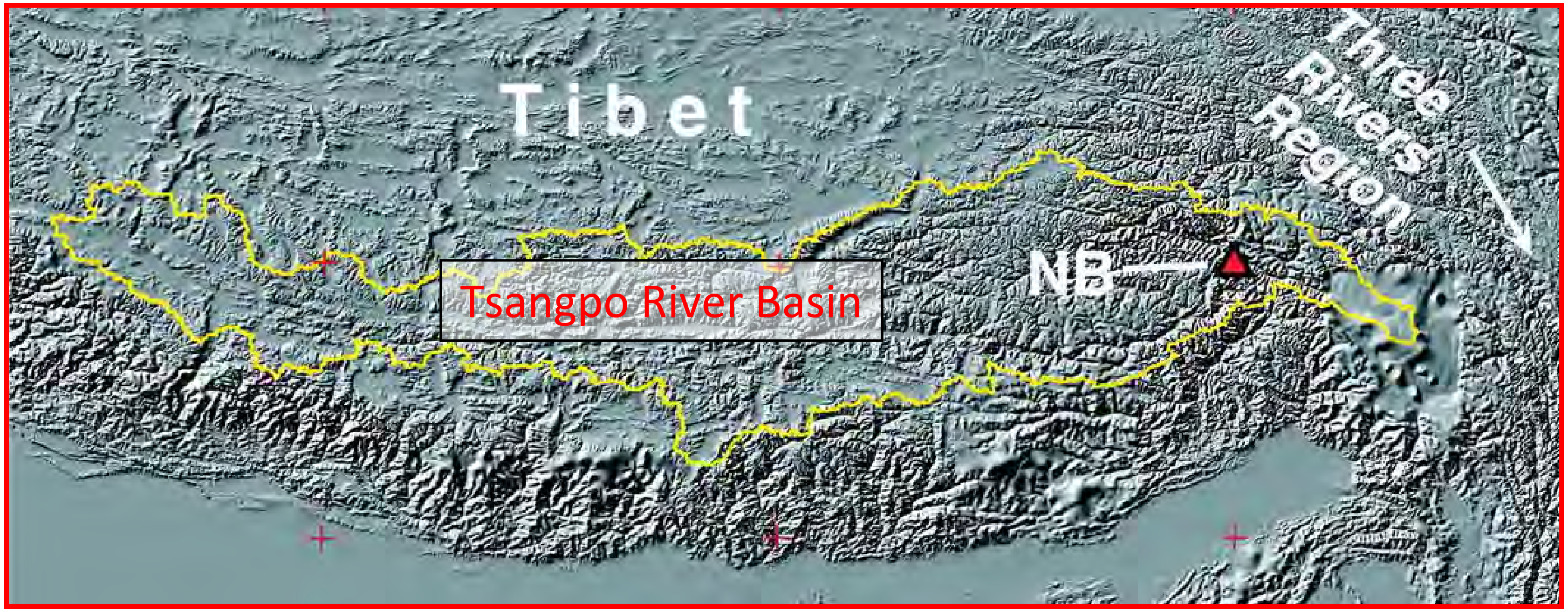


Mt Vernon
Oak Harbor
Stanwood
Arlington
Marysville
Lake Stevens
Everett
Mukilteo
Snohomish
Sultan
Edmonds
Lynnwood
Monroe
Poulsbo
Bothell
Woodinville
Silverdale
Kirkland
Redmond
Bremerton
Seattle
Bellevue
Snoqualmie
99
Issaquah
North Bend
Renton
16
Vashon
Kent
18
Auburn
Tacoma
Sumner
Enumclaw
Bonney Lake
Puyallup
Orting
Graham
Yelm
Omak
Chelan
Deer Park
Veradale
Medical Lake
Spokane
Cheney
Wenatchee
Ephrata
Quincy
Moses Lake
90
395
Ellensburg
82
97
Othello
Pullman
Selah
Yakima
Wapato
Toppenish
Sunnyside
Grandview
Prosser
12
West Richland
Richland
Pasco
Kennewick
Walla Walla
College Place
Milton-Freewater
Umatilla
Hermiston
Goldendale
Battle Ground
205
Camas
84
30
Hood River
Pendleton
Portland
Troutdale
Gresham
City of the Dalles

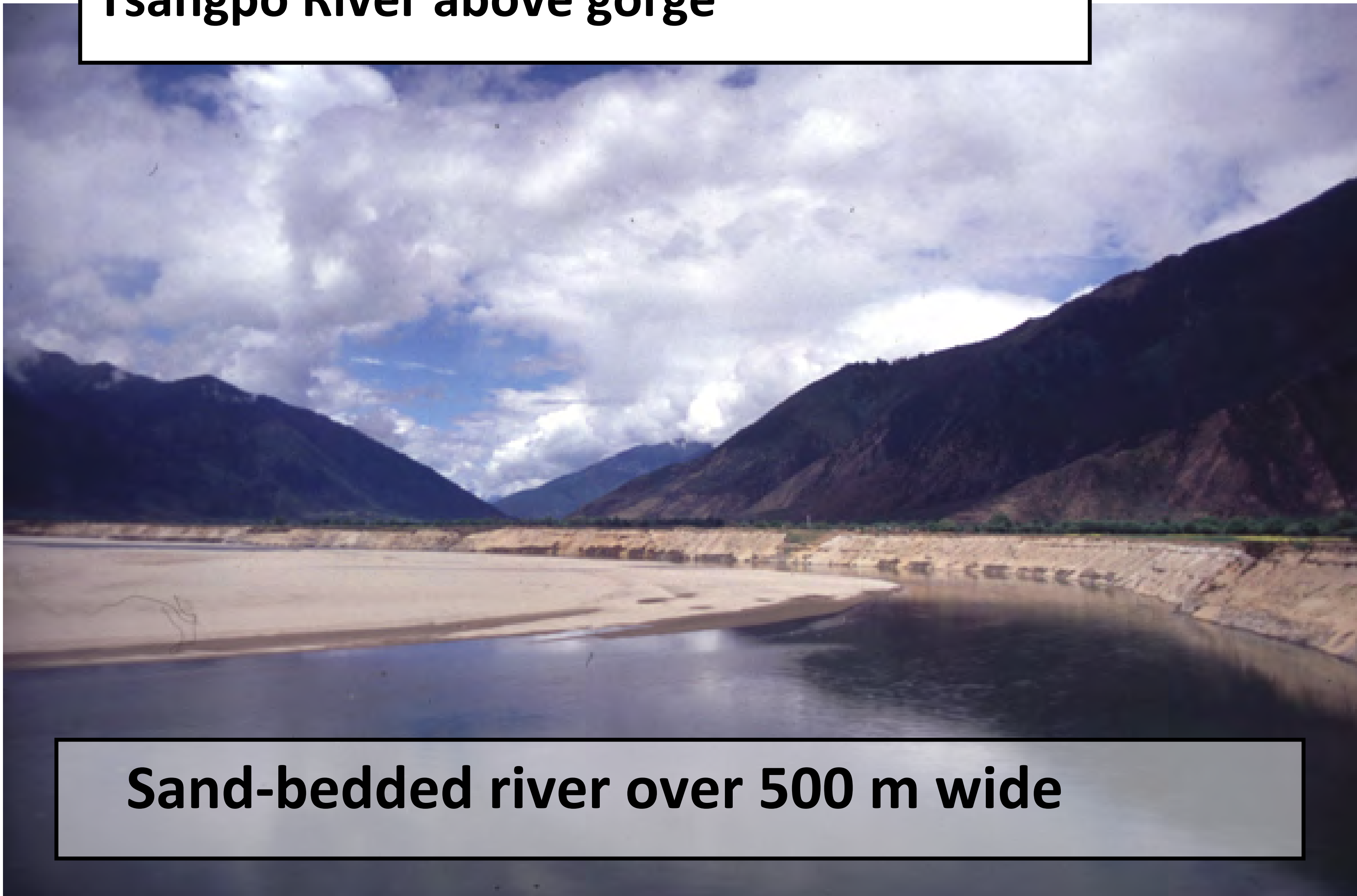


Natural glacier dams on the Tsangpo River, eastern Tibet



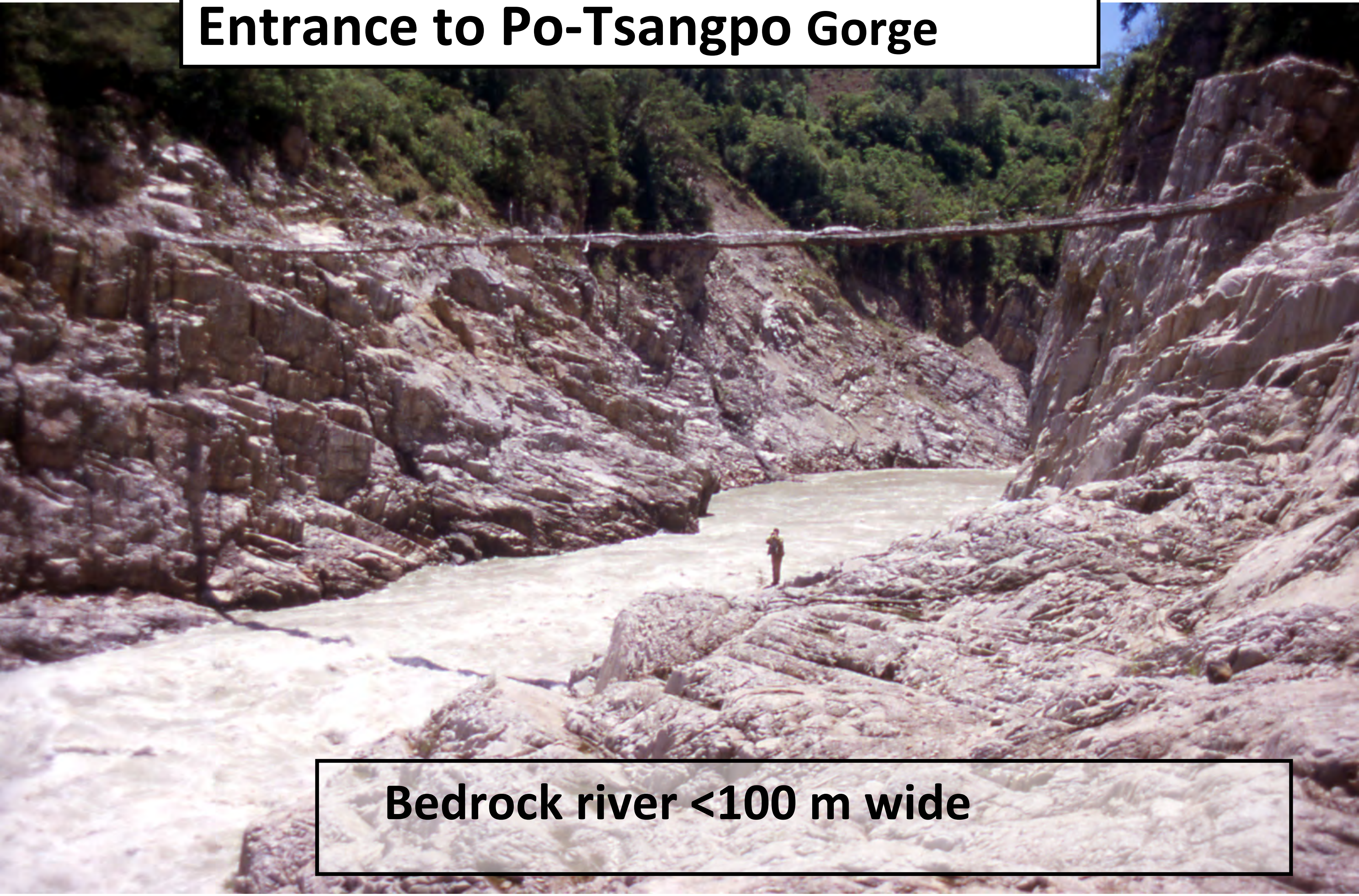


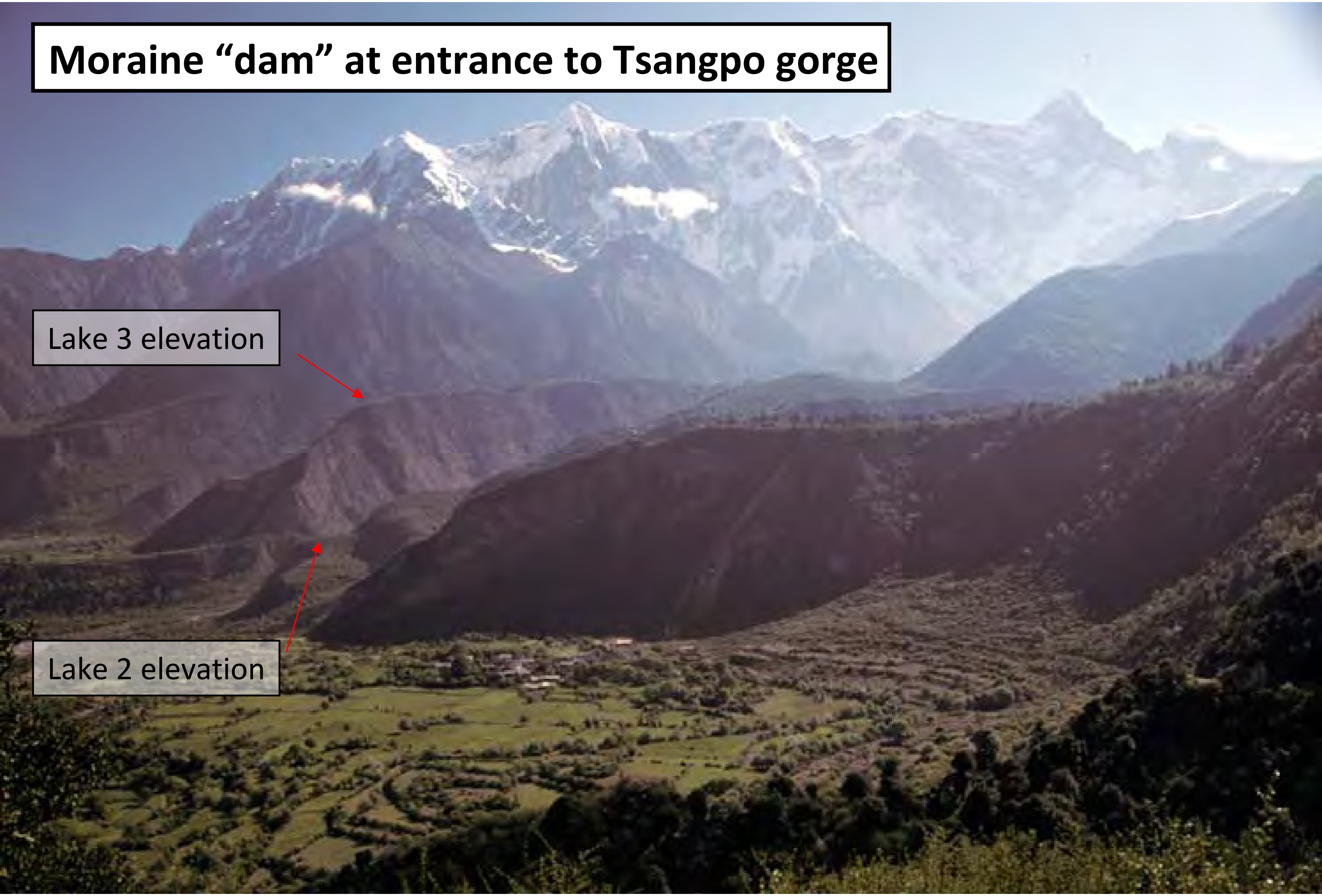
Tsangpo River above gorge

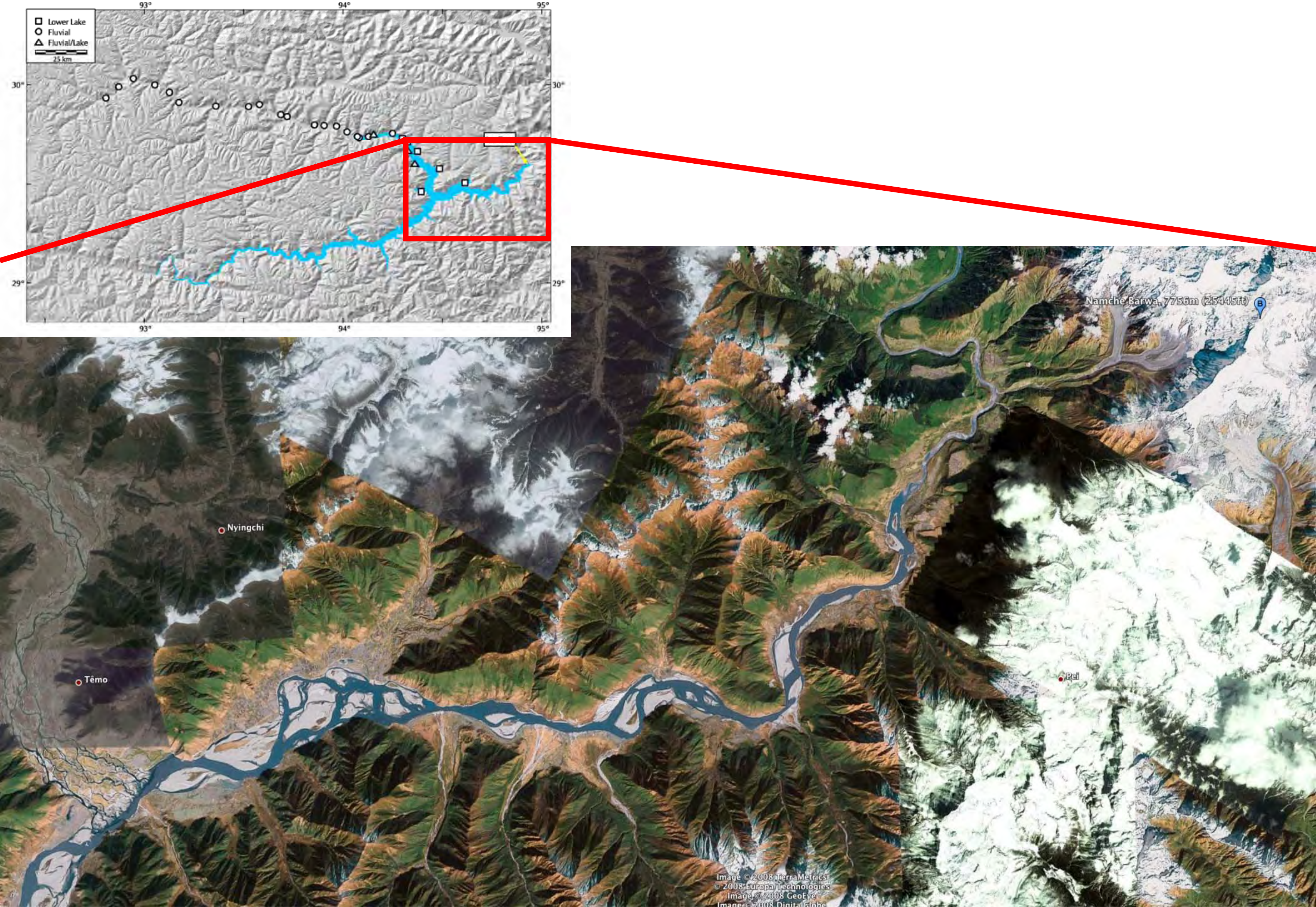


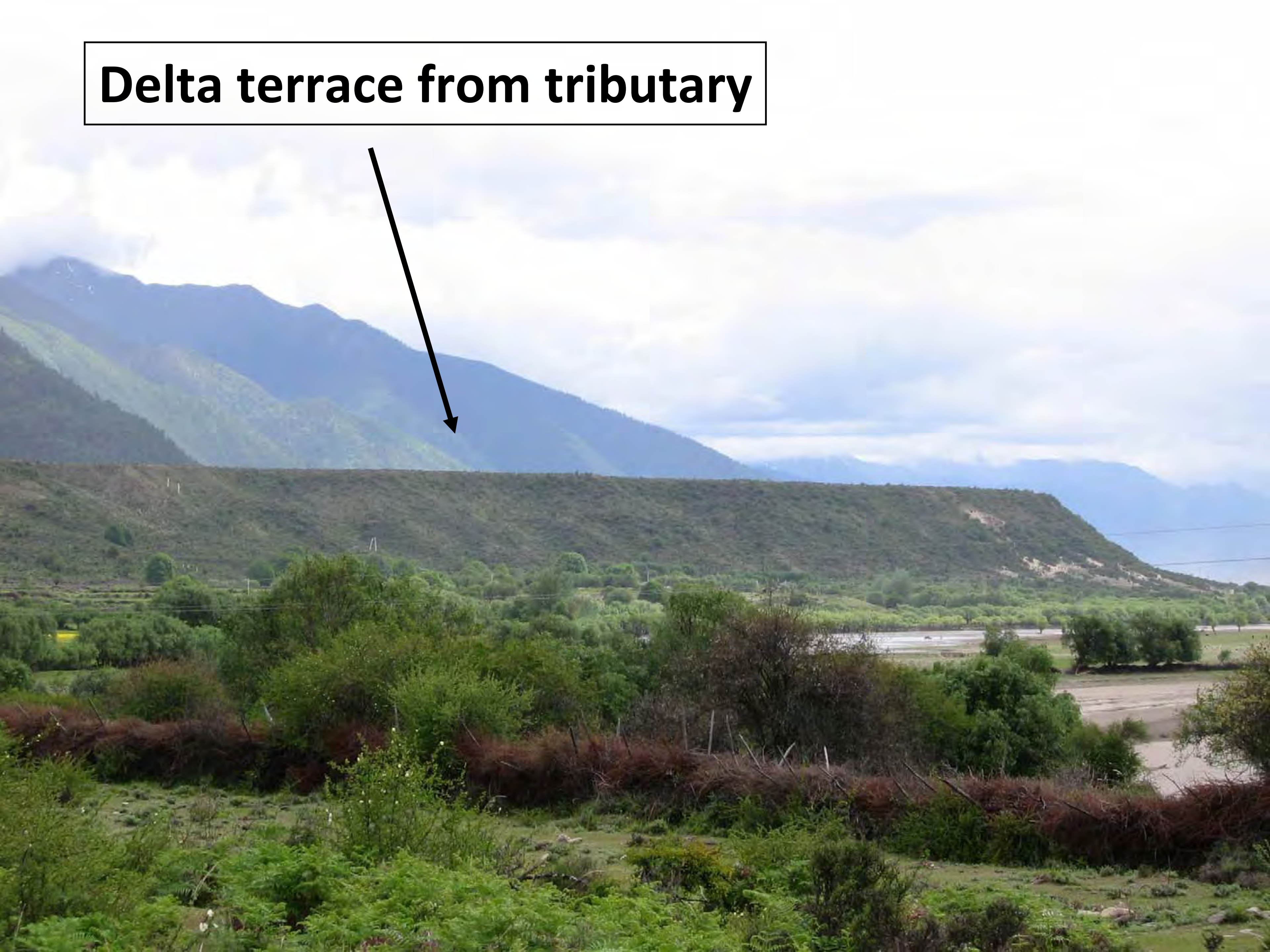
Sand-bedded river over 500 m wide

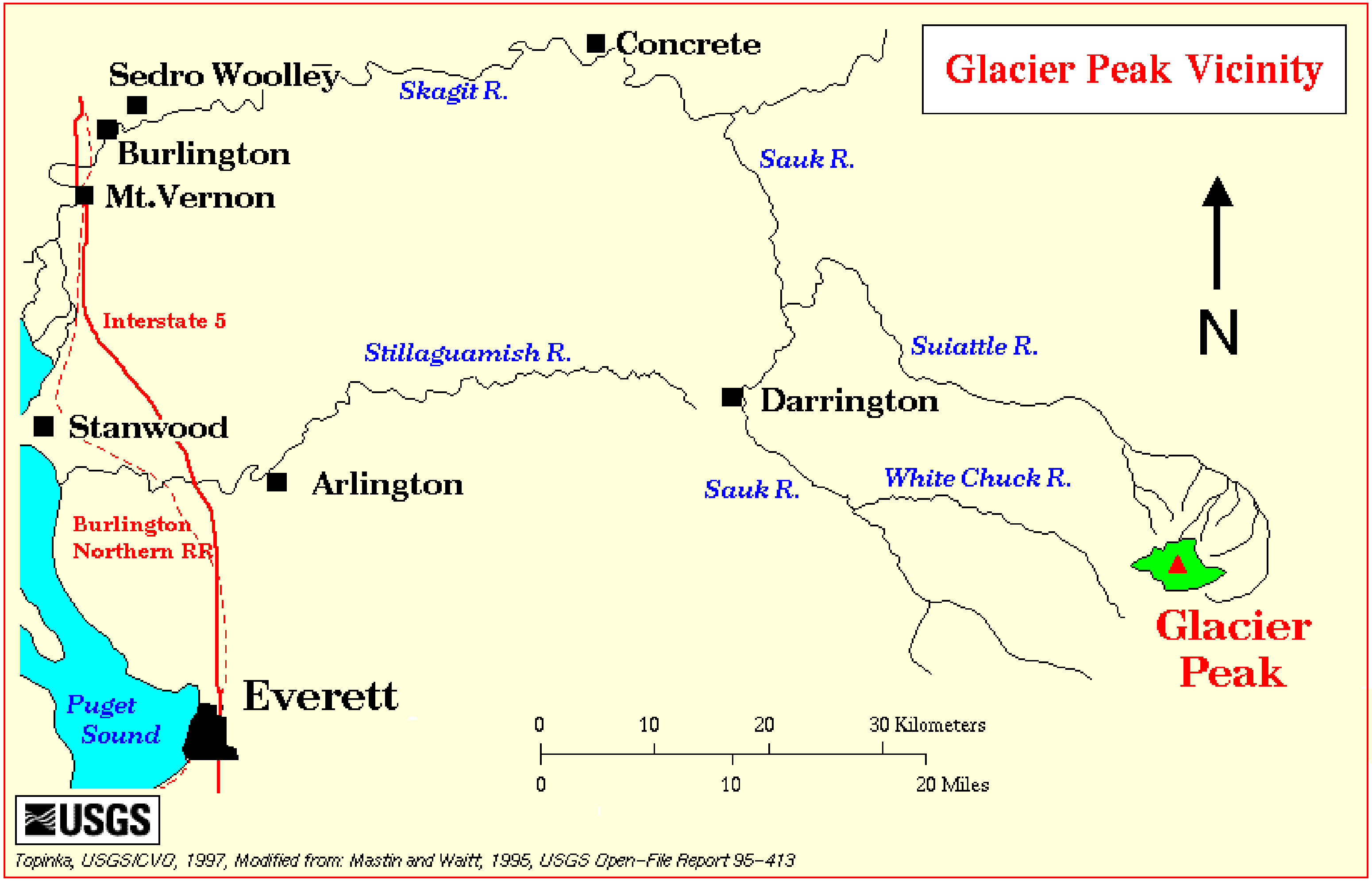
Entrance to Po-Tsangpo Gorge



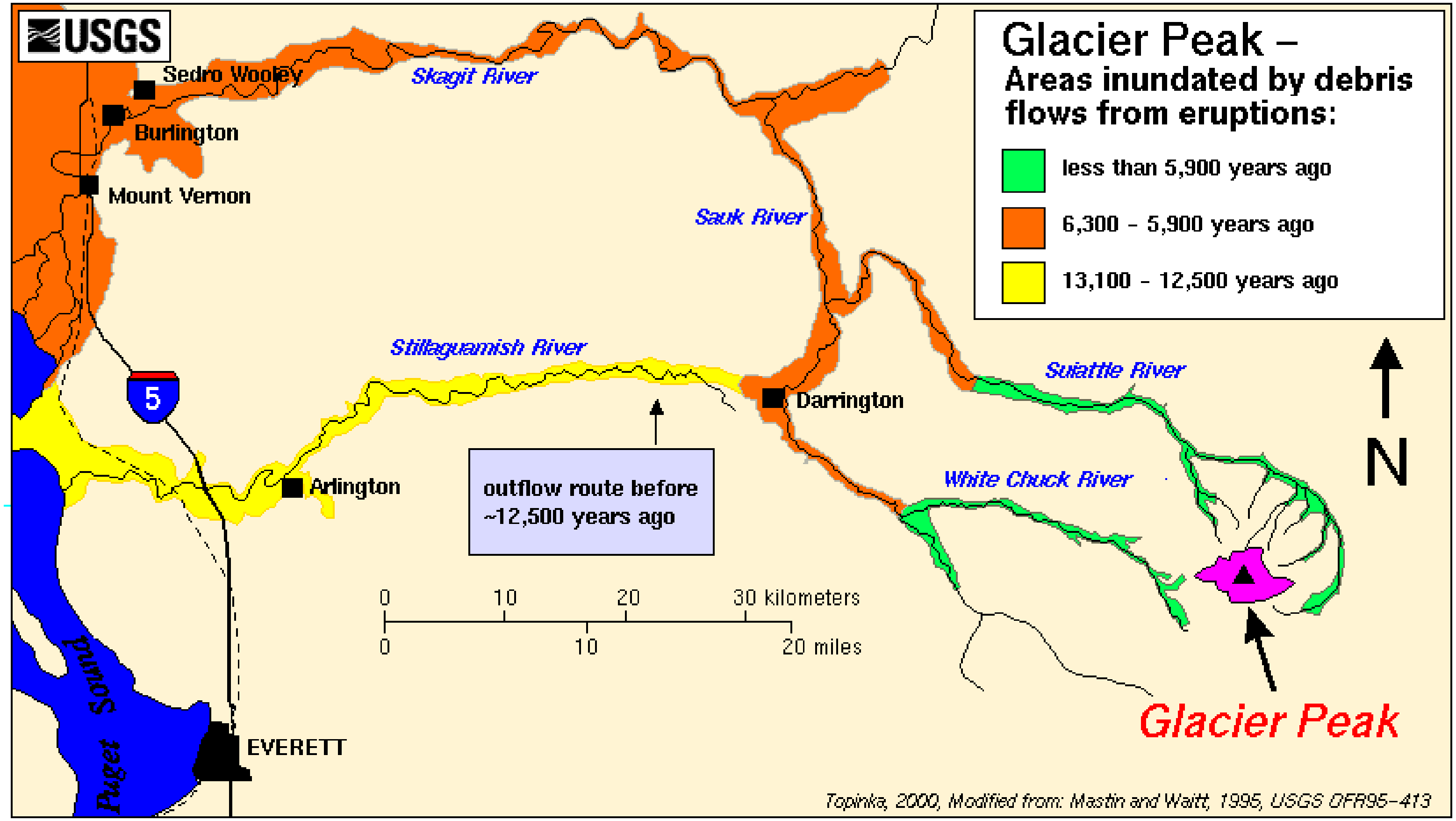

Moraine "dam" at entrance to Tsangpo gorge
Lake 3 elevation
Lake 2 elevation

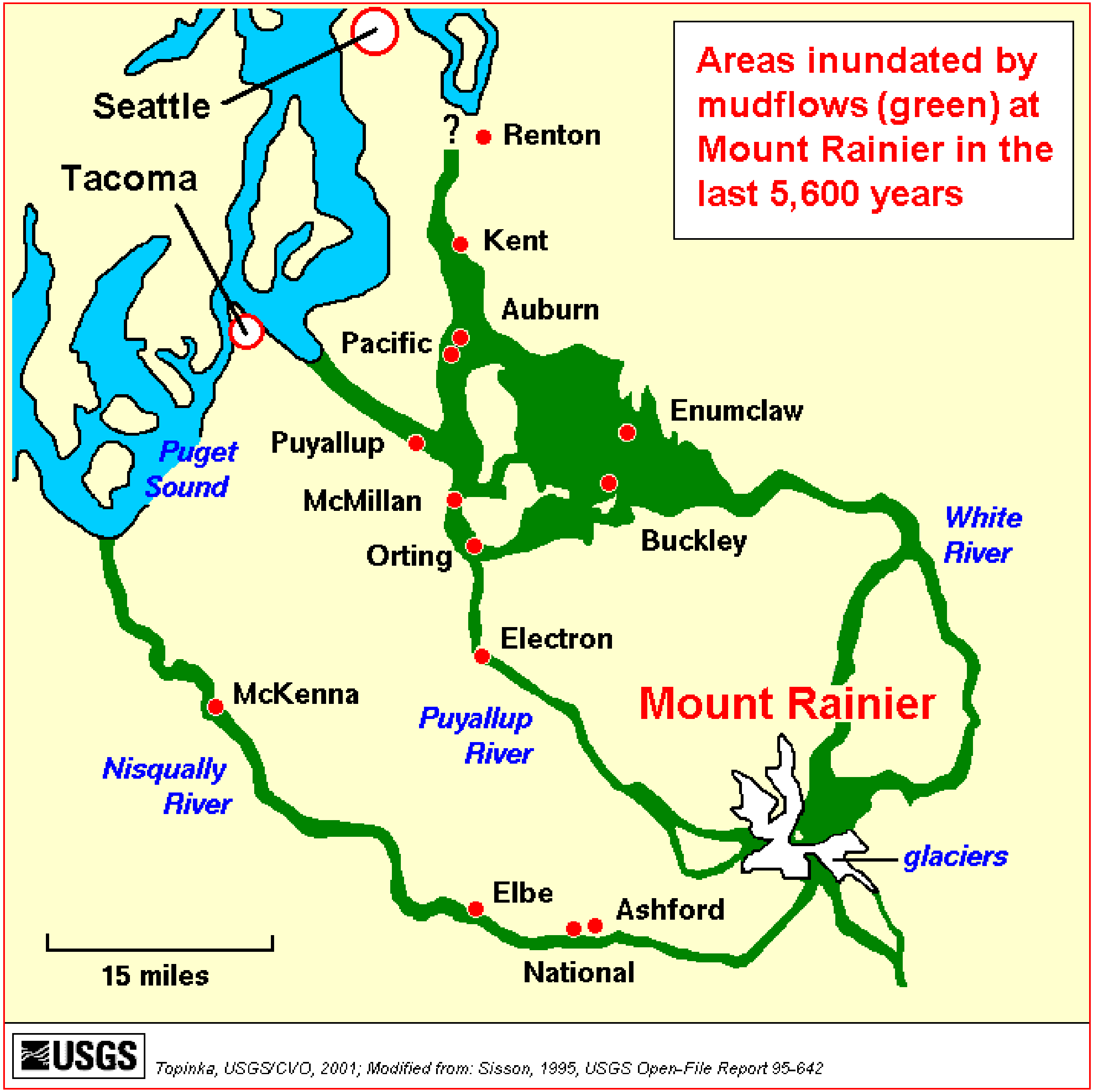

Lower Lake
Fluvial
Fluvial/Lake
25 km
93°
94°
95°
30°
29°
Namche Barwa, 7756m (25445ft)
Nyingchi
Têmo
Pei
Image © 2008 TerraMetrics
© 2008 Europa Technologies
Image © 2008 GeoEye


Delta terrace from tributary

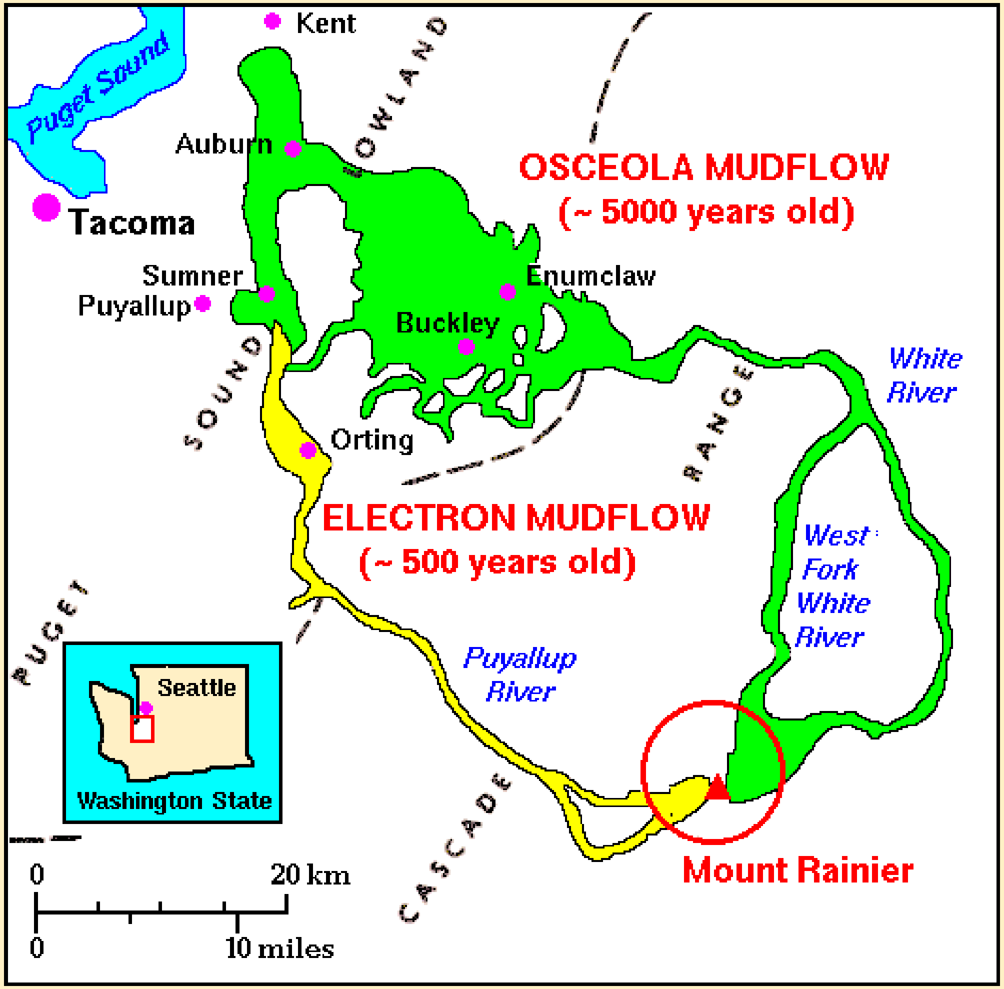


Glacier Peak Vicinity
Concrete
Sedro Woolley
Skagit R.
Burlington
Mt.Vernon
Sauk R.
N
Interstate 5
Stillaguamish R.
Suiattle R.
Darrington
Stanwood
Arlington
Sauk R.
White Chuck R.
Burlington
Northern RR
Glacier
Peak
Everett
Puget
Sound
0 10 20 30 Kilometers
0 10 20 Miles
USGS
Topinka, USGS/CVO, 1997, 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
EVERETT
Puget Sound
5
outflow route before ~12,500 years ago
0 10 20 30 kilometers
0 10 20 miles
N
Glacier Peak
Topinka, 2000, Modified from: Mastin and Waitt, 1995, USGS OFR95-413


Areas inundated by mudflows (green) at Mount Rainier in the last 5,600 years
Seattle
Tacoma
?
Renton
Kent
Auburn
Pacific
Enumclaw
Puyallup
Puget Sound
McMillan
Orting
Buckley
White River
Electron
McKenna
Mount Rainier
Puyallup River
Nisqually River
glaciers
Elbe
Ashford
National
15 miles
USGS
Topinka, USGS/CVO, 2001; Modified from: Sisson, 1995, USGS Open-File Report 95-642

Extent of Two Holocene Mudflows from Mount Rainier



USGS

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