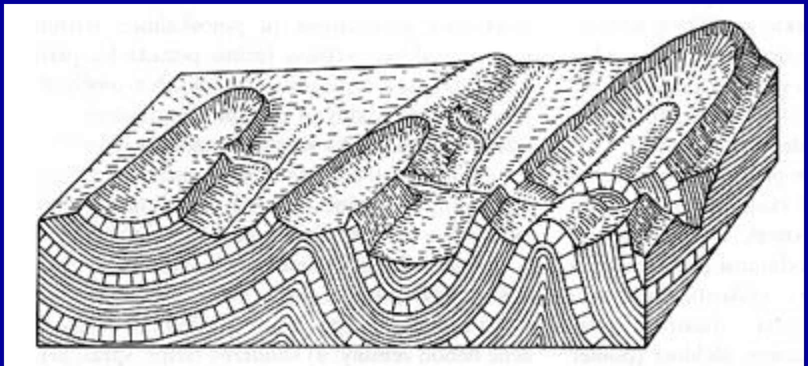
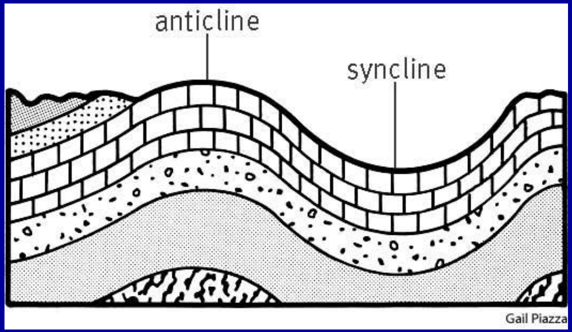
Response of tectonic processes in fluvial systems

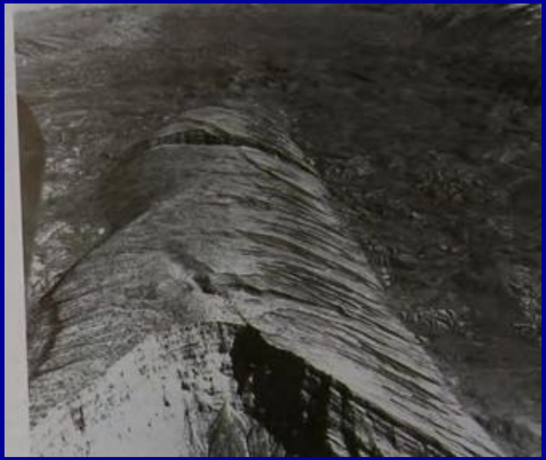
Tectonic geomorphology – tectonic landforms and landform which could be potentially related and influenced by tectonics

- Tectonic landforms - controlled directly by tectonic movements

- Fold landforms - syncline valley, anticline ridge







Inverse relief

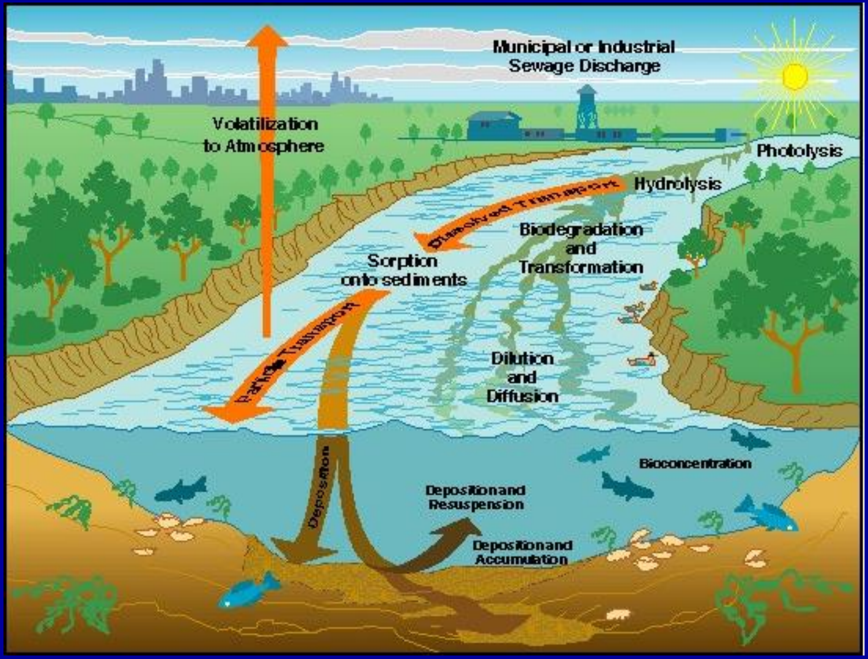
Tectonic landforms versus landforms influenced by tectonics

- Expression of tectonics in river system

- Valley system sensitive to endogenous and also exogenous processes – good information on tectonic movements

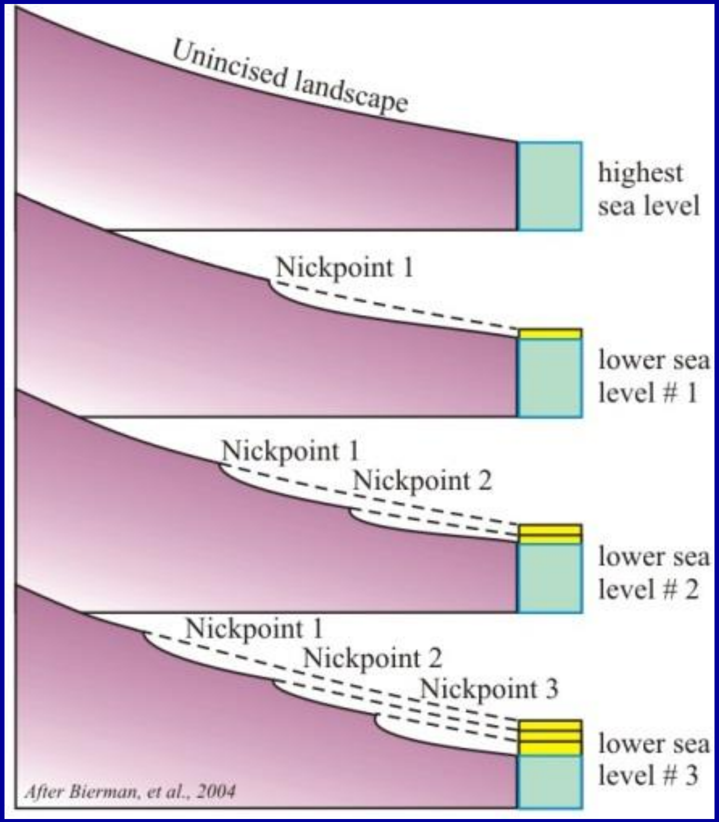
- Streams - parameters: width and depth of the channel, amount of transported material, slope of the channel, channel sinuosity, flow velocity

  These parametres are in balance in river system – sensitive to any changes

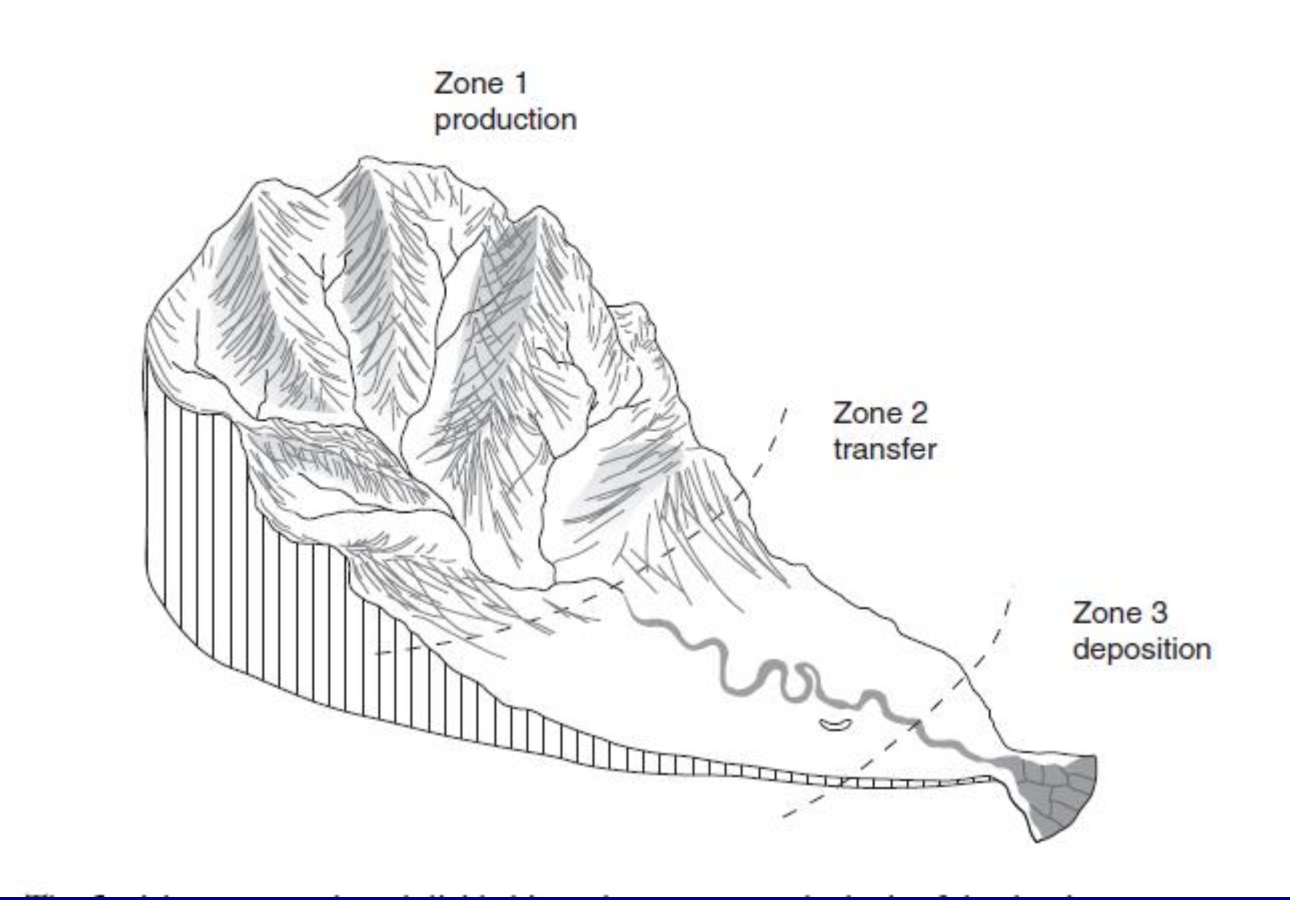


Climate changes in Quaternary (2.6 mil yrs) – large effects on river system – global changes of ocean level – cycles of aggradation (accumulation) and degradation (erosion)

= change of erosion base – the lowermost point of the stream, below this point river cannot erode (local erosional base on stream, sea level)



River actions: erosion, transportation, deposition



1) production of sediments (erosion prevails)
2) transport of material
3) deposition of material

River types based on transported material

- Alluvial rivers – parameters such as roughness of the channel bottom, viscosity, slope of channel etc. don´t allow to transport the material = river flow wittin their own sediments

  - more sensitive to tectonic movements, react to change of any parameter quickly, very young tectonics

- Bedrock rivers – material is transported, rivers erode and flow in exposed bedrock

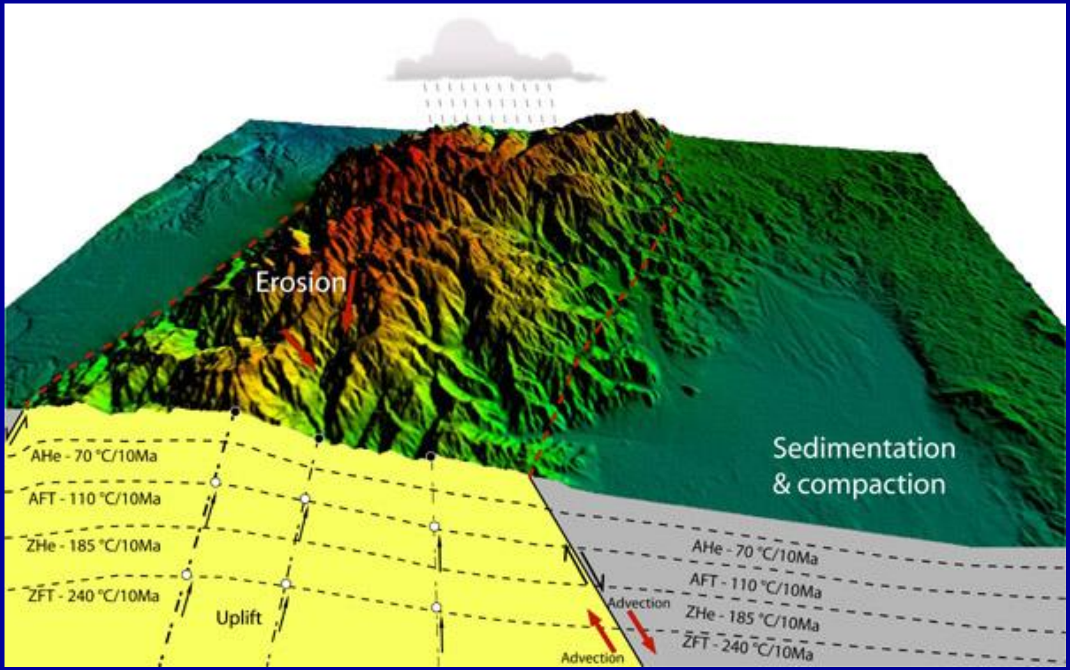
  - less sensitive to tectonics, it takes longer when they are adjusted to tectonics, tectonics is obscured by local differences in lithology

- Graded river – rivers in dynamic balance, onyl transportation, no erosion, no accumulation

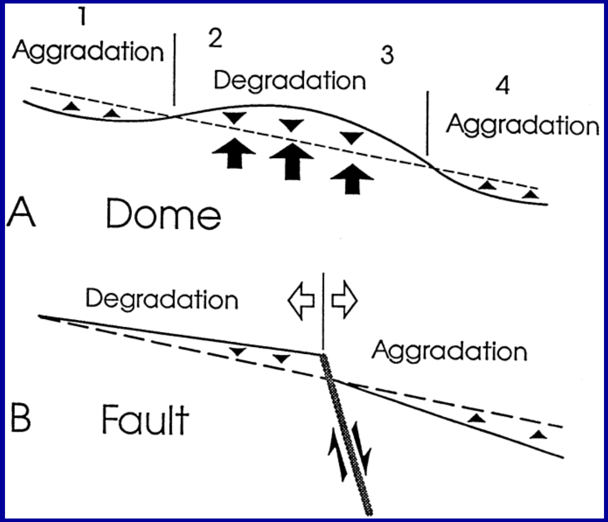
Accumulation and erosion

➪ Uplift – causes increased erosion or reduction in accumulation

- higher erosion = higher amount of material, sudden increase of material coarseness in alluvial fan sequences,

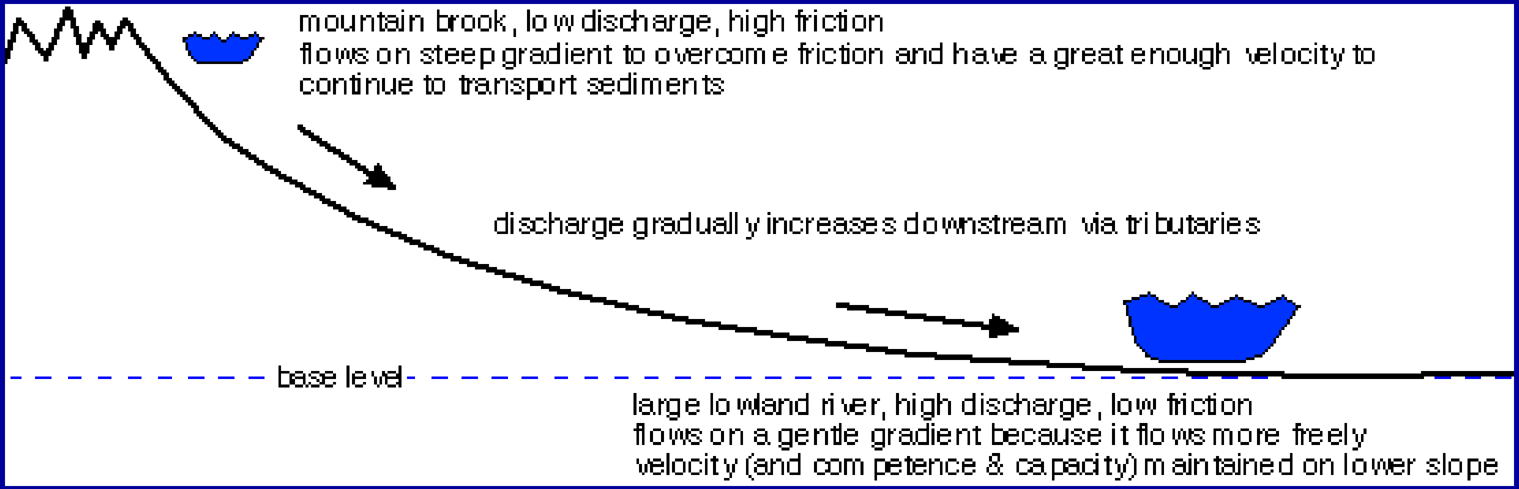


- Subsidence, – favors sedimentation or at least increase existed accumulation



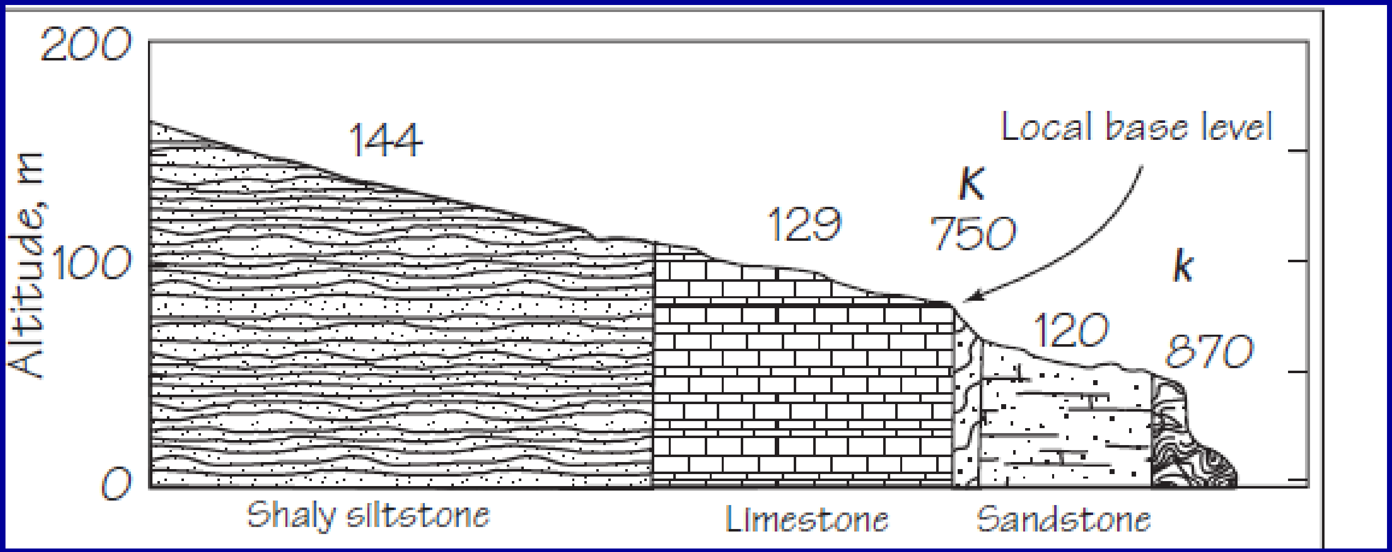
- Changes are expressed in longitudinal river profile
  Tectonics on regional scale – shape of the profile
  local scale– anomalies, knickpoints

Graded river – concave shape

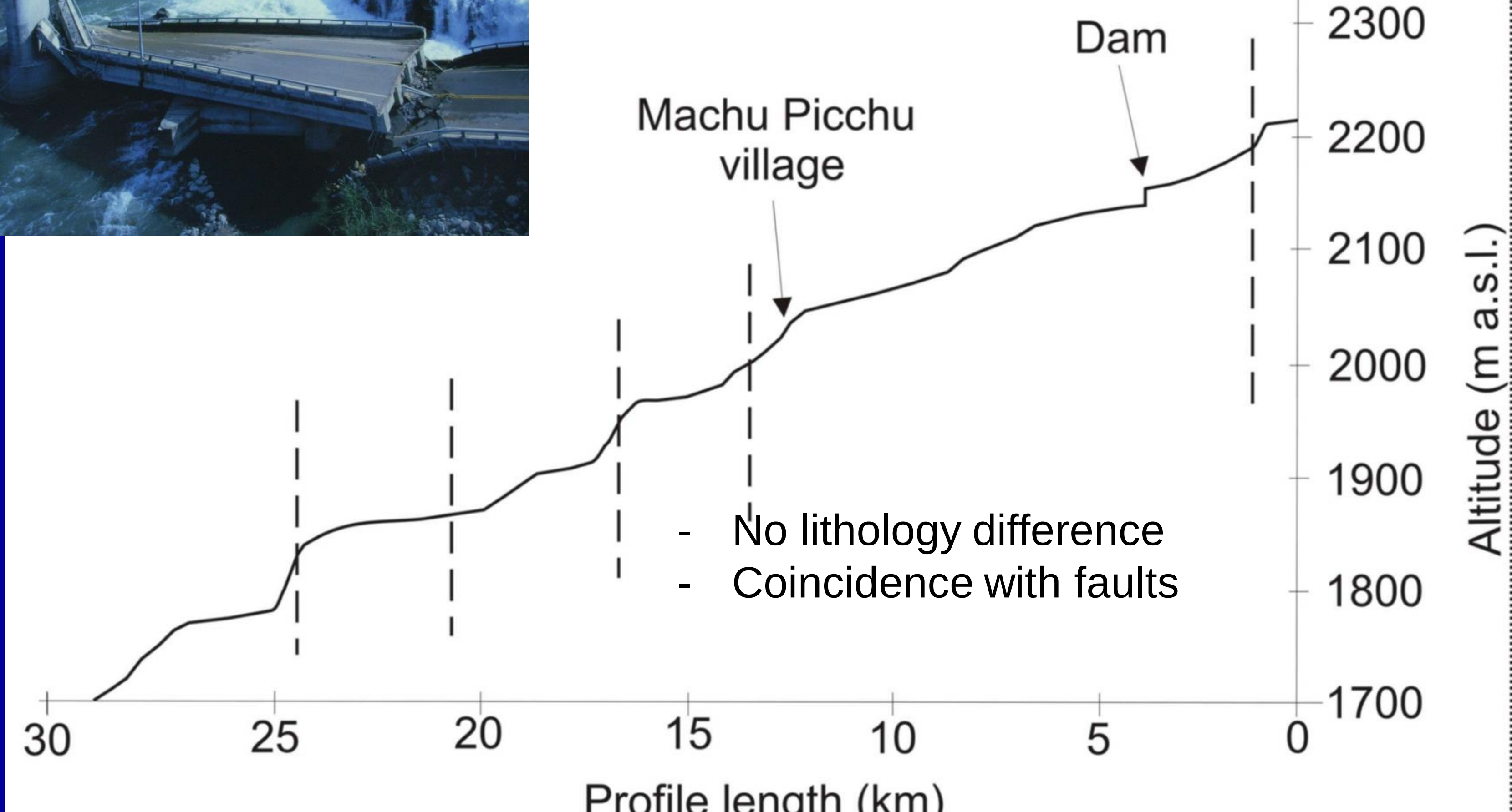


!! Causes of anomalies (knickpoints) in longitudinal river profiles:

- different lithology- more resistant / less resistant
- incision of the main river (hanging valley)
- reach of the headward erosion
- tectonic movements
- change of discharge (e.g. tributary)
- chnage in amount of transported material) (landslide, side erosion)
- antropogenic influence

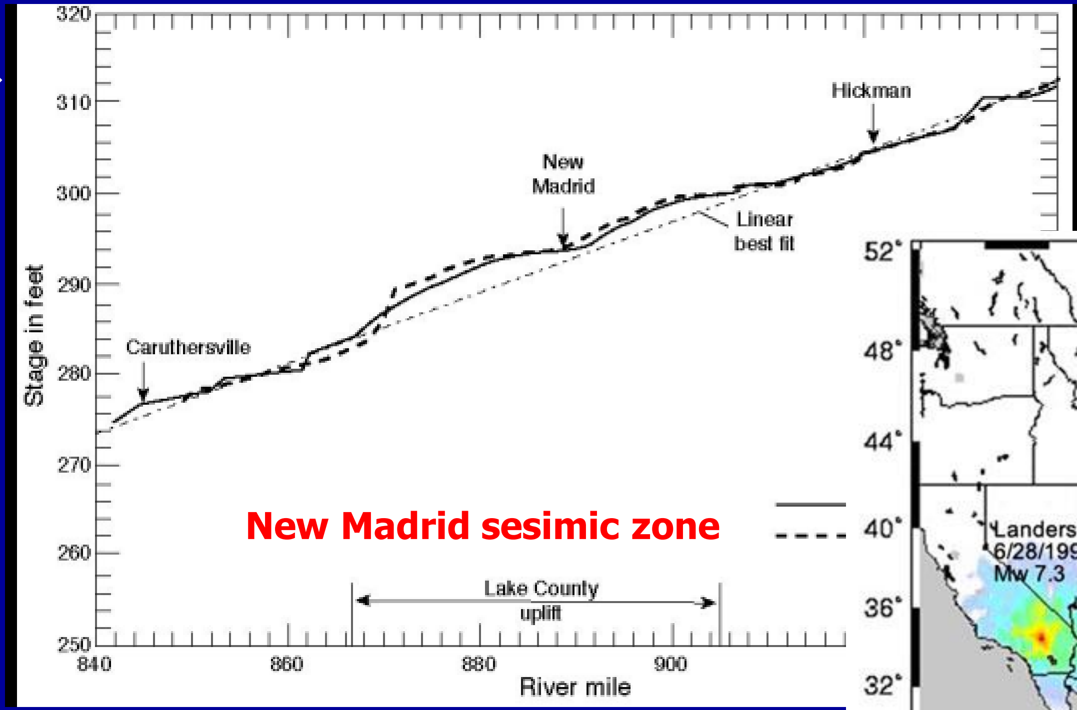


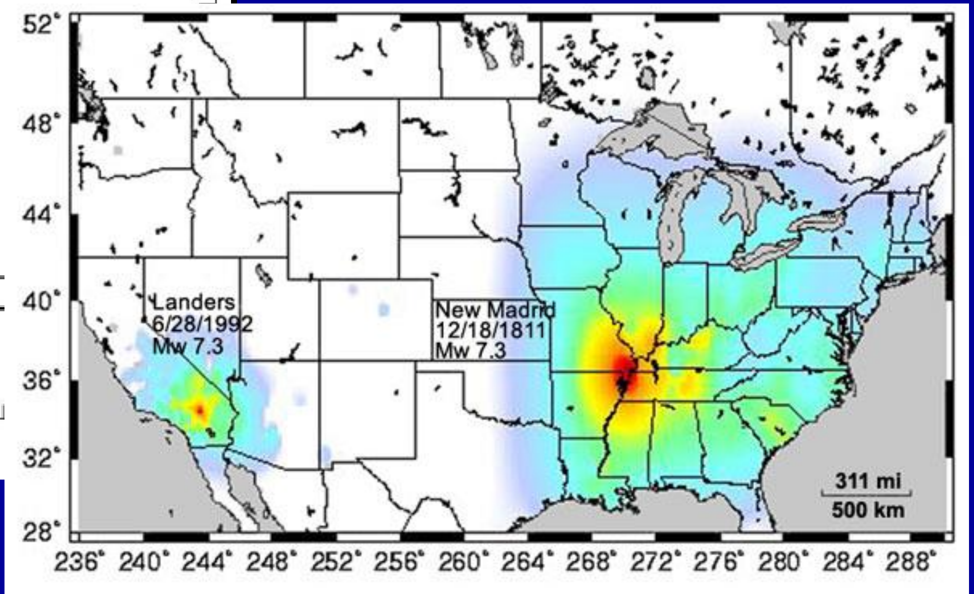
Lithologically controlled knickpoint



Anomalies tectonically controlled

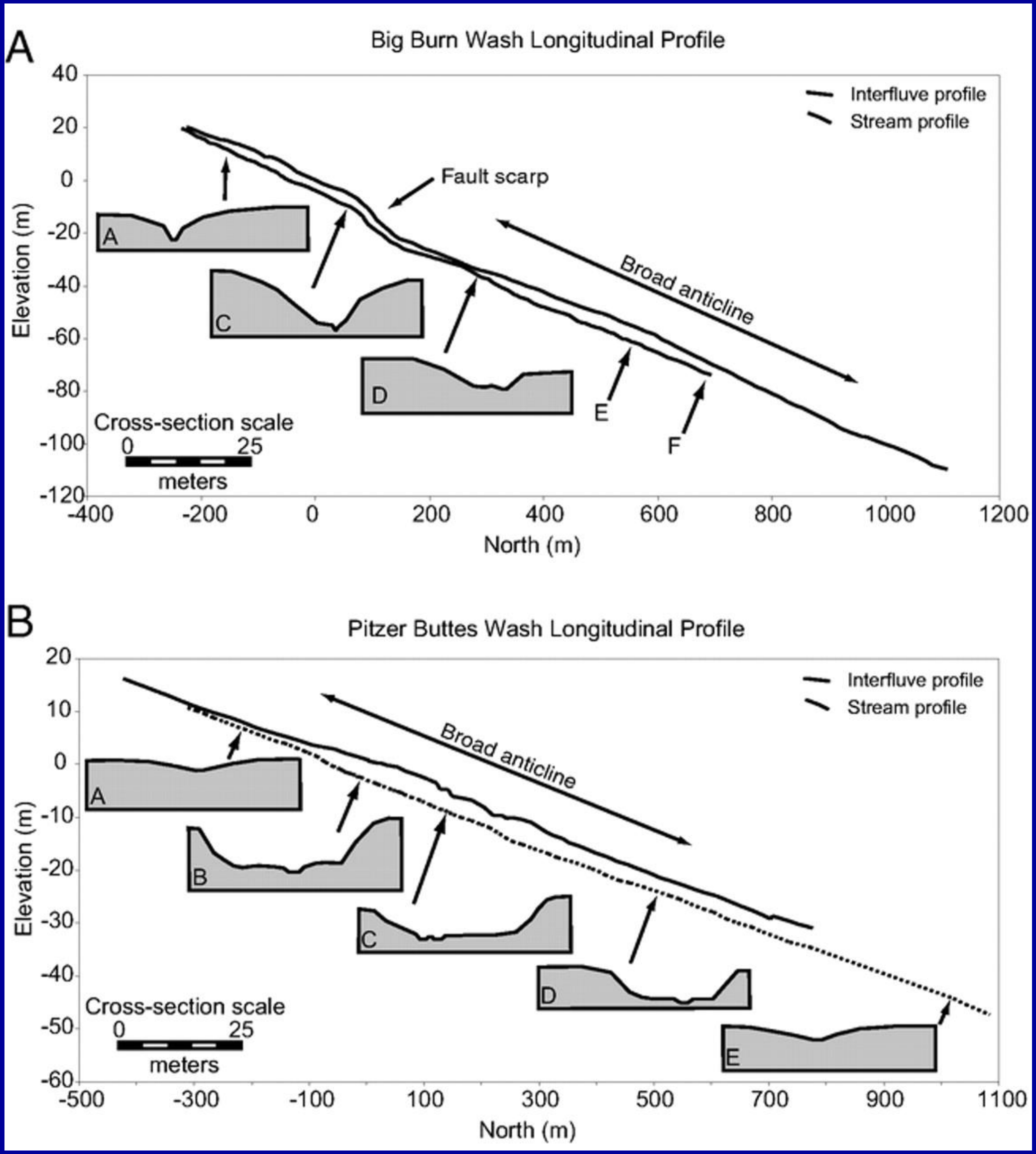
- New Madrid 1811-1812 – during month 4 large earthquakes M = 7-8
  Large regional changes in landscape – subsidence, uplift, fissures, landslides…

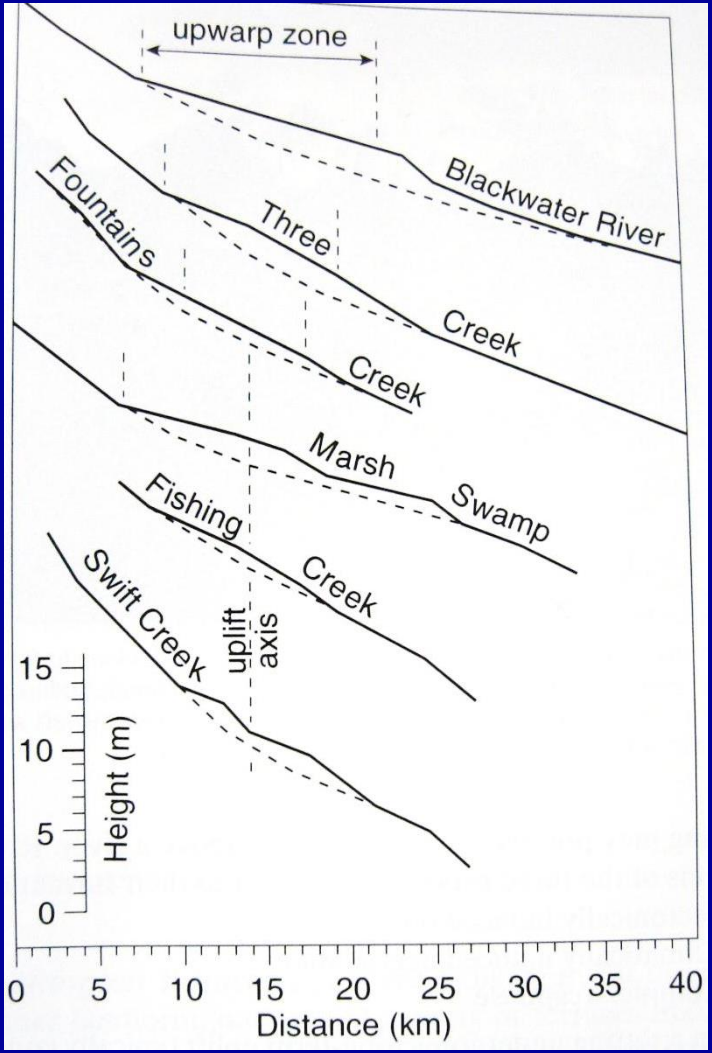




PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	None	None	None	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VELOCITY	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Present-day longitudinal profile
– response to uplift



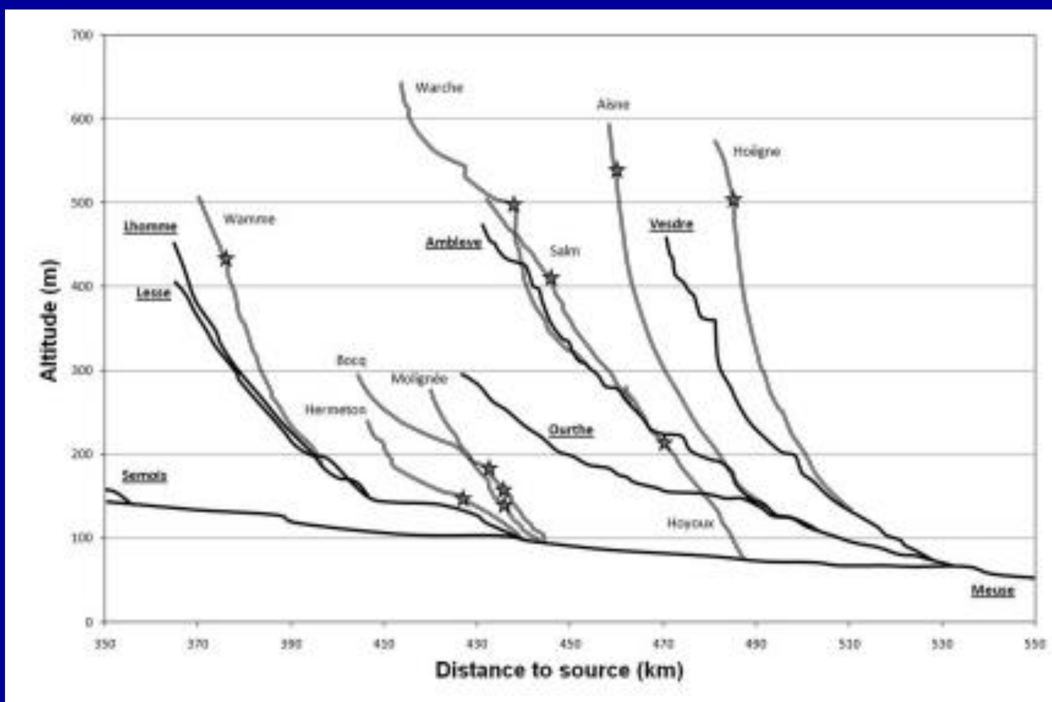


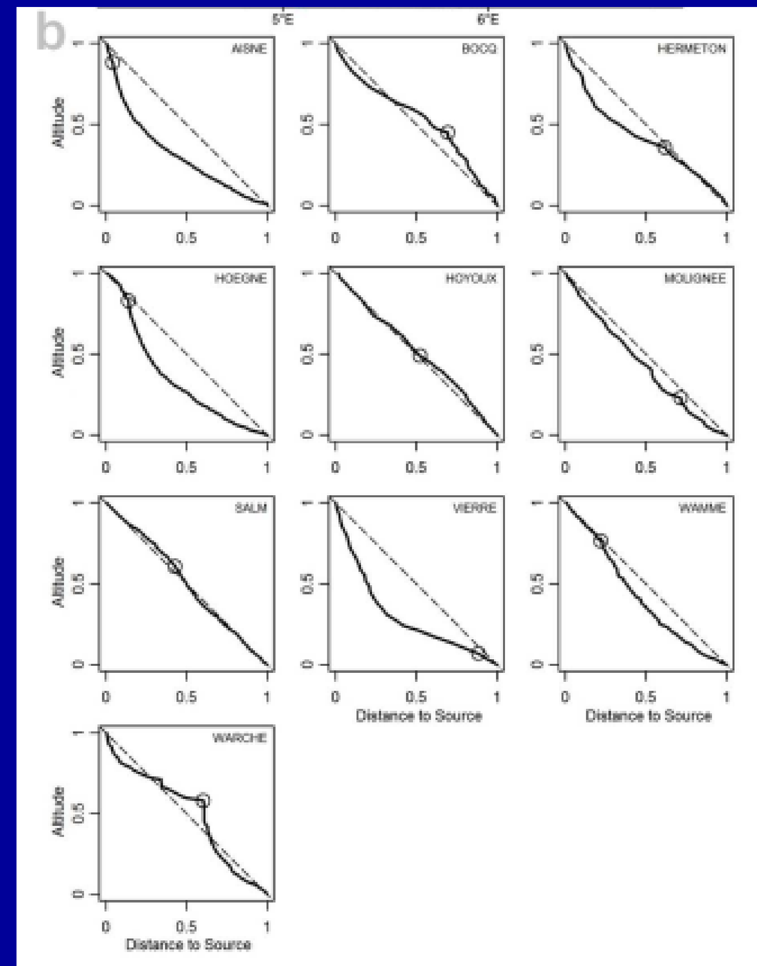
Rivers on atlantic coast showing upwarping

Shape of lingitudinal profile – reflects regional tectonics

profile convexity

- River not afftected by tectonics – concave profile
  - variabilties: lithology, different uplift rate

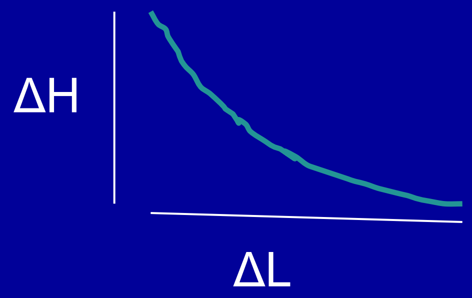




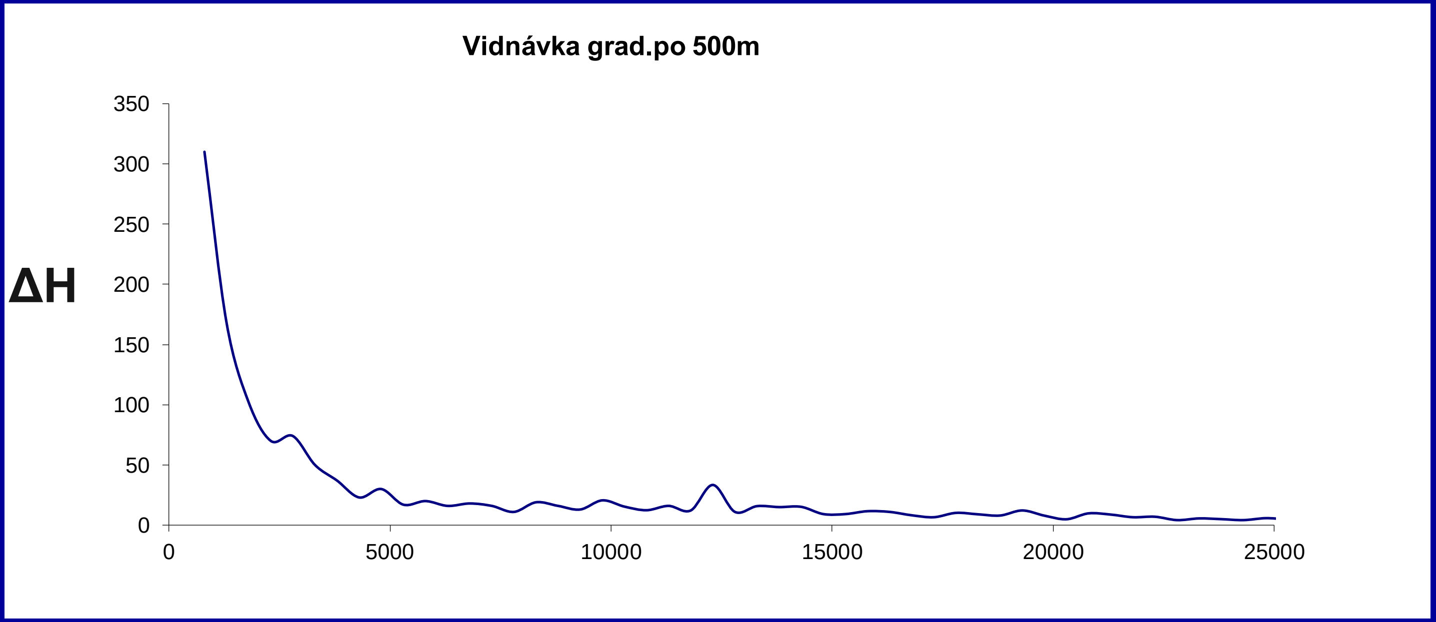
Normalized river profiles

- River analysis – several methods – construction of longitudinal profiles, gradient, SL gradient, convexity

- **Gradient** – m/km =(ΔH/ΔL)



ΔL … length of a segment (e.g. 100 m, 500m, ...)



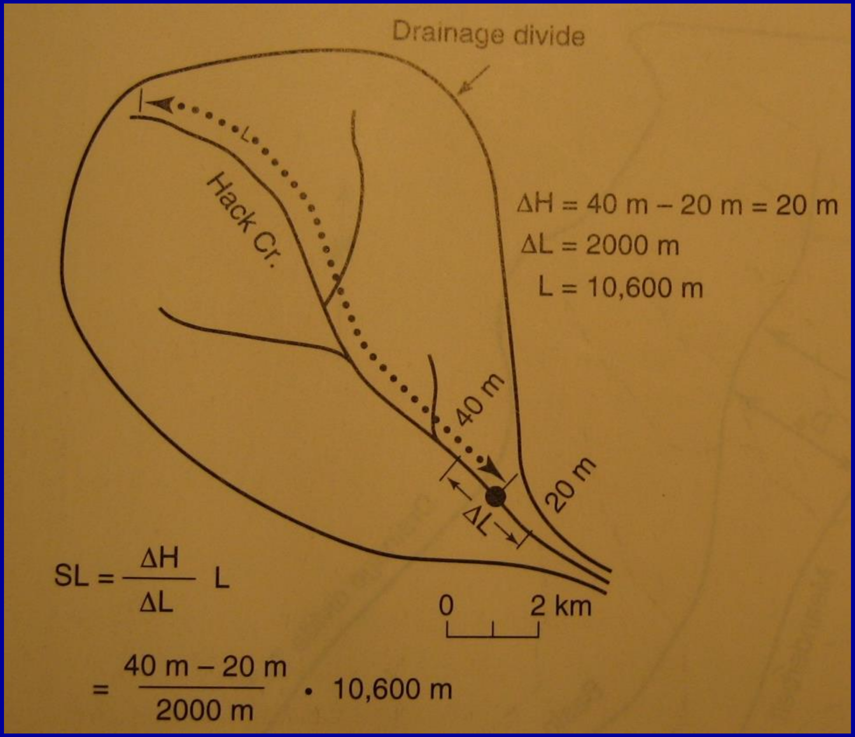
Distance from the spring

SL-index (stream-length gradient) (Hack (1973))

Indicator of anomalies on long profile

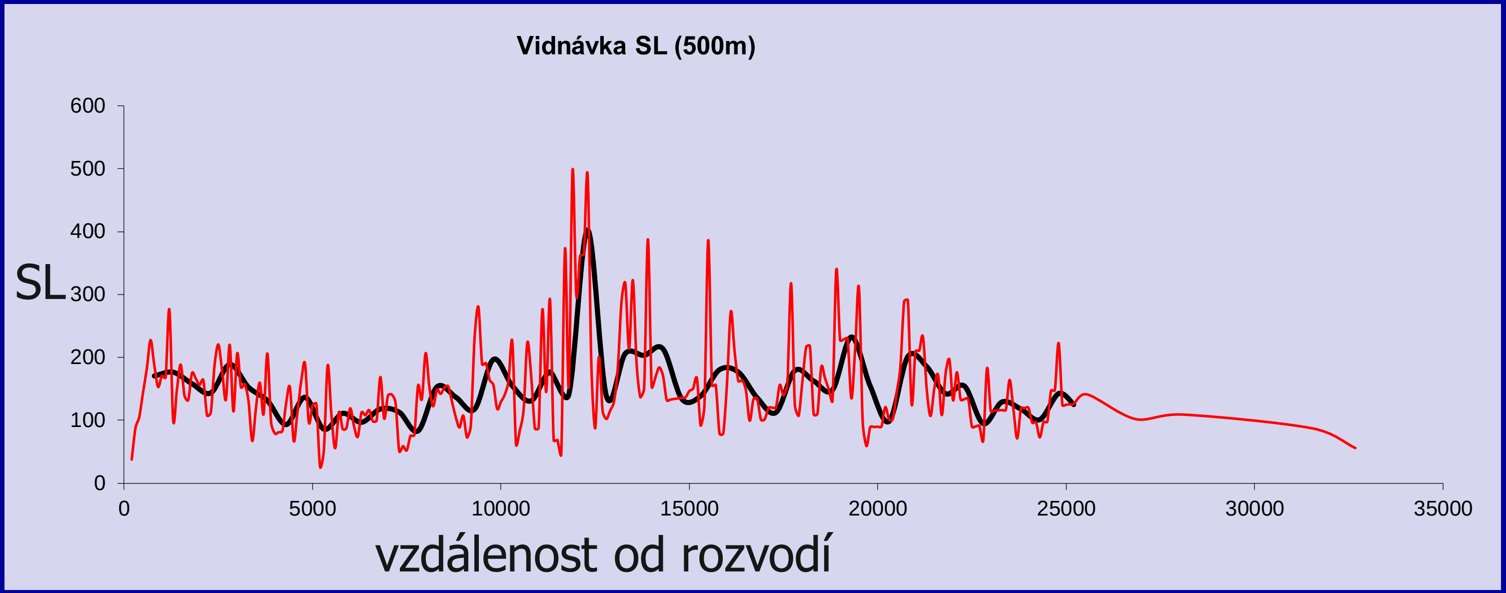
$$SL=(\Delta H/\Delta L)/L$$

ΔH … height difference in a segment
ΔL … length of segment (e. g. 100m)
L … distance of the segment centre from the water divide



There is a relationship between discharge, basin area and stream length

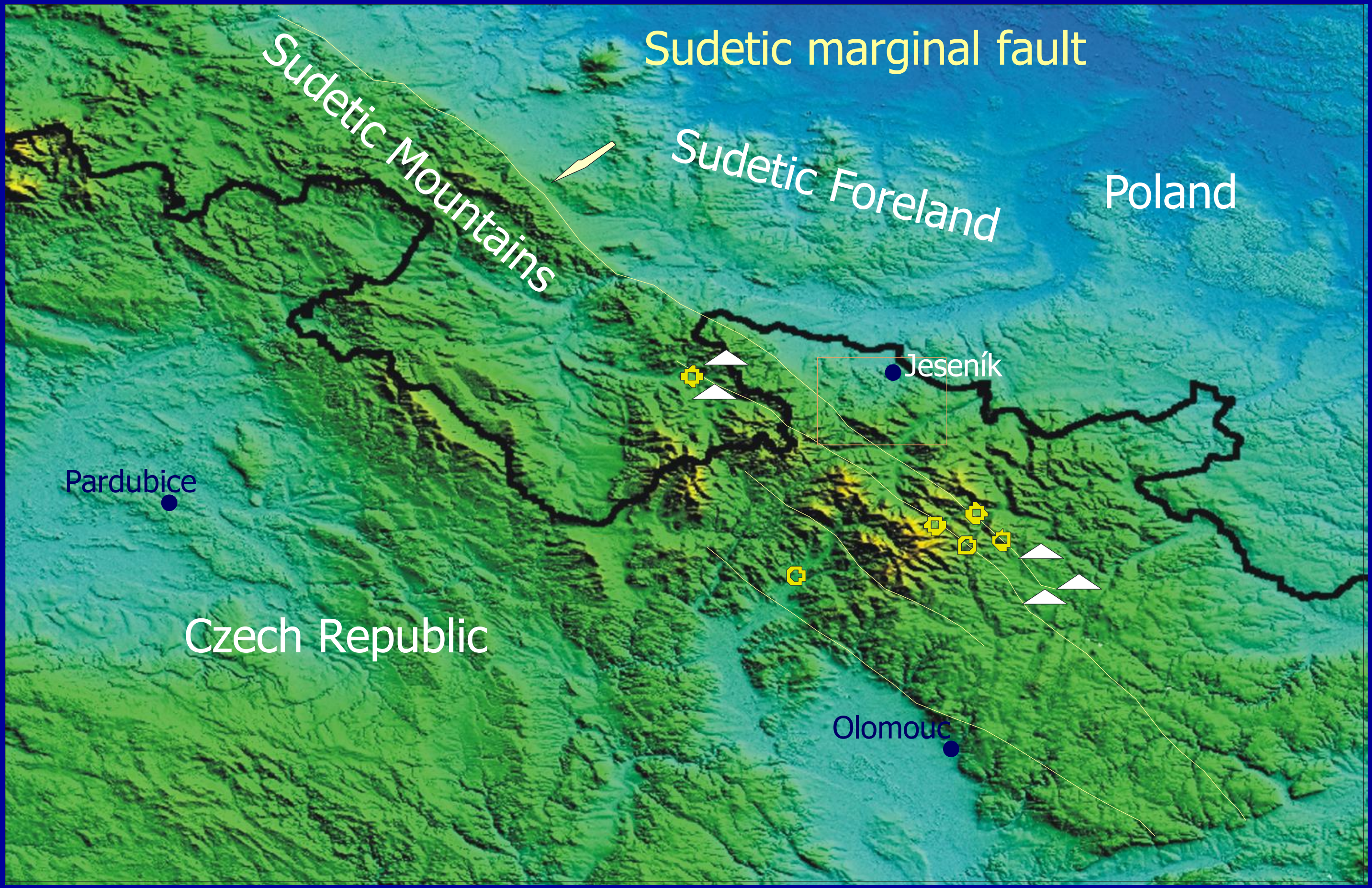
Farther from spring (source) – smaller gradient, higher discharge,
SL – respects the distance from source area



Graded rivers – SL index constant along the stream

Changes in index value can reflect:

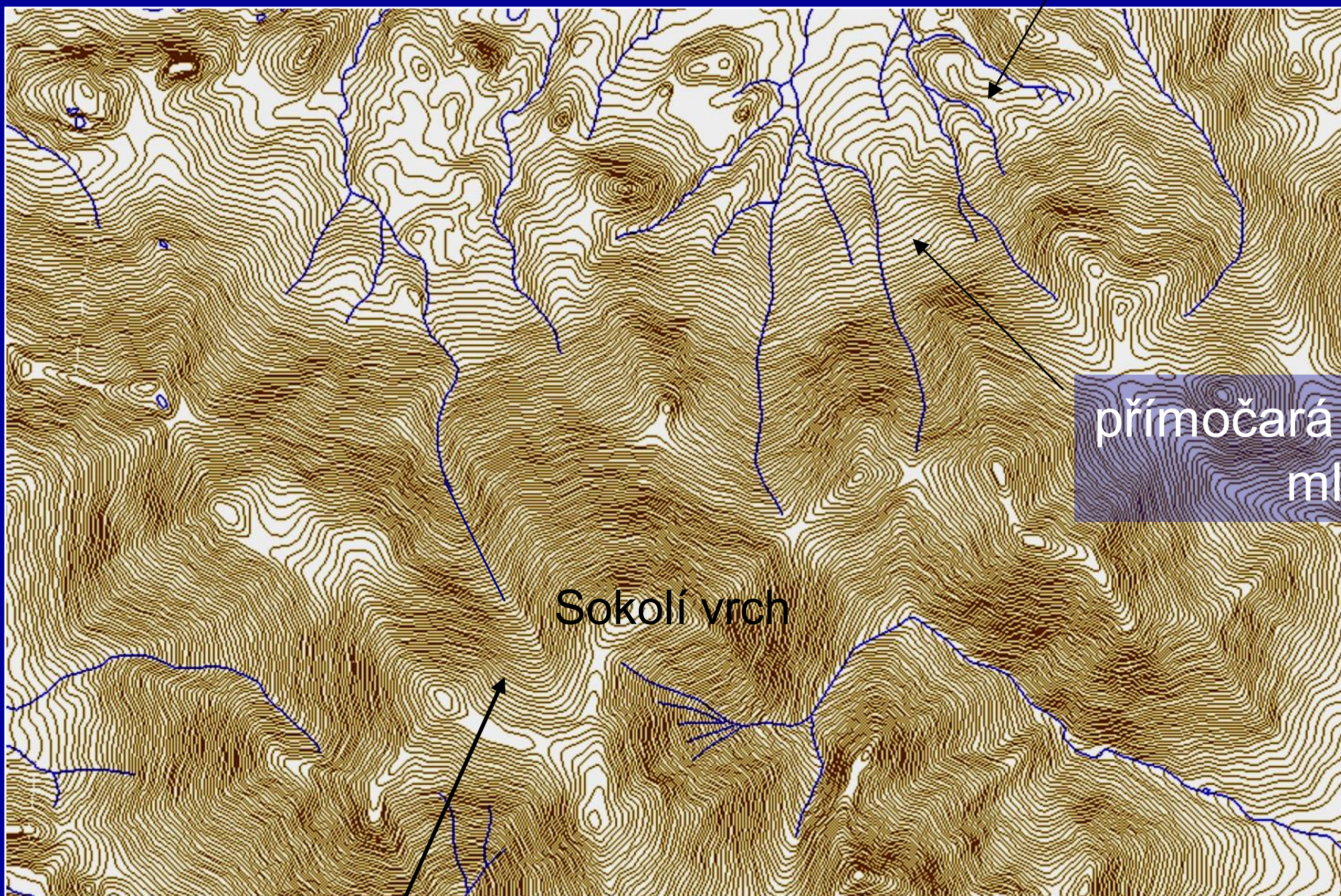
- lithology change
- tectonic activity
- local changes – headward erosion
    - joining of tributaries
    - antropogenic influence



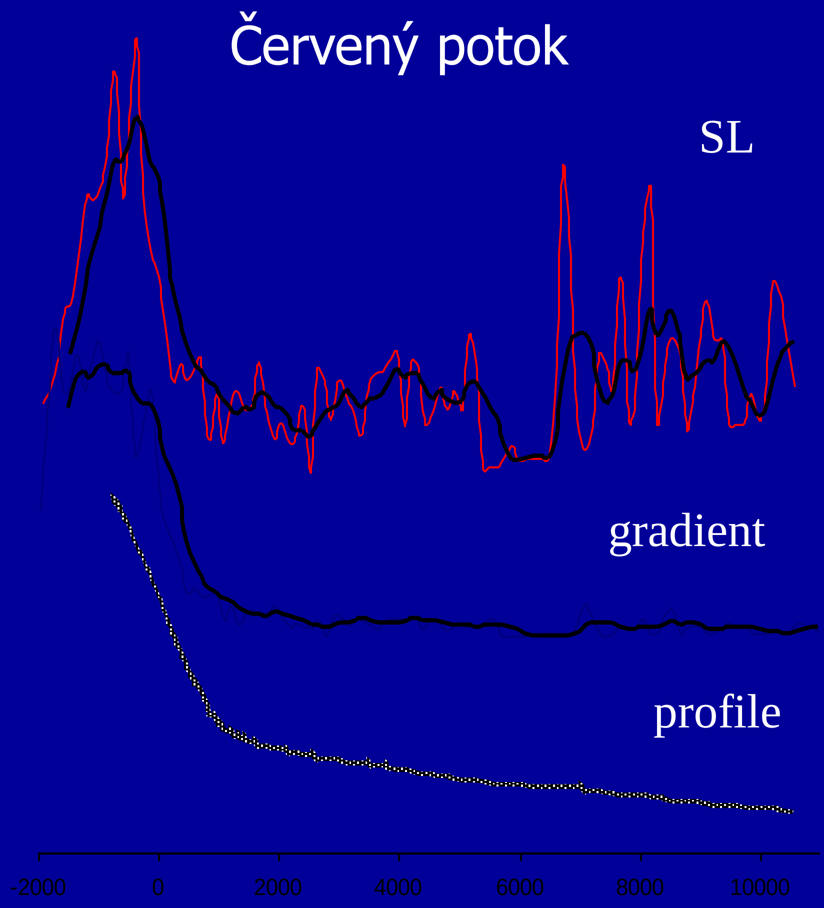
Neogene to Quaternary volcanism

mineral springs with CO2

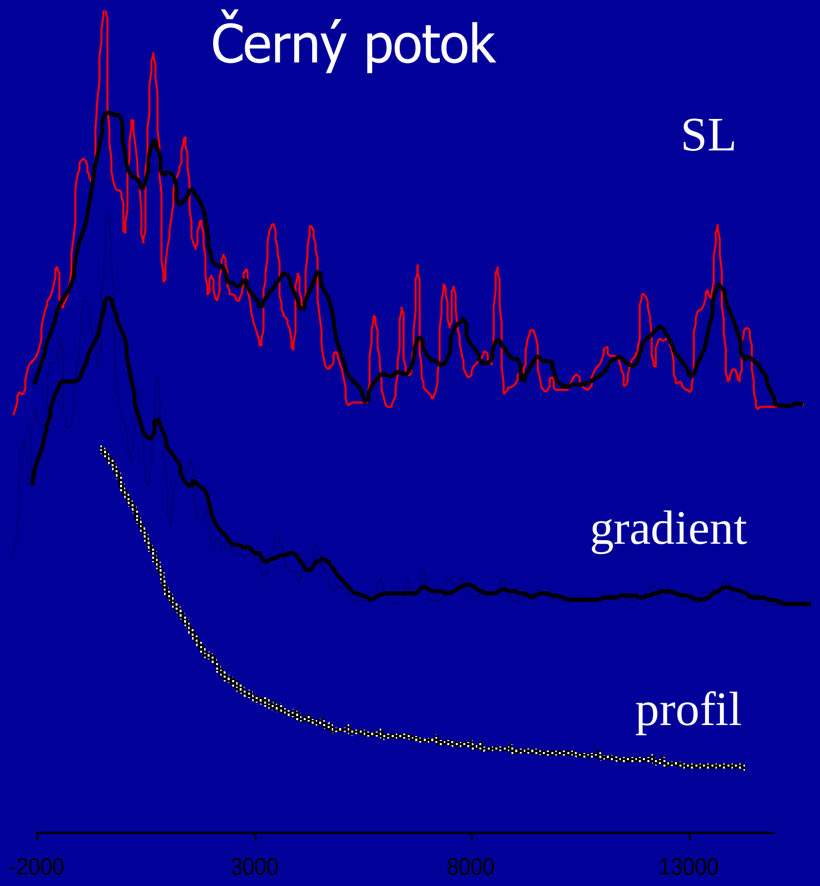
- analysis of valleys in Sokolský Ridge



Longitudinal profiles, gradient, SL index



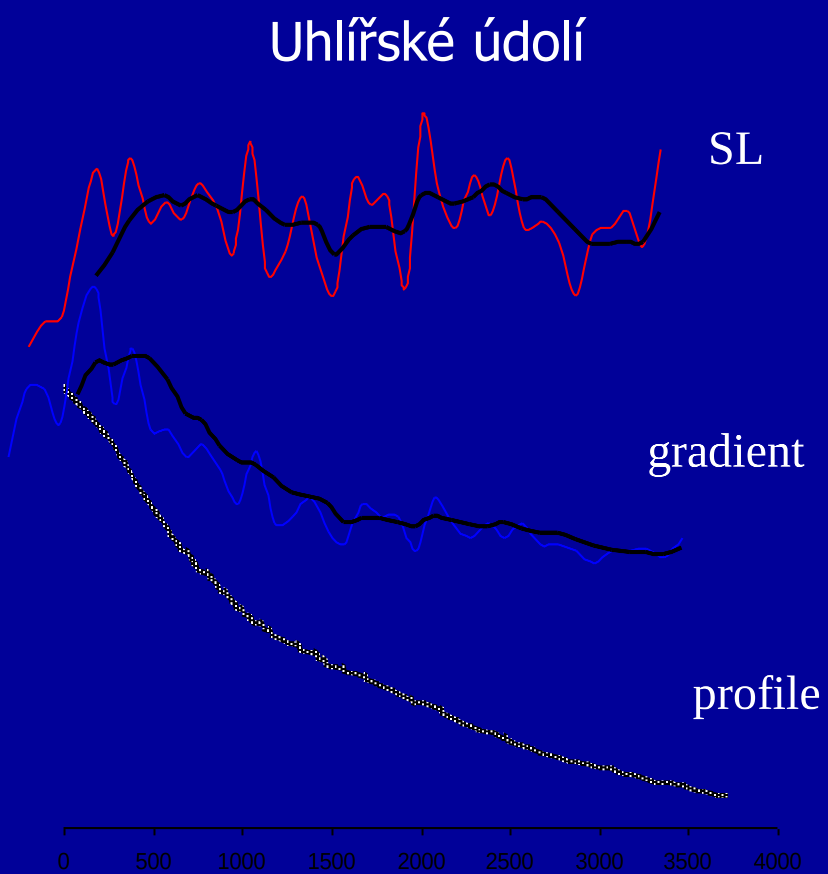
Černý potok

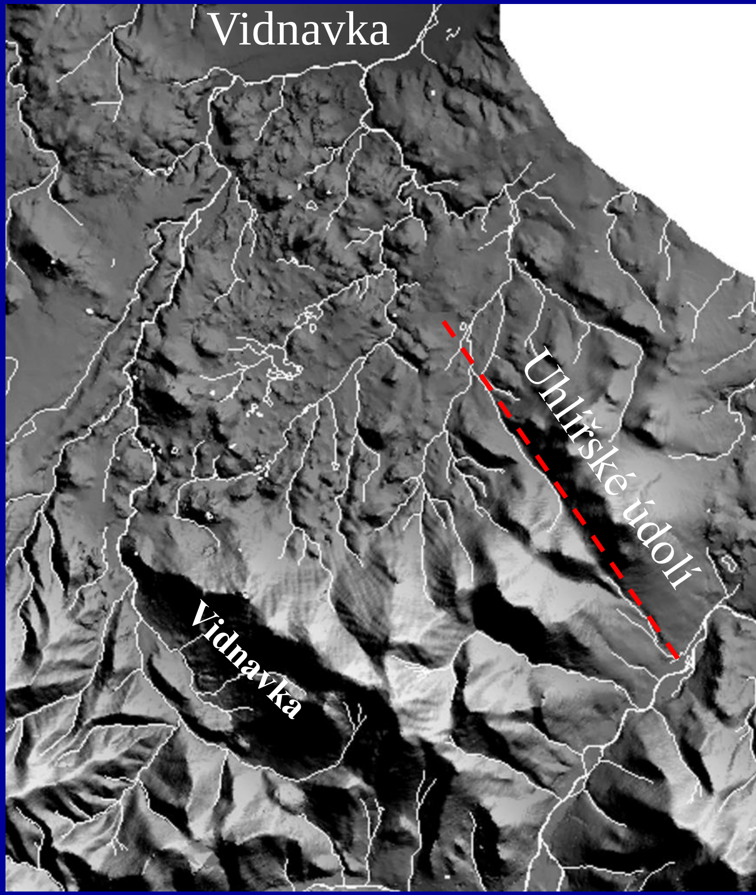


SL
gradient
profil
-2000
3000
8000
13000

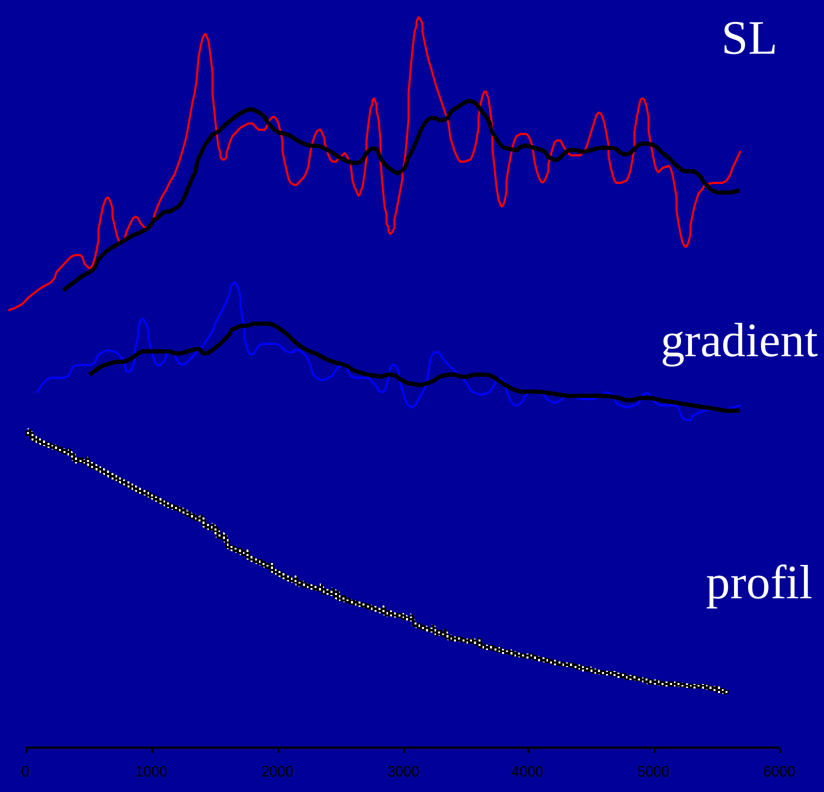
Černý potok
Vidnavka

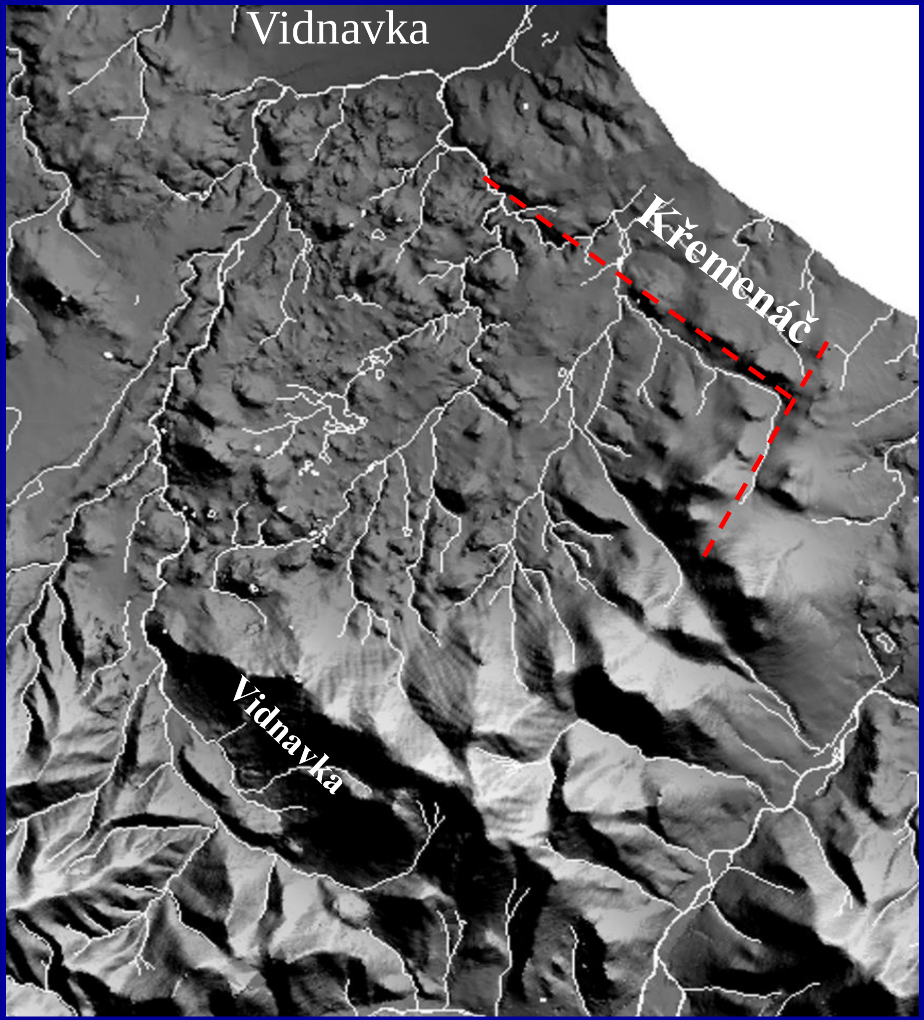
x exemption


Uhlířské údolí
SL
gradient
profile
0
500
1000
1500
2000
2500
3000
3500
4000

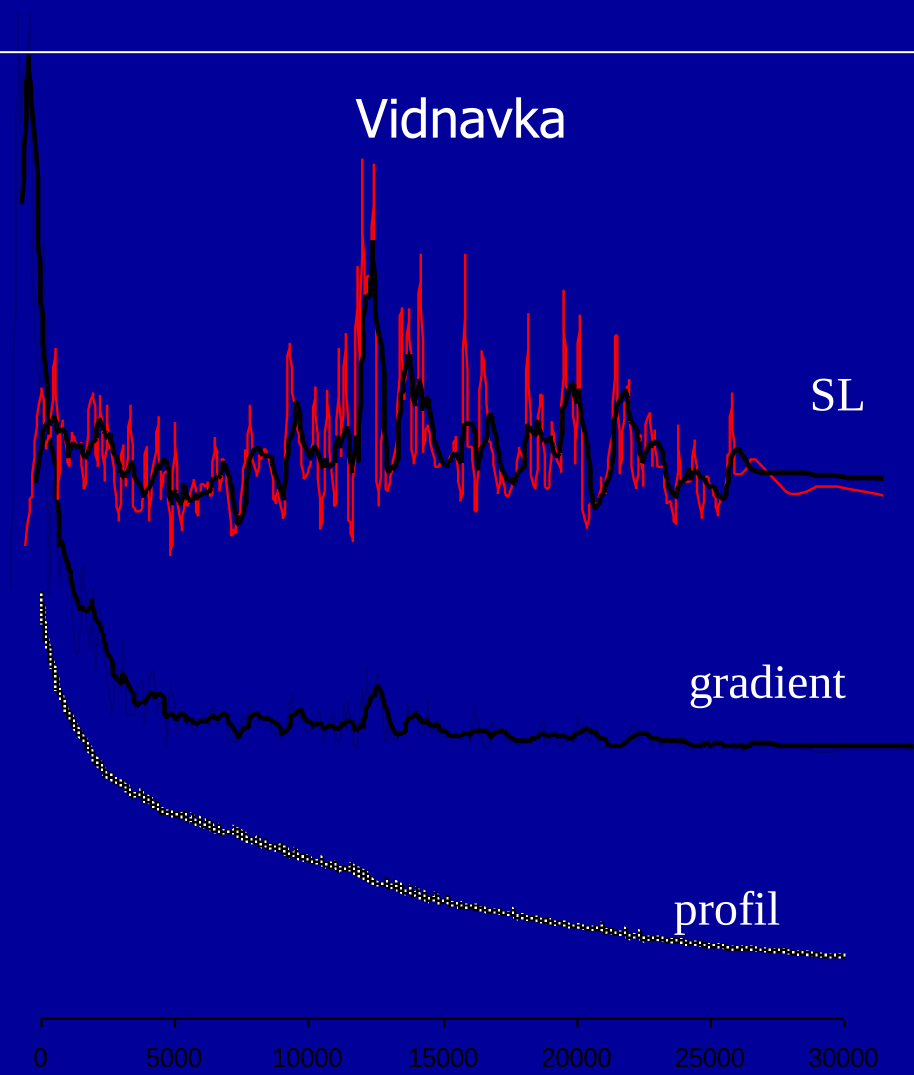

Vidnavka
Uhlířské údolí
Vidnavka

Křemenáč


SL
gradient
profil
0
1000
2000
3000
4000
5000
6000


Vidnavka
Křemenáč
Vidnavka

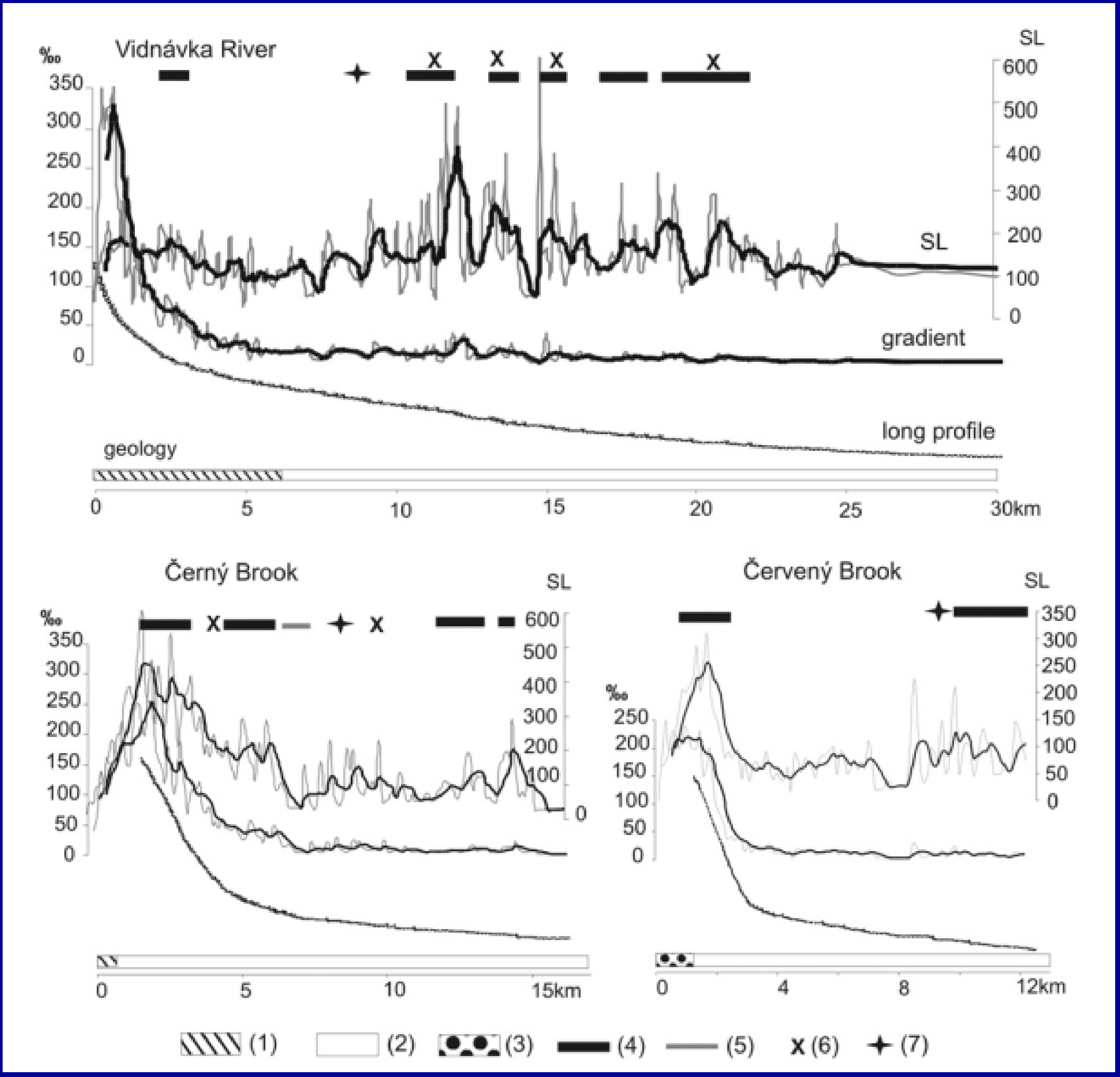
Vidnavka

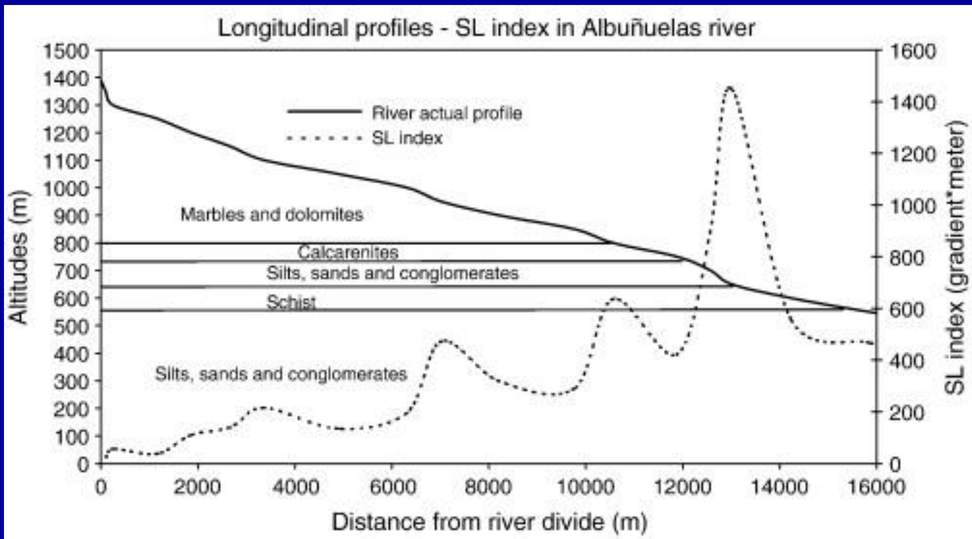


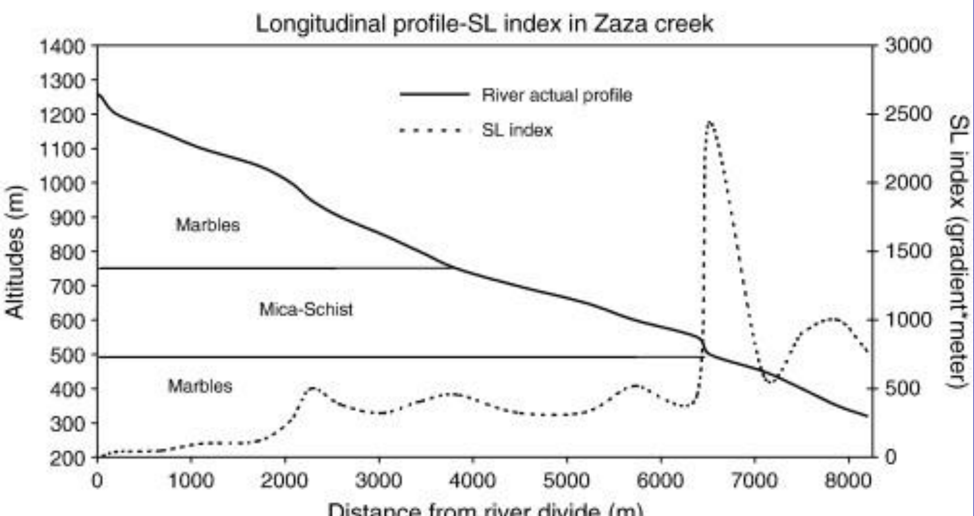
SL
gradient
profil
0
5000
10000
15000
20000
25000
30000

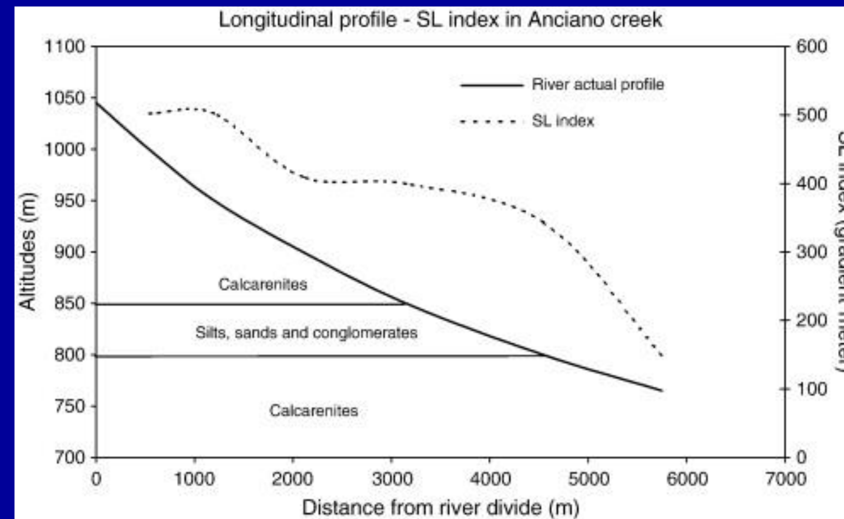
Vidnavka
Vidnavka

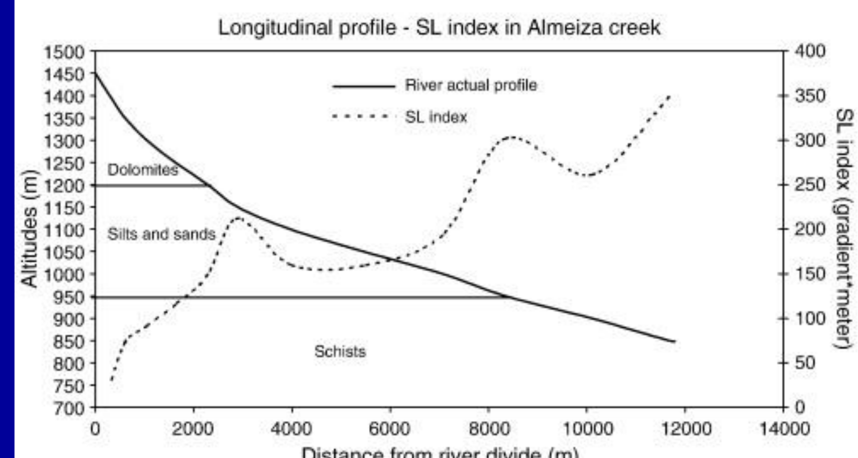
(1) — metamorphic rocks (gneisses, marbles, phyllites, amphibolites),
(2) — granitoids,
(3) — segment of stream flowing along the lithological boundary;
(4) — stream follows a morpholineament/fault,
(5) — river crosses a morpholineament/fault,
(6) — beginning of the deepened valley,
(7) — river flows into the planation surface (etchplain).

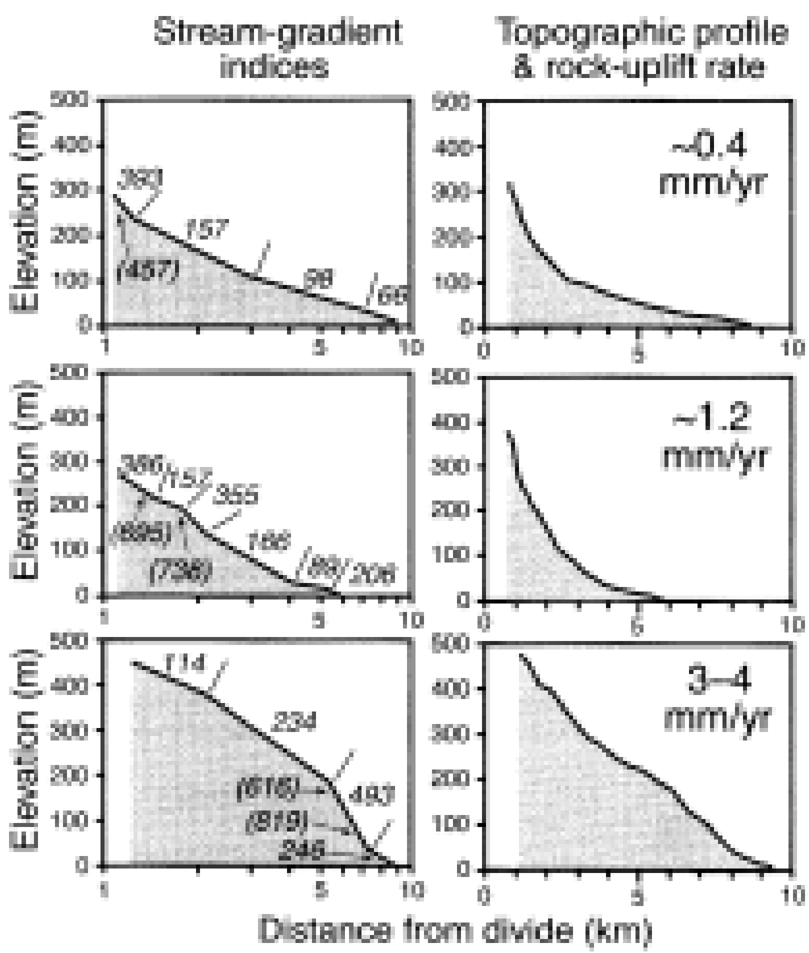



Longitudinal profiles - SL index in Albuñuelas river
1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100 0
Altitudes (m)
1600 1400 1200 1000 800 600 400 200 0
SL index (gradient*meter)
River actual profile
SL index
Marbles and dolomites
Calcarenites
Silts, sands and conglomerates
Schist
Silts, sands and conglomerates
0 2000 4000 6000 8000 10000 12000 14000 16000
Distance from river divide (m)

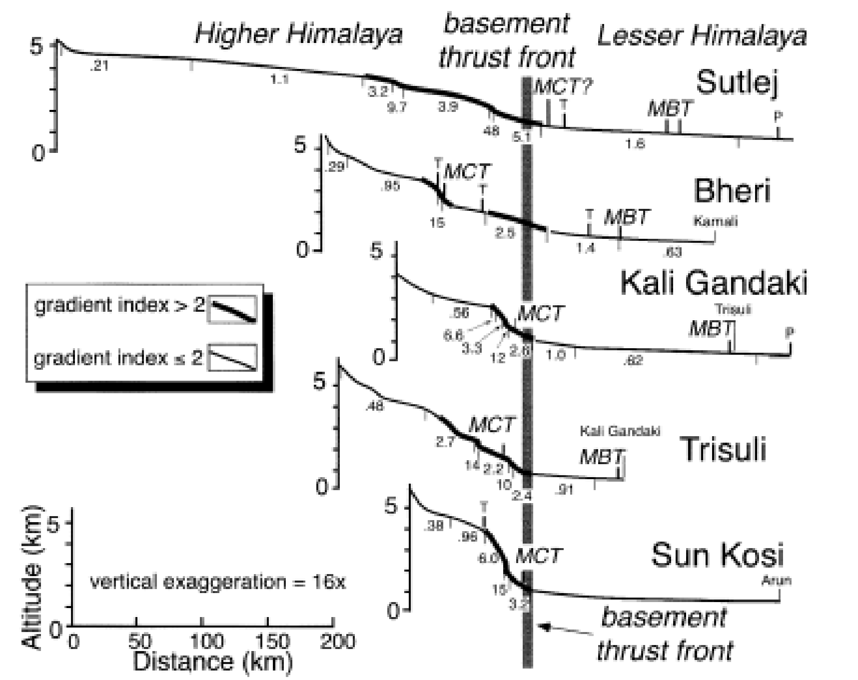

Longitudinal profile-SL index in Zaza creek
1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200
Altitudes (m)
3000 2500 2000 1500 1000 500 0
SL index (gradient*meter)
River actual profile
SL index
Marbles
Mica-Schist
Marbles
0 1000 2000 3000 4000 5000 6000 7000 8000
Distance from river divide (m)


Longitudinal profile - SL index in Anciano creek
1100 1050 1000 950 900 850 800 750 700
Altitudes (m)
600 500 400 300 200 100 0
SL index (gradient*meter)
River actual profile
SL index
Calcarenites
Silts, sands and conglomerates
Calcarenites
0 1000 2000 3000 4000 5000 6000 7000
Distance from river divide (m)


Longitudinal profile - SL index in Almeiza creek
1500 1450 1400 1350 1300 1250 1200 1150 1100 1050 1000 950 900 850 800 750 700
Altitudes (m)
400 350 300 250 200 150 100 50 0
SL index (gradient*meter)
River actual profile
SL index
Dolomites
Silts and sands
Schists
0 2000 4000 6000 8000 10000 12000 14000
Distance from river divide (m)



Note that the zone of rapid rock uplift has a steeper gradient, higher relief, and higher gradient indices. Modified after Merritts and Vincent (1989)



Thicker segments of the profile indicate reaches where the local gradient index (SL) is more than twice the index (k) for the entire profile: SL / k = 2. The steepest gradients are not associated with the Main Boundary thrust or active deformation to the south. Rather they occur near the Main Central thrust and appear to result from upward ramping of the overthrusting Himalayas above a deep-seated basement thrust. Modified after Seeber and Gornitz (1983).

- Valley cross sections
- Anomalies in long profiles => changes in valley cross - sections
- Valley slope asymmetry – different lithology
  - climate (various erosion – variously oriented slopes)
- Height asymmetry of valley slopes – lithology, tectonics, evolution of the region
- Valley types – erosional phases, different erosion intensity
  controlled by - tectonic activity
  structural-lithological conditions
  river gradient and hydrology

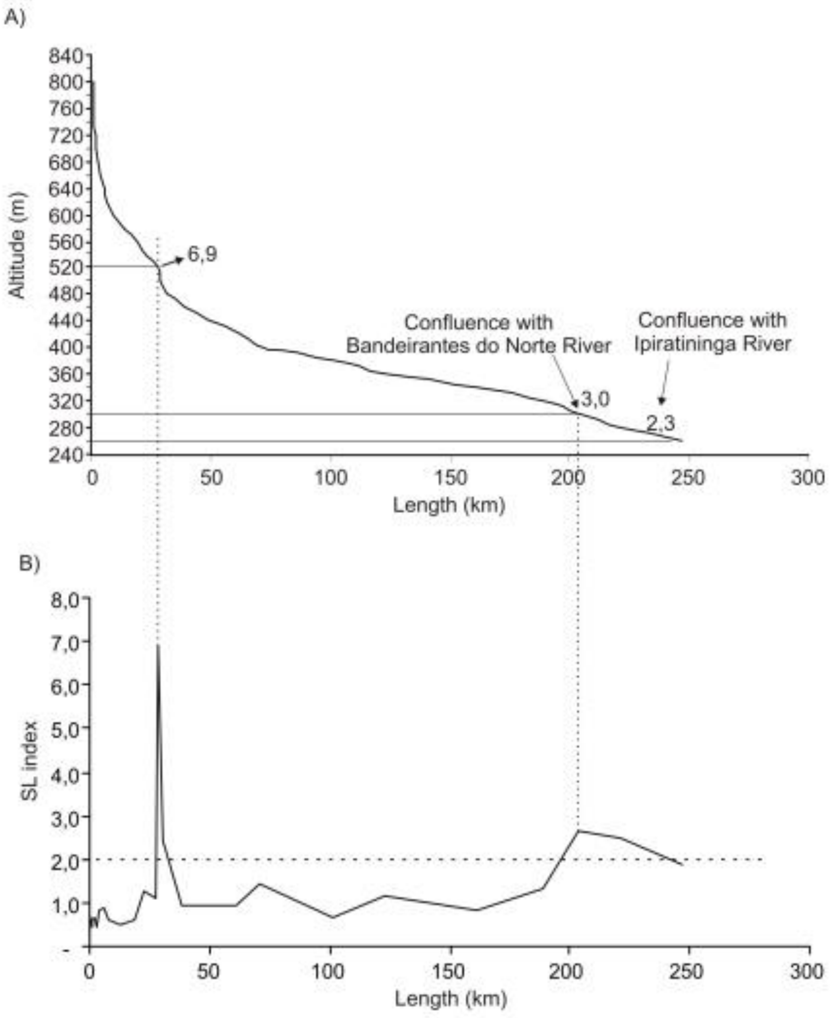


FIGURE 4. Longitudinal profile (A) and SL index of the Pirapó River (B).

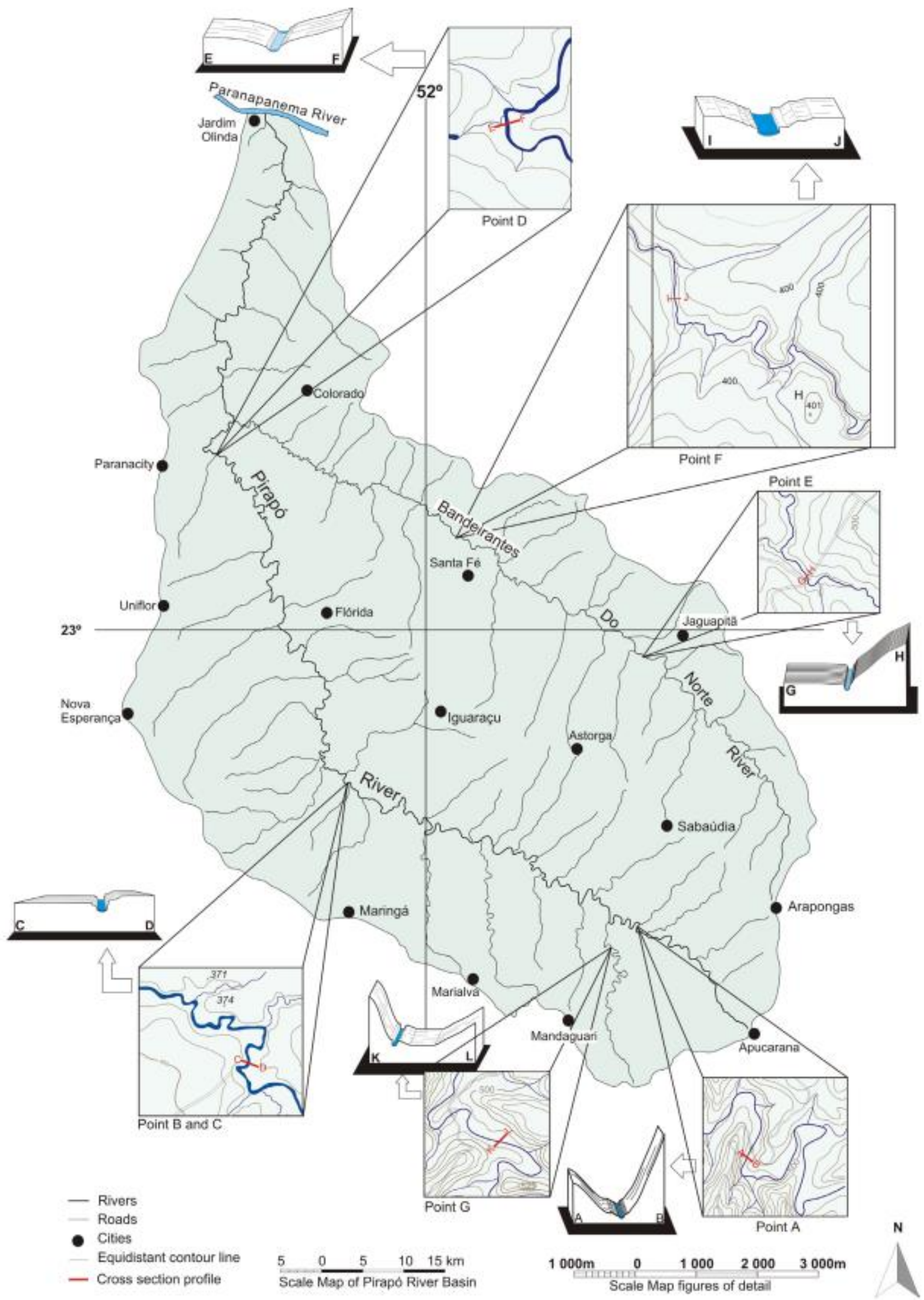
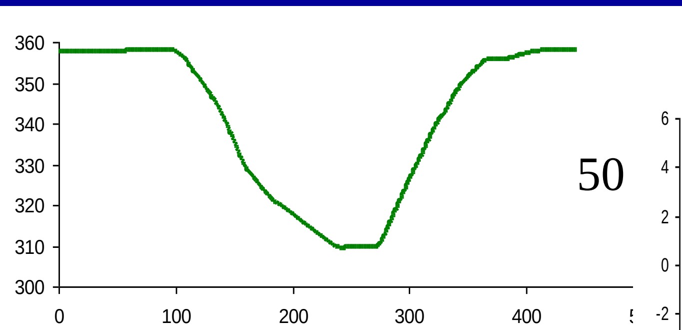
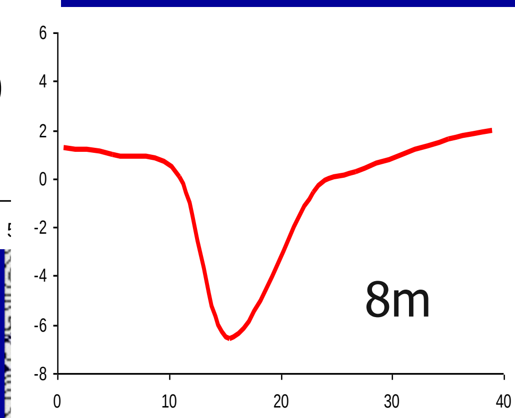


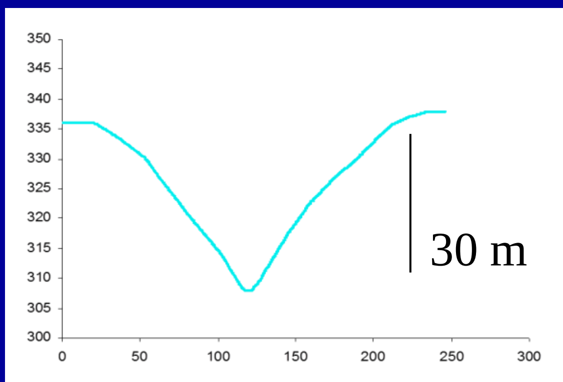
FIGURE 7. Hydrographic basin of the Pirapó River with anomalous points and valley cross sections.

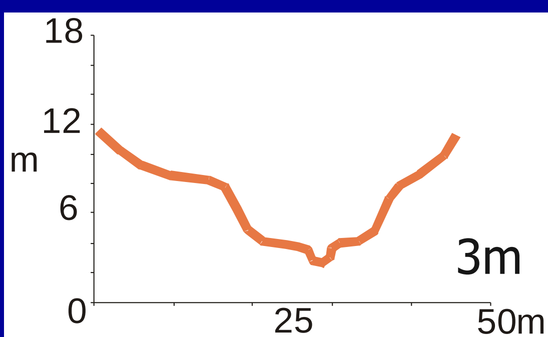
Valley types based on cross section

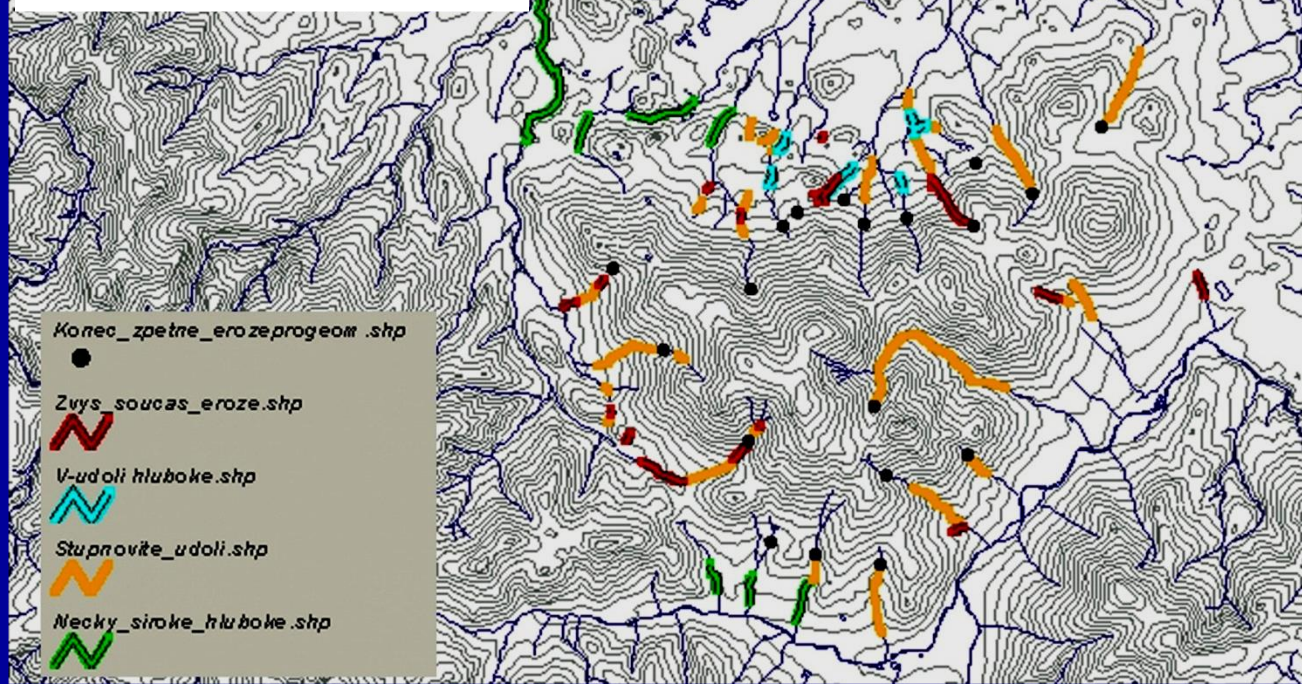
Ongoing uplift of the mountains











River terraces

- Former floodplain

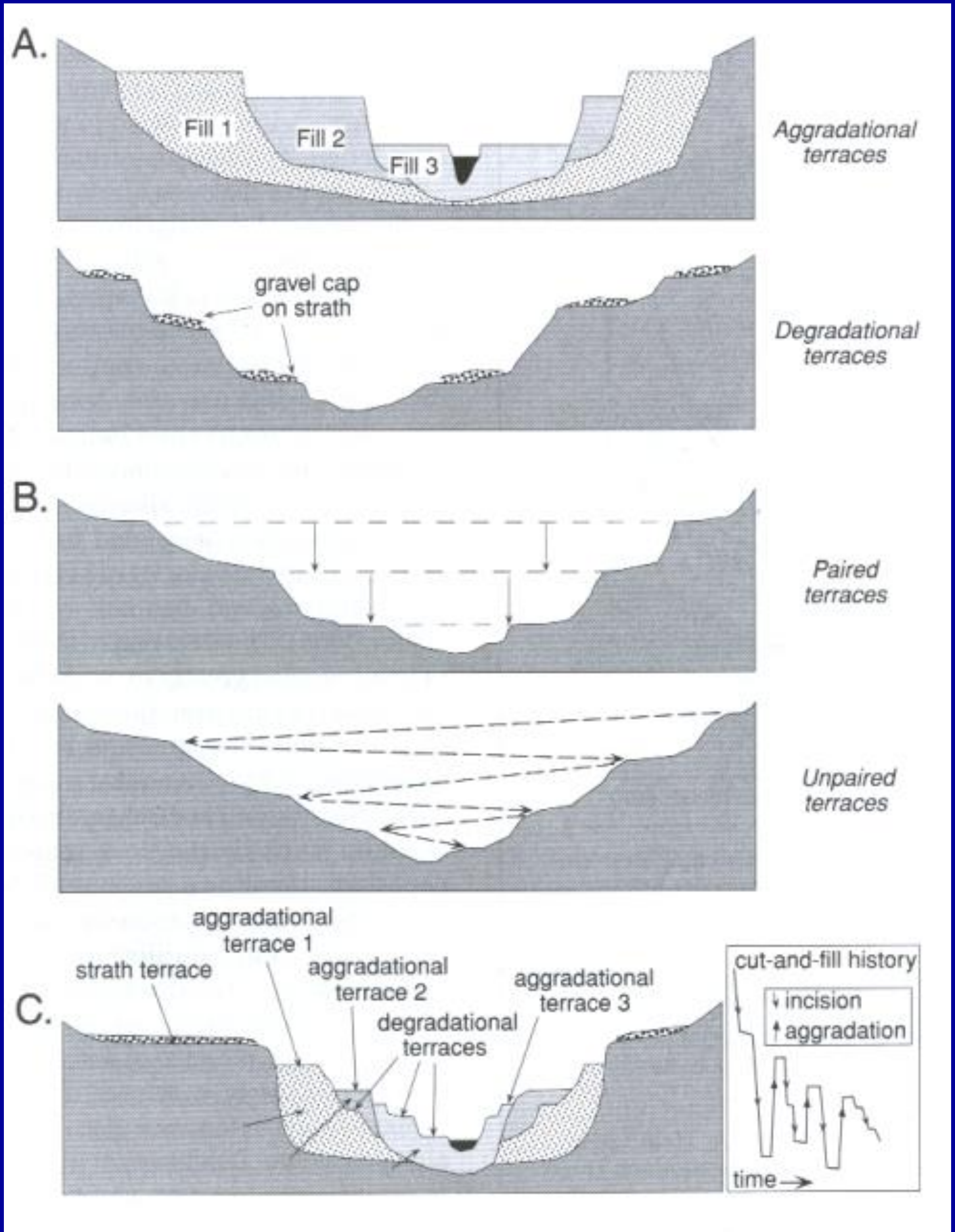
- Terraces origin– complex response, many causes

  - Repeated tectonic uplift

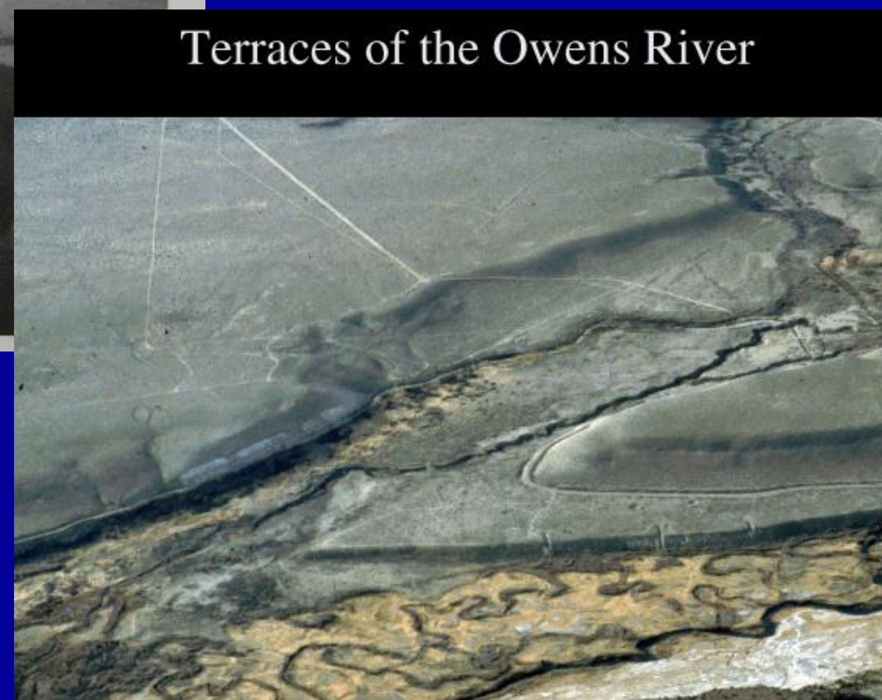
  - Slow continuous uplift combined with alternating of glacial period and interglacial period

  - Climate influence - =/= plus drop of the erosional base

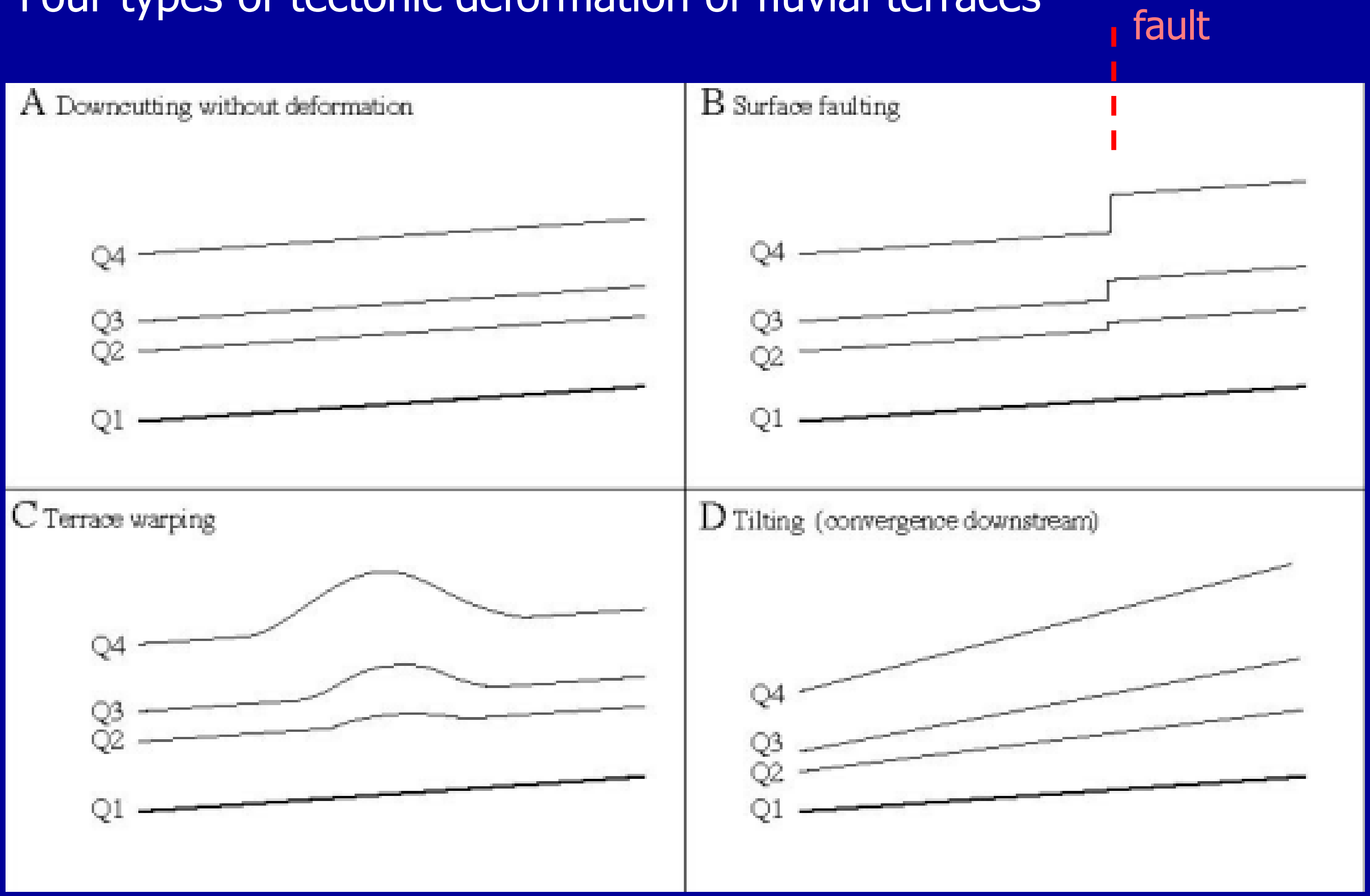
- Terraces – important ptential indicator of tectonic activity
  - more to the past



Terraces of river Mijar in Kyrgyzstan
– Trans Alai Range

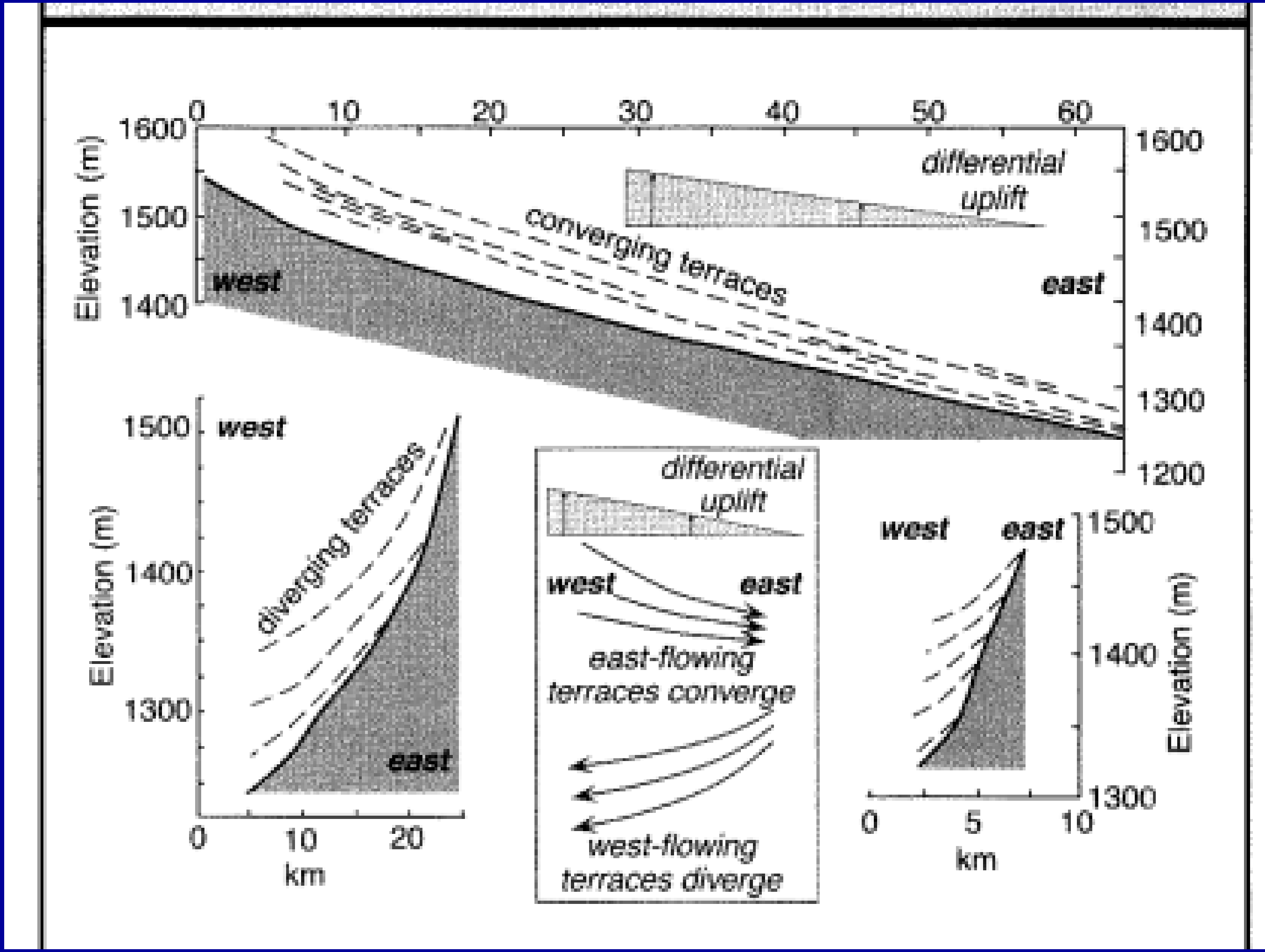


Four types of tectonic deformation of fluvial terraces



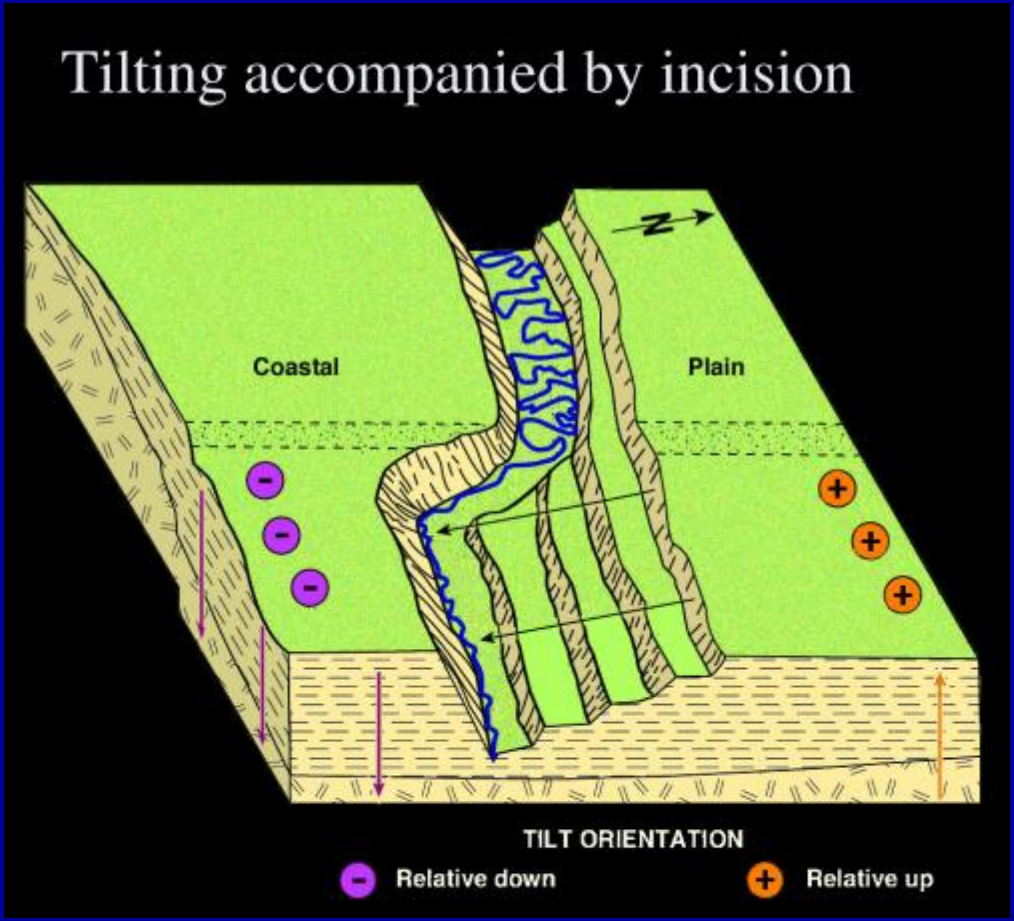
up-warping

tilting



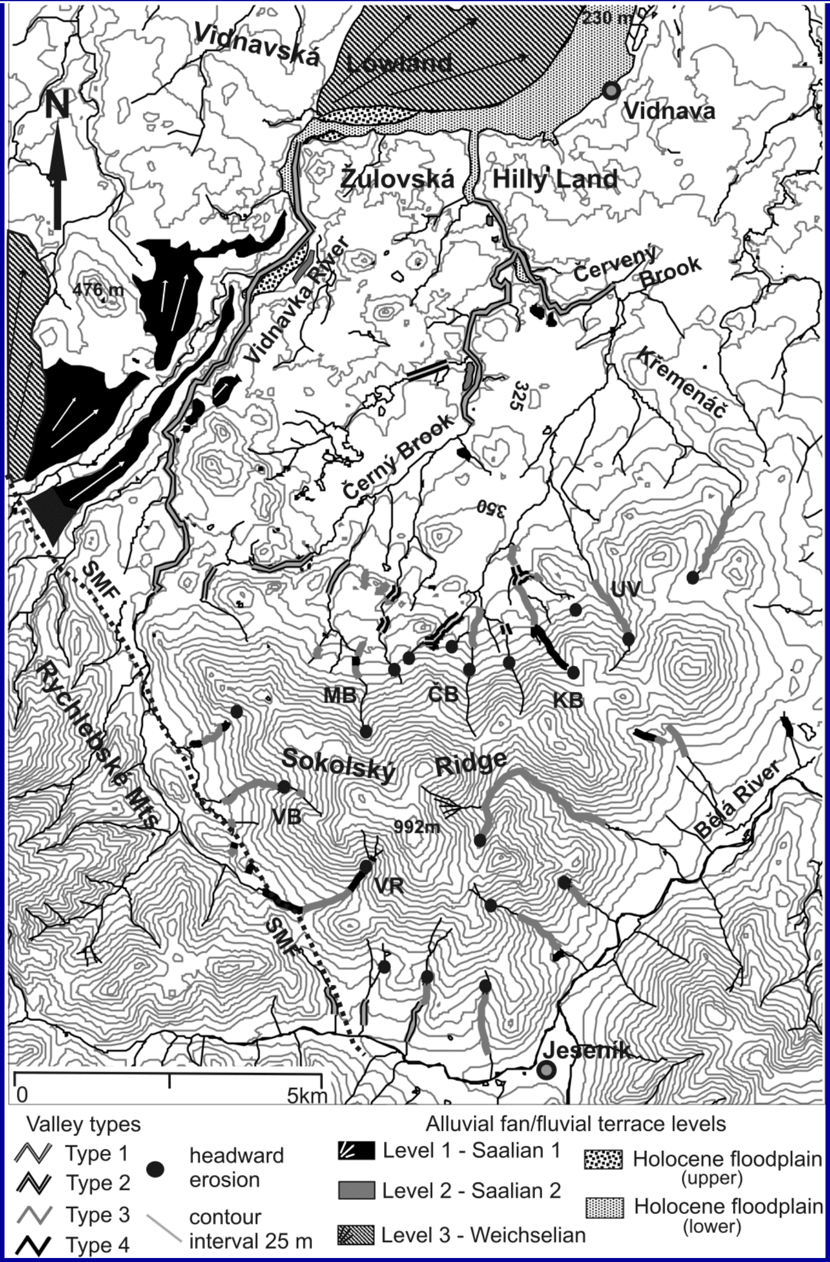
Convergent terraces down to the river – uplift of lower part
Divergent – subsidence in the lower part

Transversional tilting – unpaired terraces



River terraces of Vidnavka river

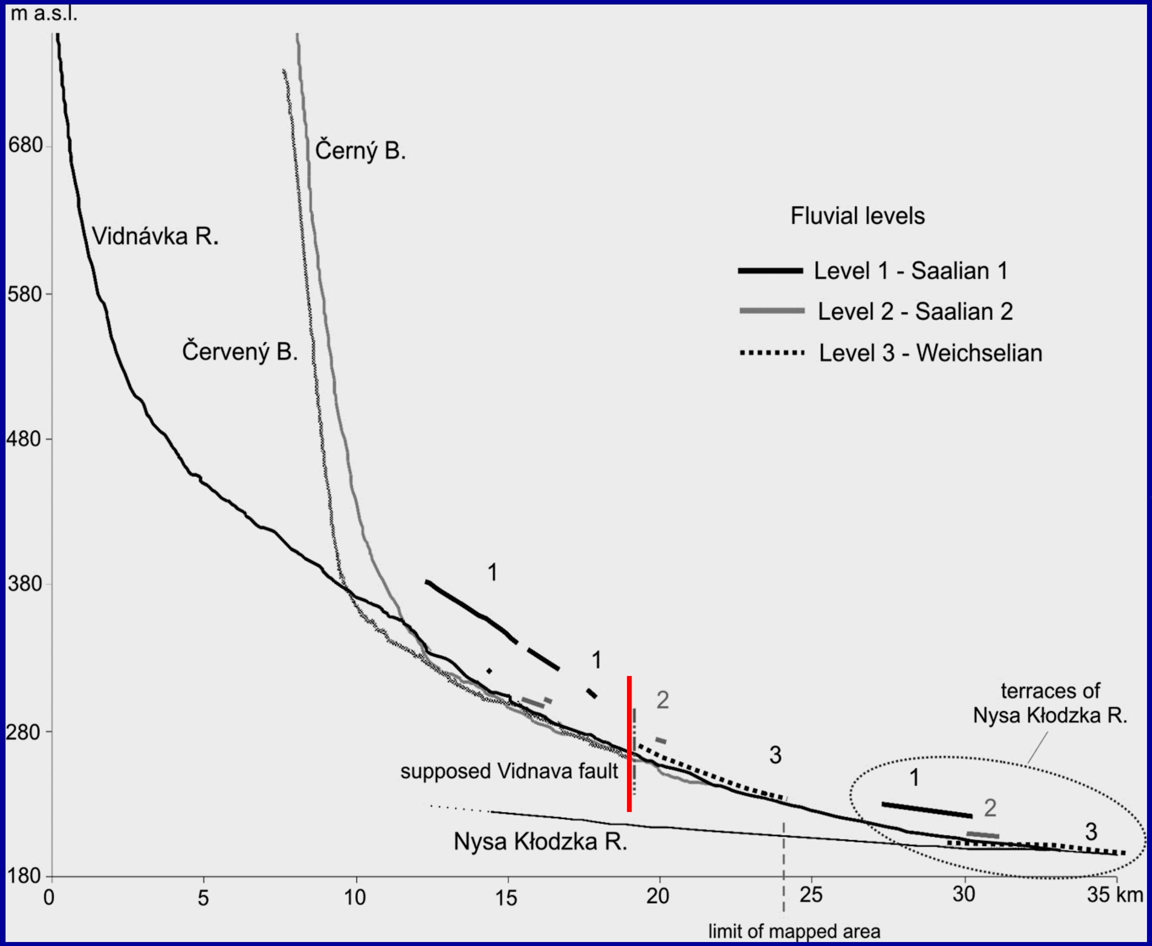
Terraces of tributaries – usually lower relative height above the river than in the main river



Uplift of Žulovská Hilly Land

(?glacioisostasis)

Fluvial sediments -3 post-glacial (po deglaciaci) Pleistocene terrace level and alluvial fan



Úroveň 1 – Saale 1 *Upper Terrace*

Vidnavka - 38 – 48m (relative height)

Černý potok - 20m

Červený potok - 35 – 40m

Úroveň 2 – Saale 2 *Middle Terrace*

Černý potok - 13 – 22m

Úroveň 3 – Weichselian *Lower Terrace*

Vidnavka - 4 – 8m

Anomaly in river terraces profile (Kladská Nysa)

Level 1 – difference 20m

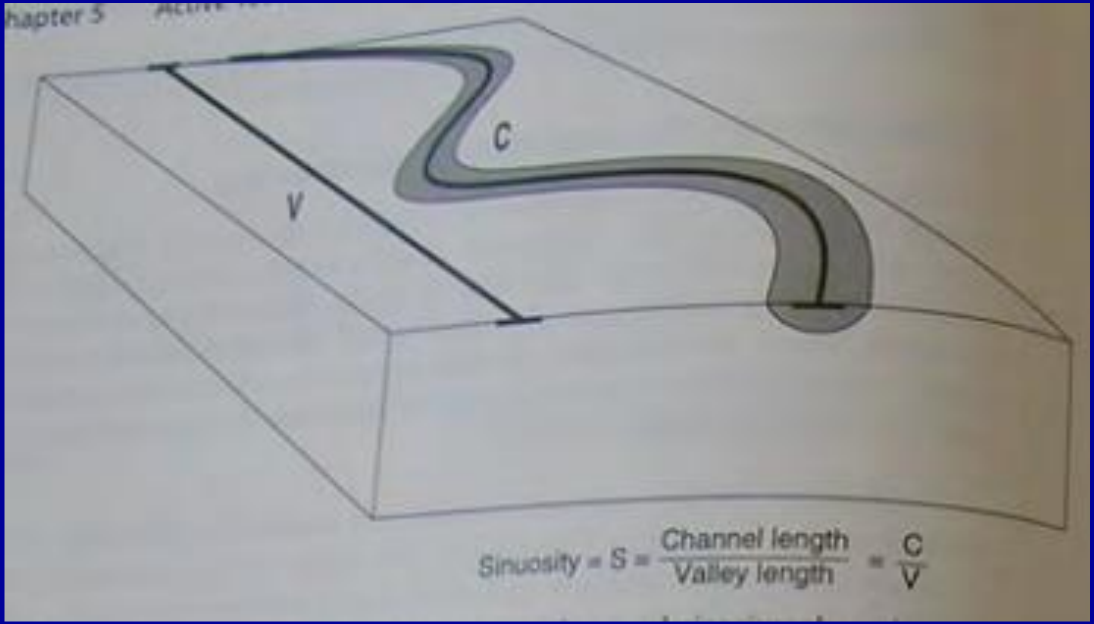
Level 2 – difference 8m

Level 3 – difference 2-3m

Stream sinuosity

- Rivers are meandering to balance the slope of the channel with discharge and transported material

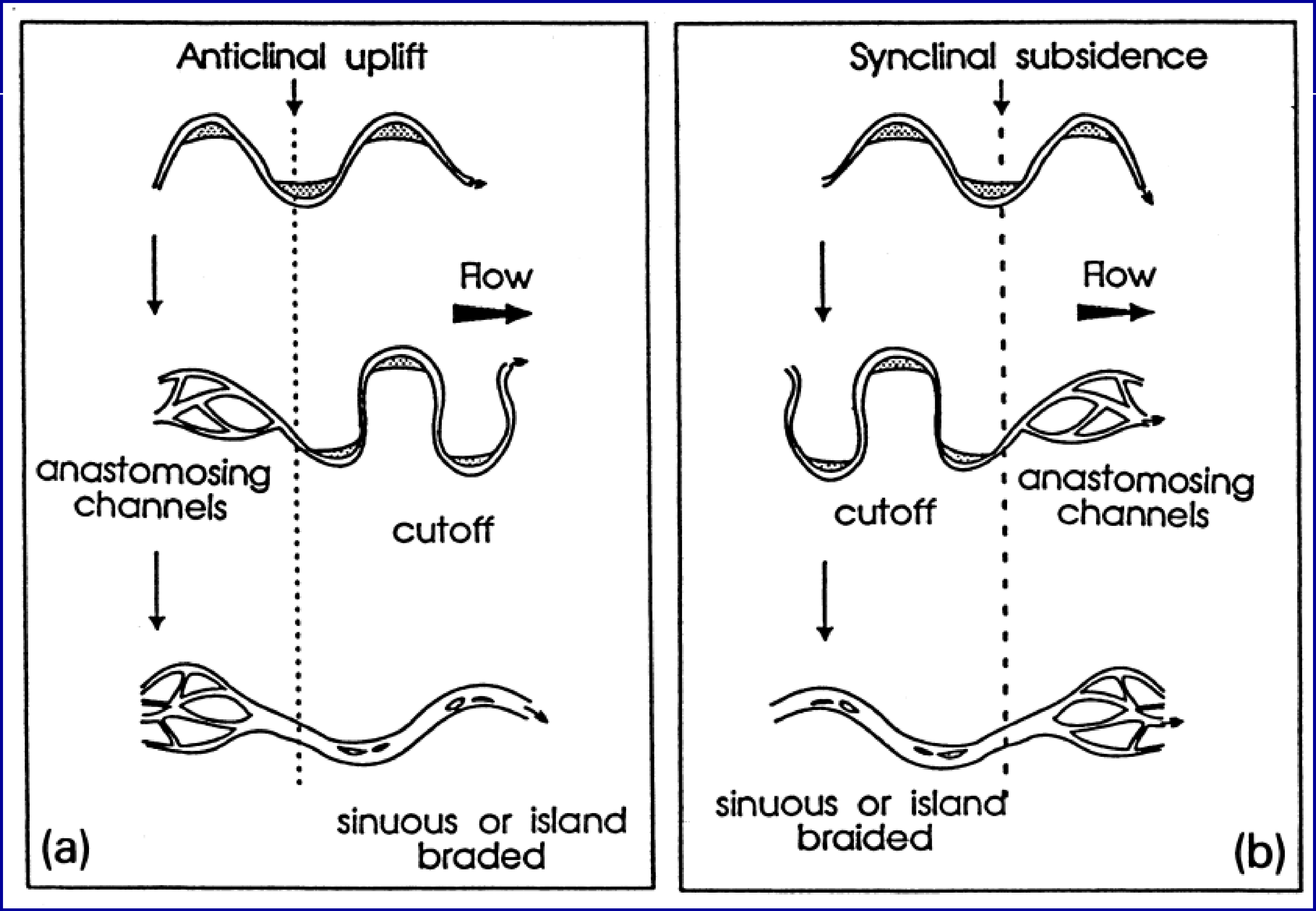
Sinuosity = channel length : valley length



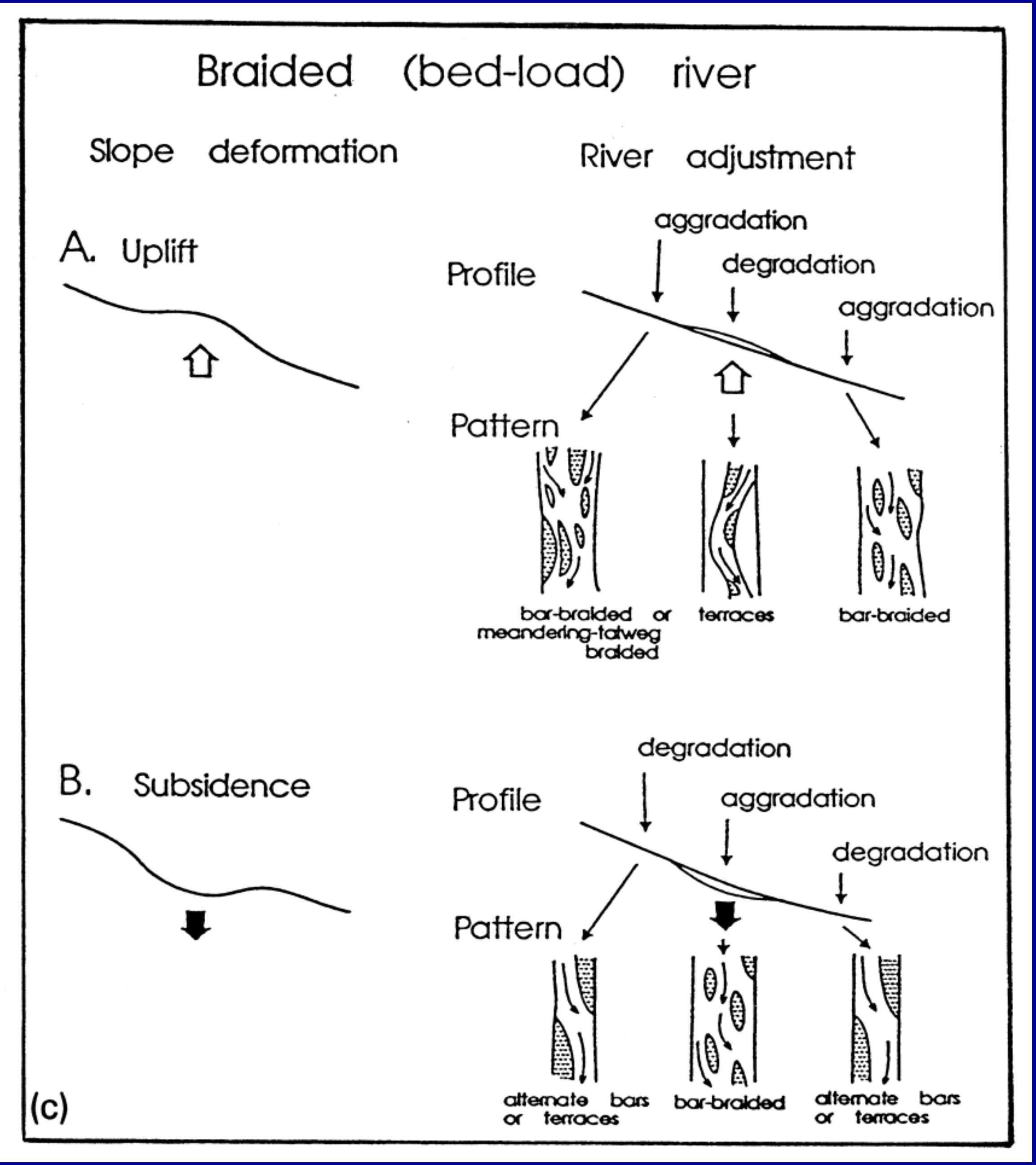
River meanders when the valley length is too steep to keep the balance

- Meandering (curving) decreases the channel slope (stream is longer – less steep profile)

During flowing through upwarping area – on the higher part – less curved, in the lower part more curved

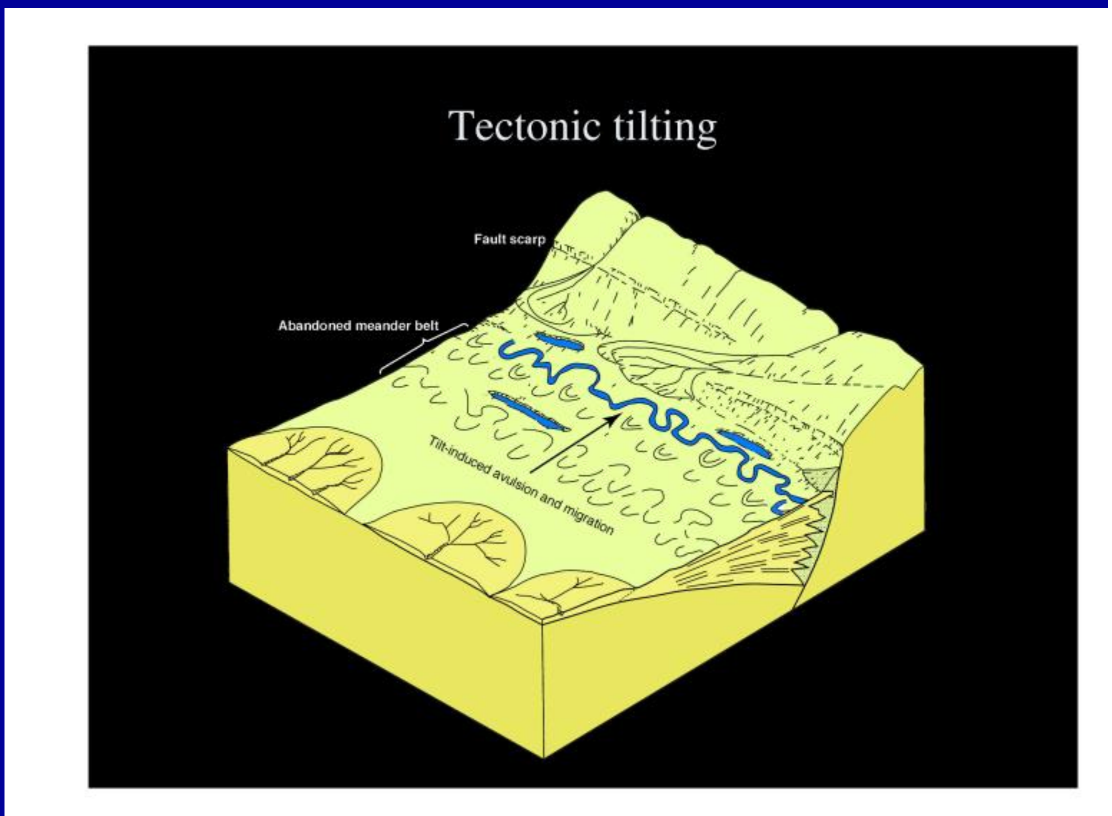


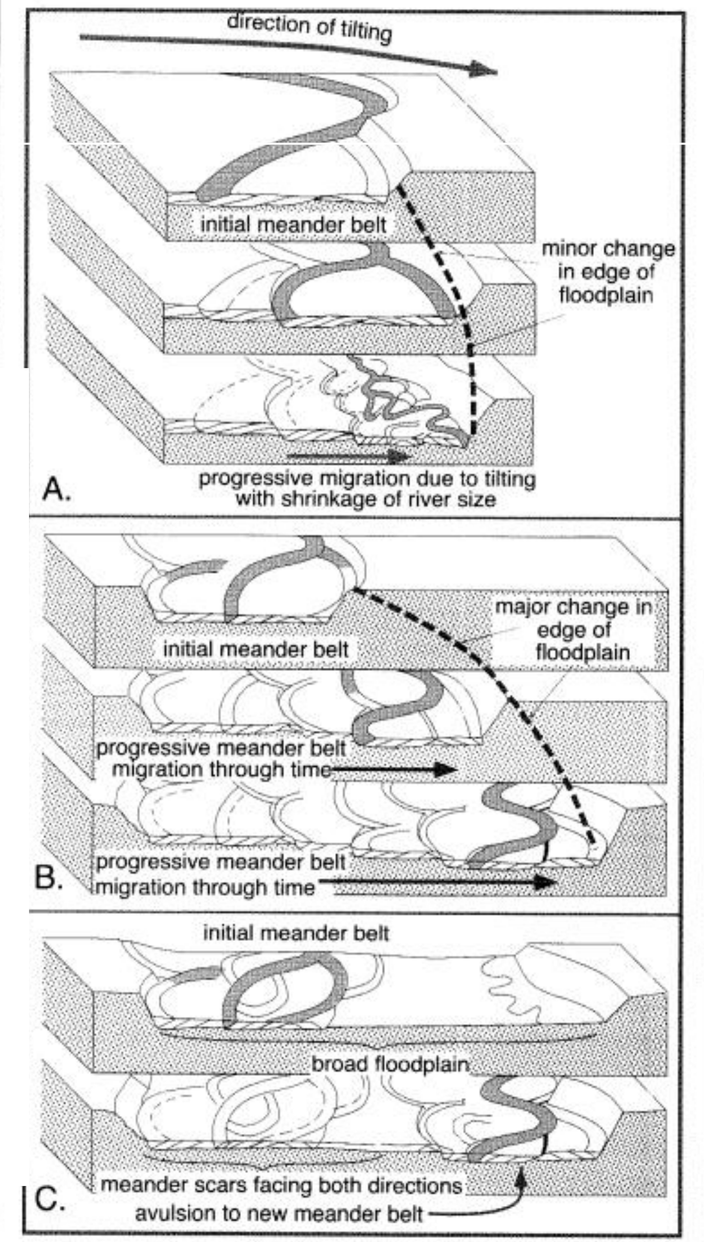
Response of meandering or straight stream in uplifted area (A) or subsided (B)



Response of braided streams (C) (Ouchi, 1983)

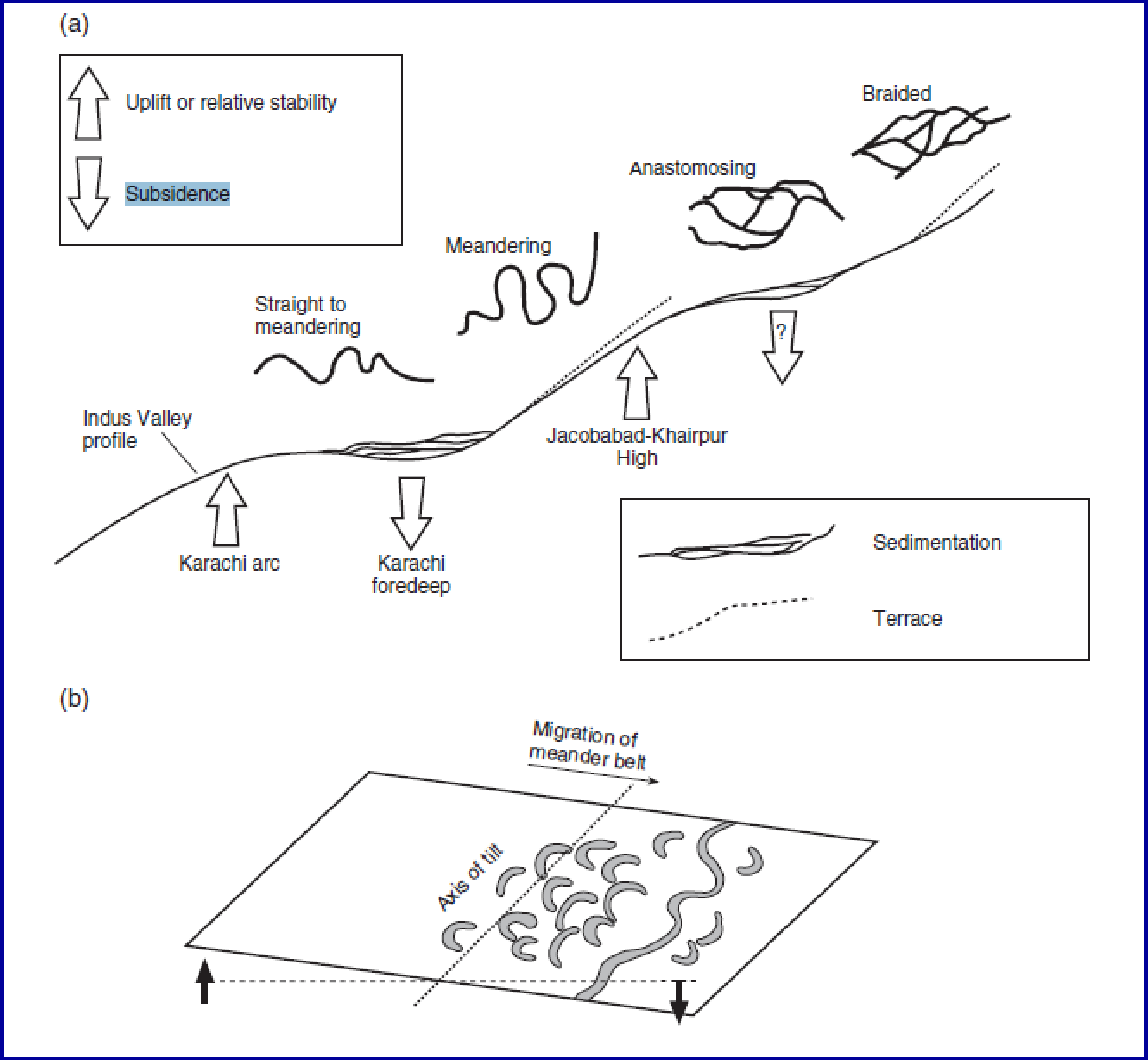
Cross sections



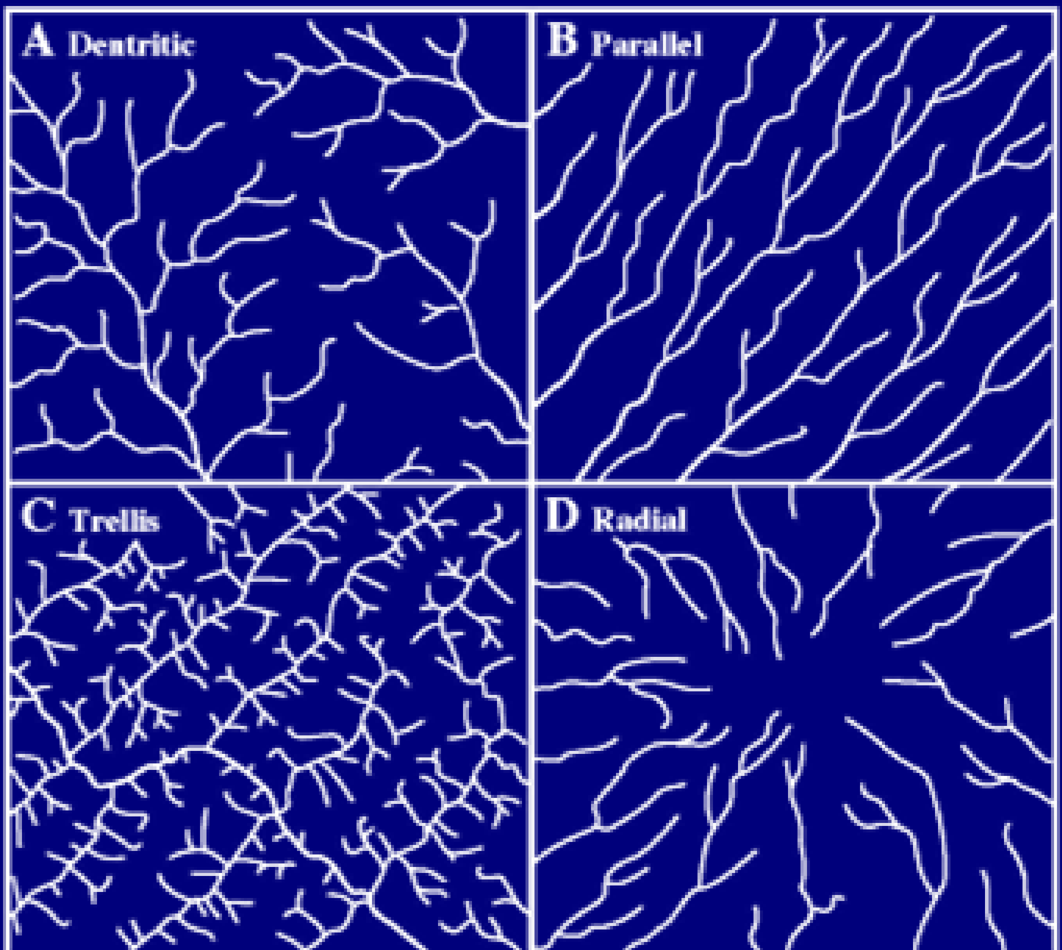


A. Steady tilting with shrinkage of river size. B. Steady tilting and migration. C. Abrupt tilting and avulsion across a floodplain. Modified after Alexander et al. (1994).

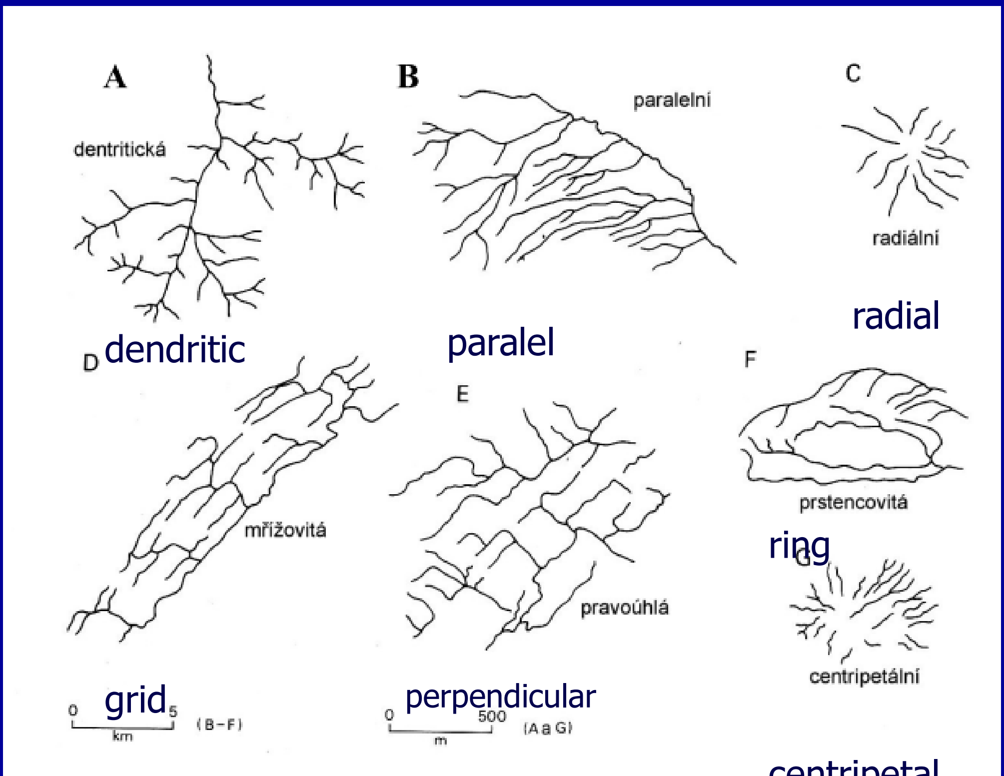
Tectonically deformed river



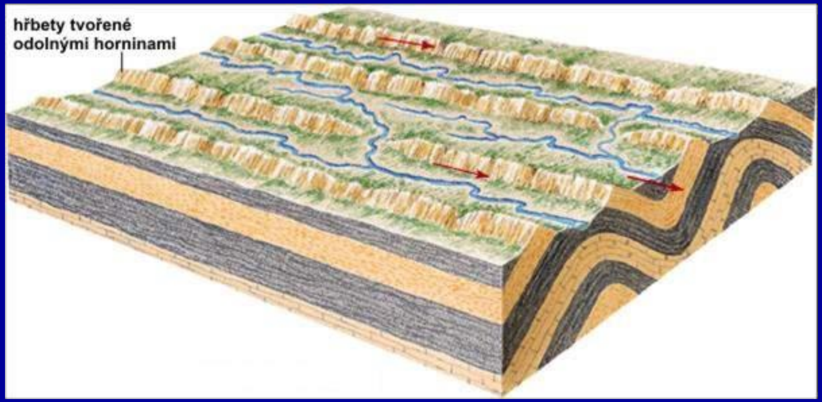
Changes in drainage and stream pattern



Dendritic	This drainage pattern forms on homogeneous bedrock or loose sediments in areas with gentle regional slopes.
Parallel	Parallel drainage pattern forms on steep slopes and where bedrock or landforms trend parallel to the regional slope.
Trellis	Pattern forms where underlying rock has one or more planes of weakness oblique to regional slope, such as on folded sedimentary rocks, or where linear landforms like beach ridges control drainage.
Radial	Pattern forms around structural high points such as volcanoes, salt domes, or tectonic upwarps.



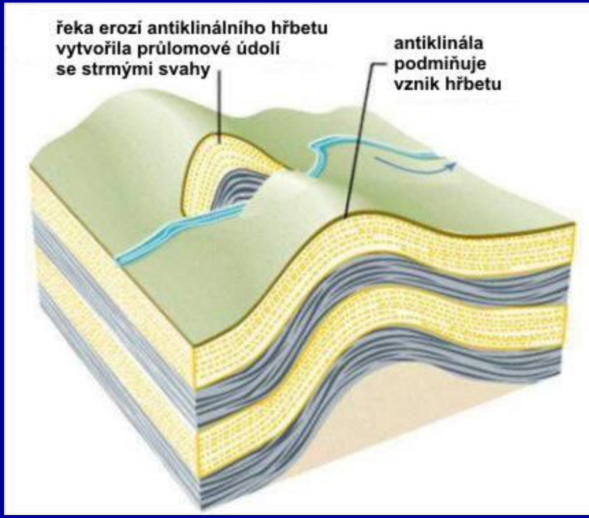
Obr. 3.8 Typy říční sítě dle Summerfield (1991).

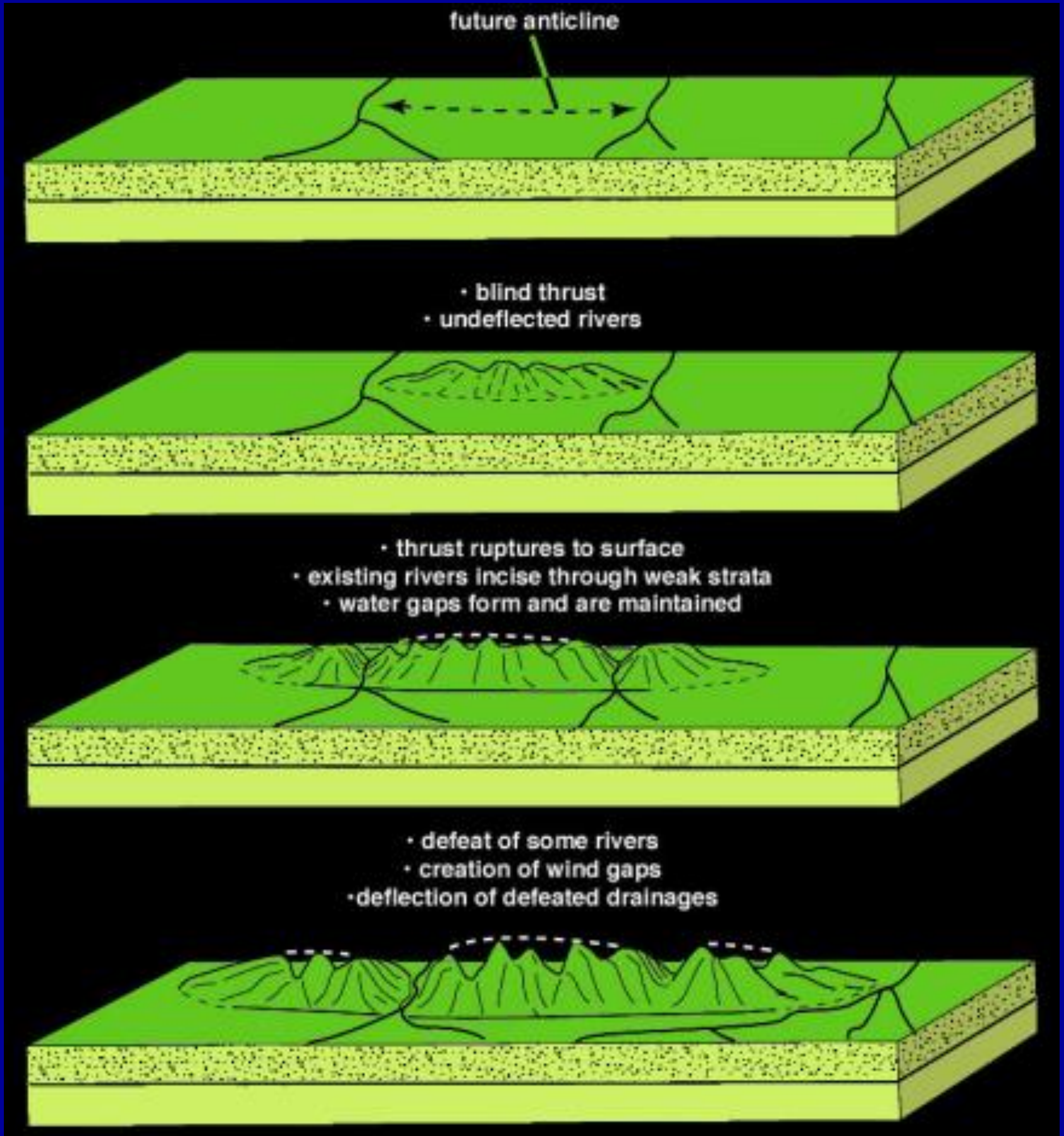


paralel

Changes in river pattern – response to uplift and erosion

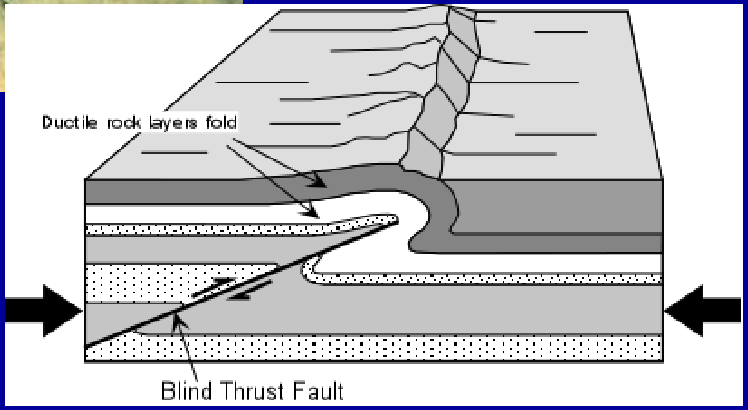
- Antecedent valley
  - water gap
- Abandoned valley
  - wind gap
- Stream deflection/diversion
- River capturing





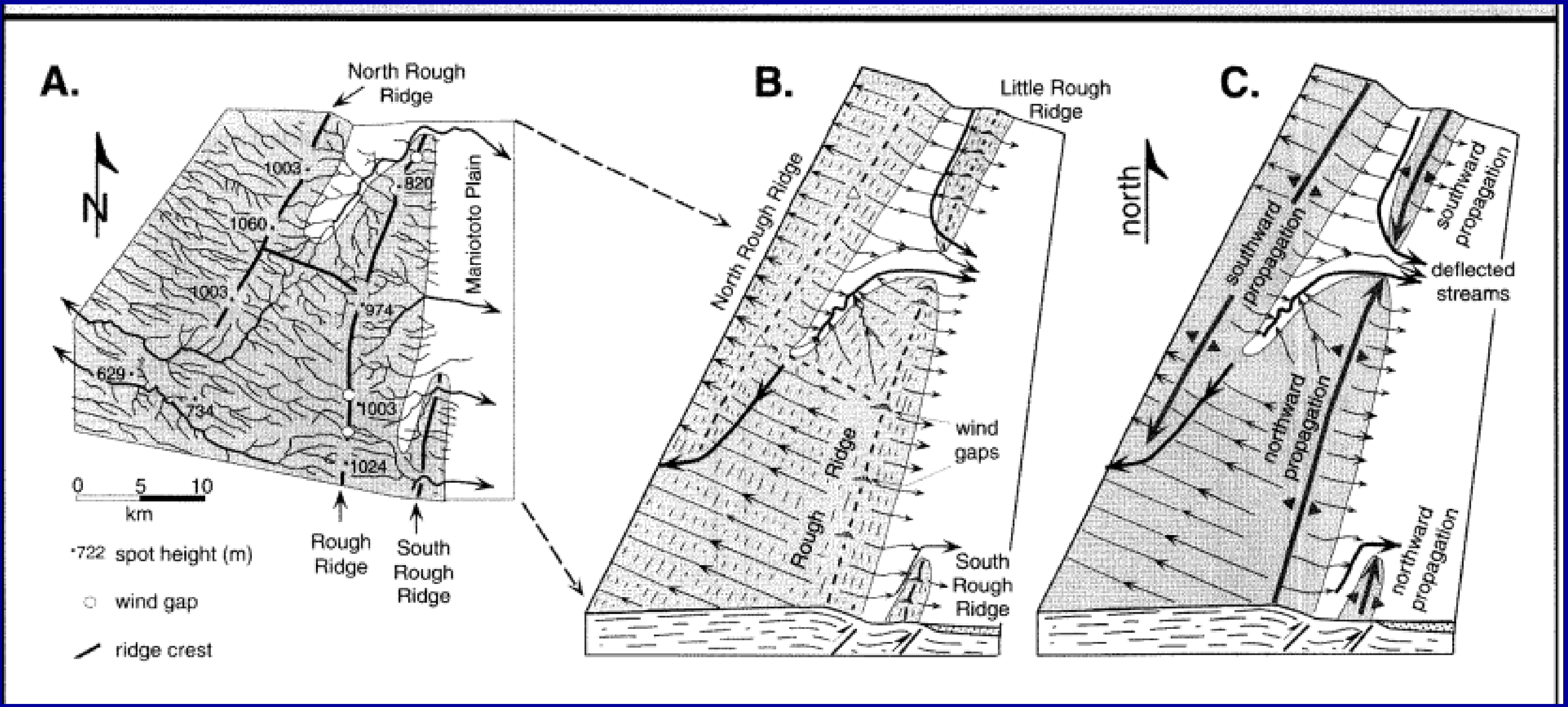
Active folding

Fault-propagation fold
- fault related fold



„**Blind thrust fault** that does not rupture all the way up to the surface so there is no evidence of it on the ground. It is "buried" under the uppermost layers of rock in the crust. „USGS

Basin asymmetry in active folding-faulting region



Vrásová osa ukloněná – water gap snižuje se výška, odklonění toků u okraje vrásy