Primary Endogenic Variables Leading to Geomorphic change

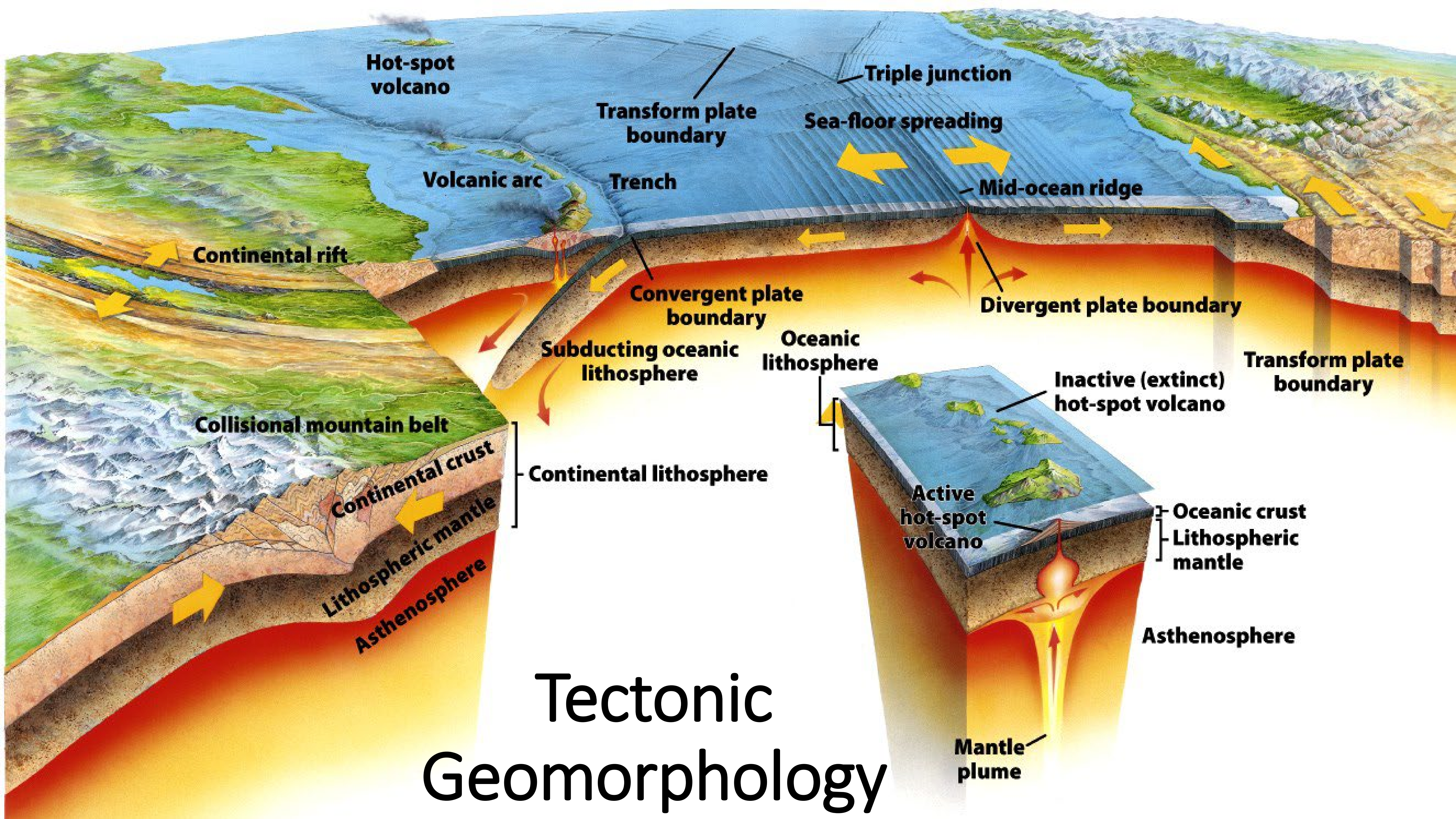
Learning objectives

- Tectonic settings – How do tectonic settings alter the types of landforms present in different regions?
- Tectonic processes – What is the role of tectonics in shaping landscapes?
- Leading to…
    - Interpreting landscape evolution as a product of tectonic events…

Grand Teton Formation Animation

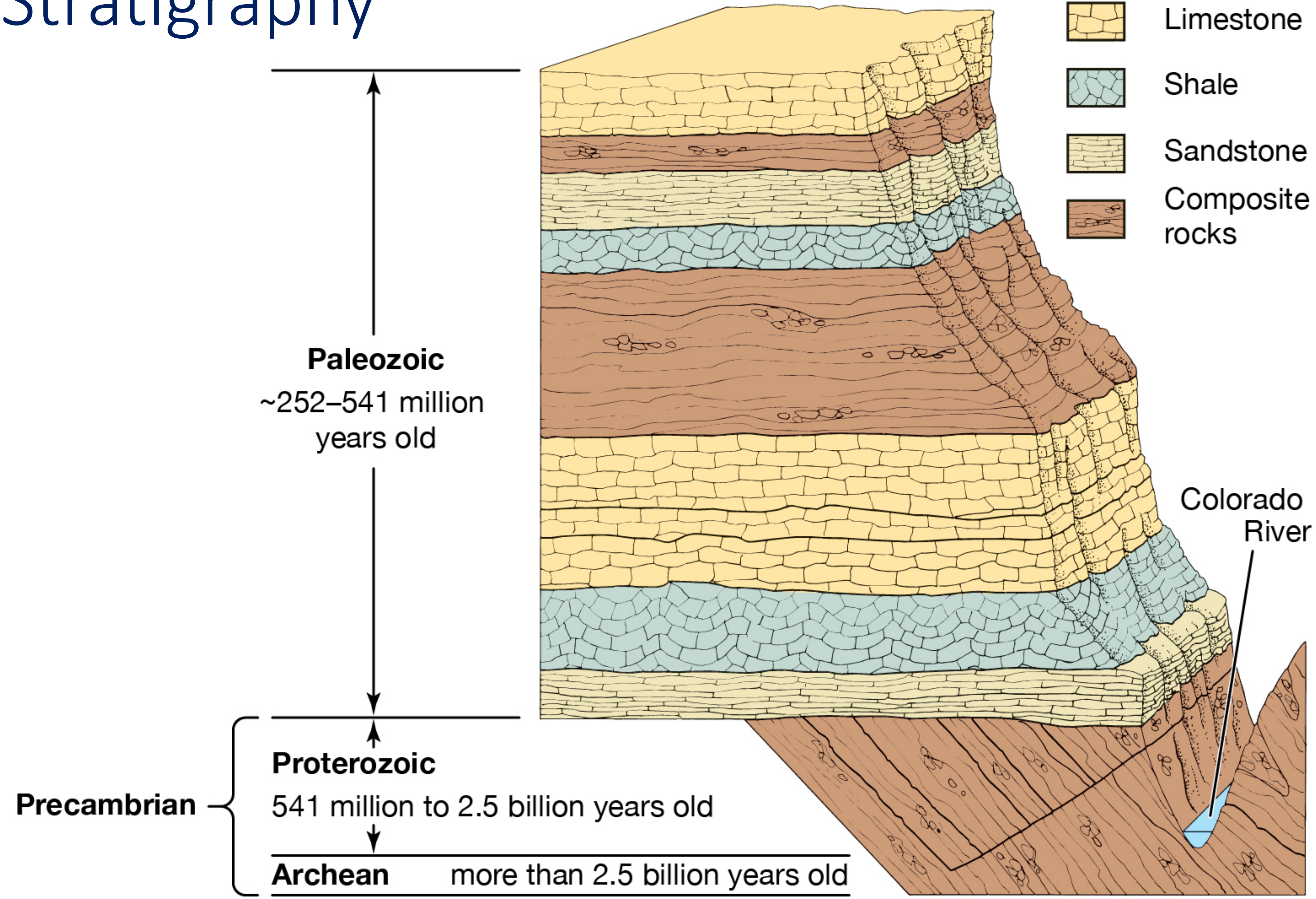
- https://youtu.be/QfXfRbJFd0g

Concept 2. Geologic structures are a dominant controlling factor/variable in the evolution of landforms and they are reflected in them.



Tectonic Geomorphology

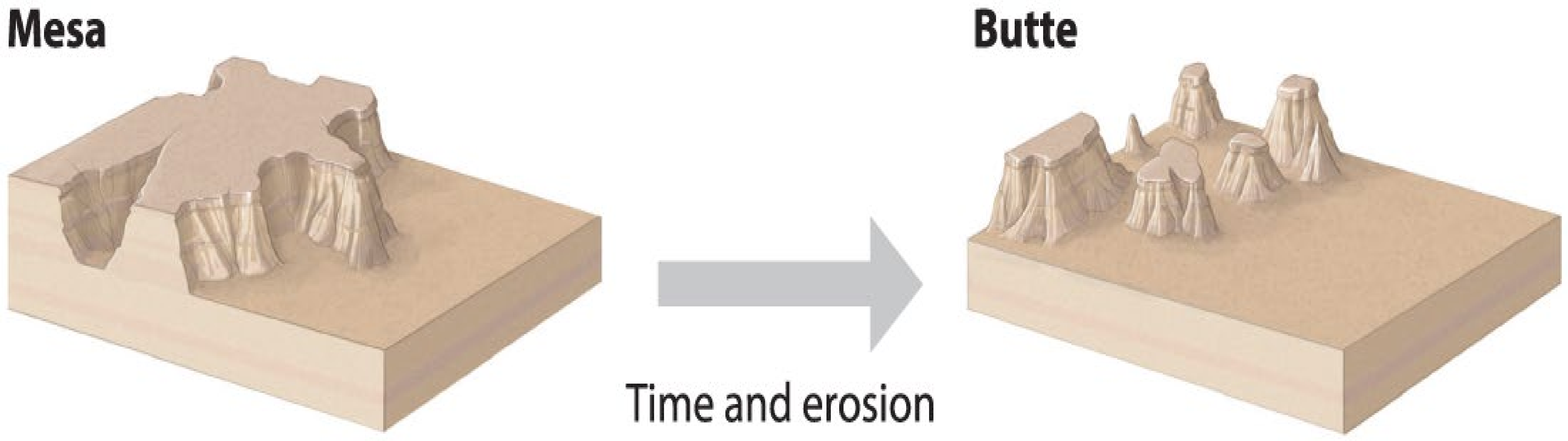
Horizontal Stratigraphy



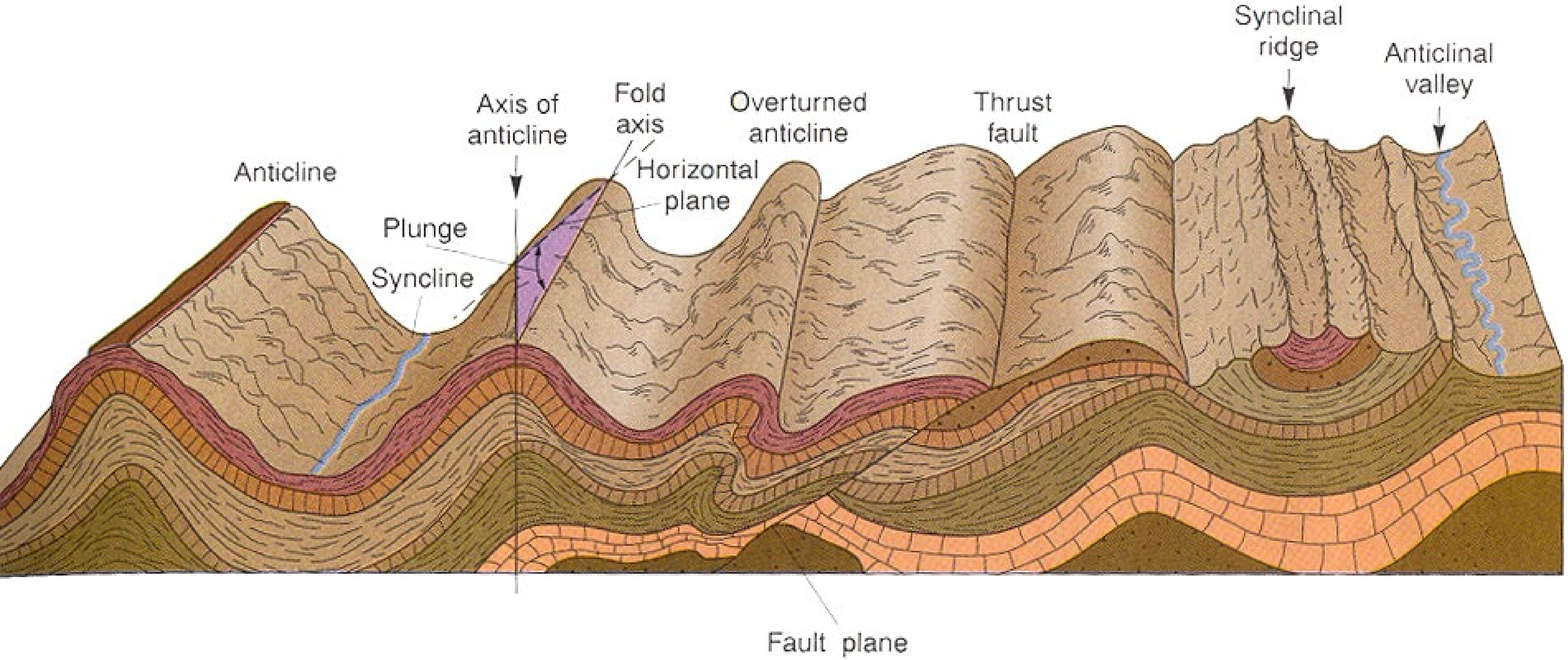

Amazing G


Boalsburg
Or
Sinking
Ons
Obg
Pine Grove Mills
Ocl
Rockspring
Baileyville
Sc
Monroe Furnace
State College Camp
Woodland
Sbm
Masseyburg
Sw
Greenwood Furnace
Cedar Hill
McAlevys Fort
Ennisville
Cottage
Manor Hill
Saulsburg
Dhb
Jackson Corner
Ovl
Creek
Obe

Flat-lying, erosion-resistant beds that protect underlying rock lead to the development of flat-topped, steep-walled mesas. Continued erosion of a mesa can lead to an isolated summit area known as a butte, like the famous outcrops of Monument Valley in Utah and Arizona.

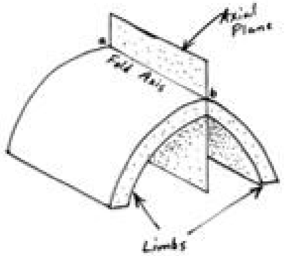


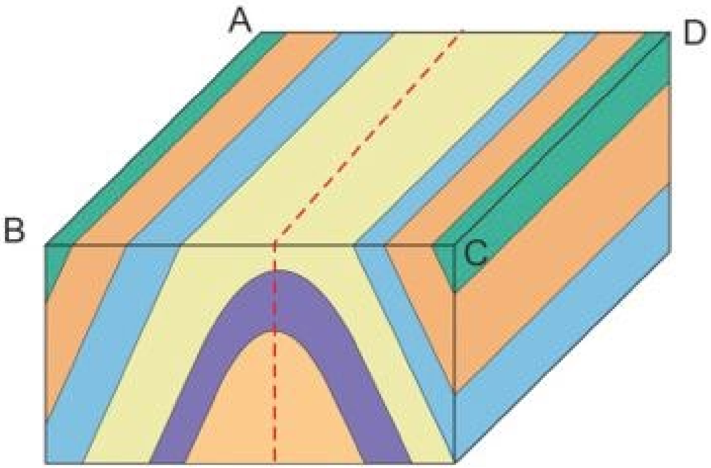
Structural folds

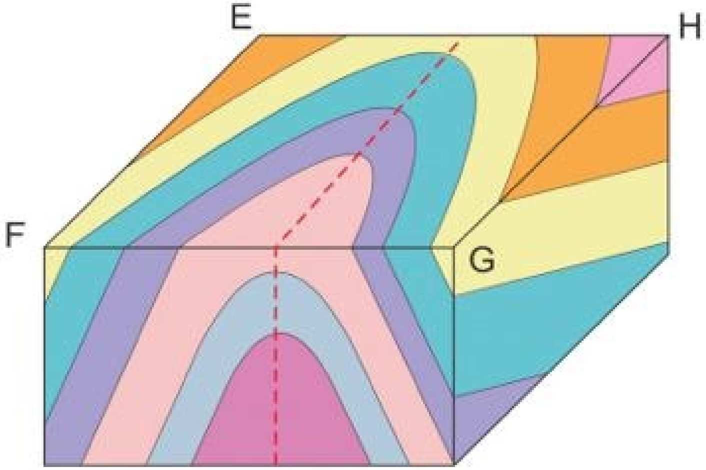


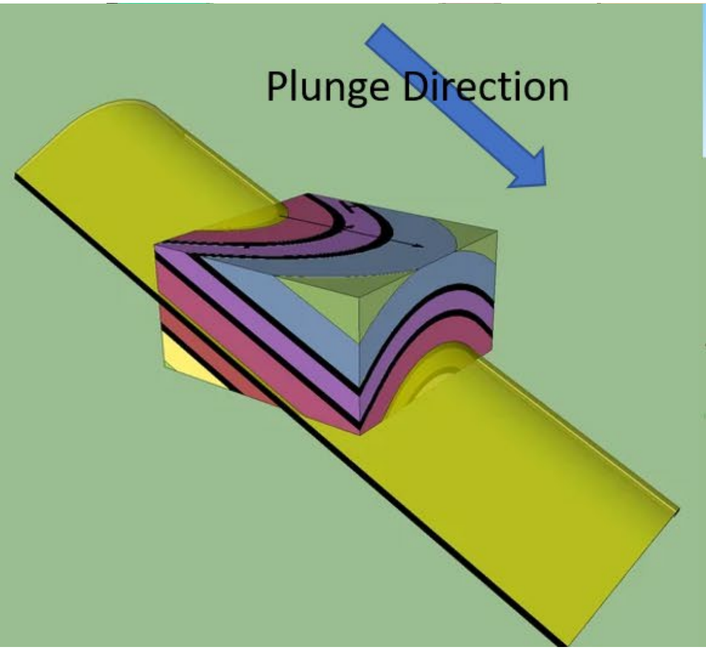
Geologic Structures

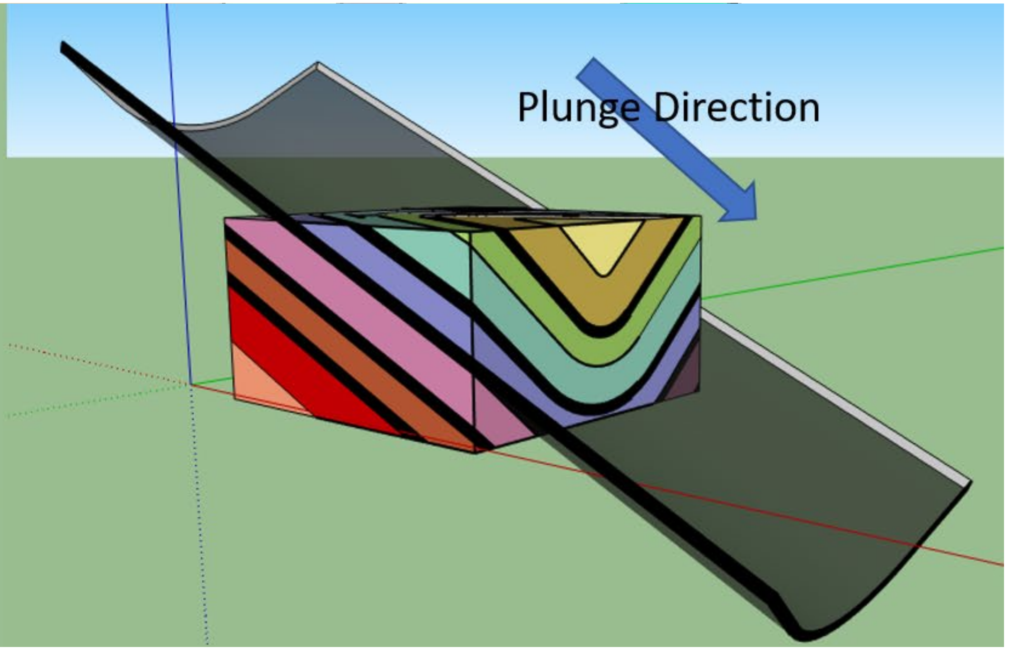
1. Examine the two 3D models below. Are the axial planes perpendicular to the surface or at a different "plunging" angle? How do the two models differ?



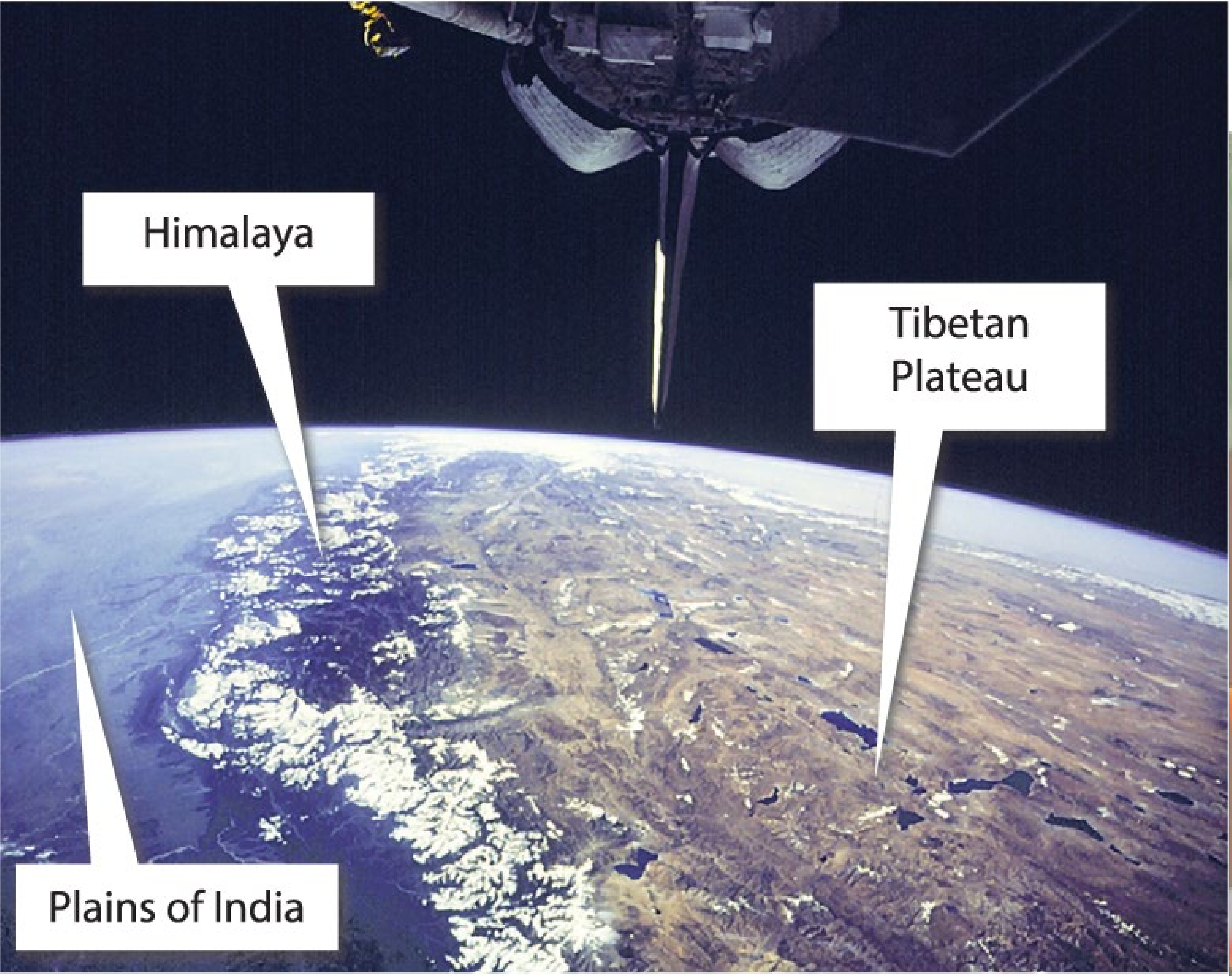




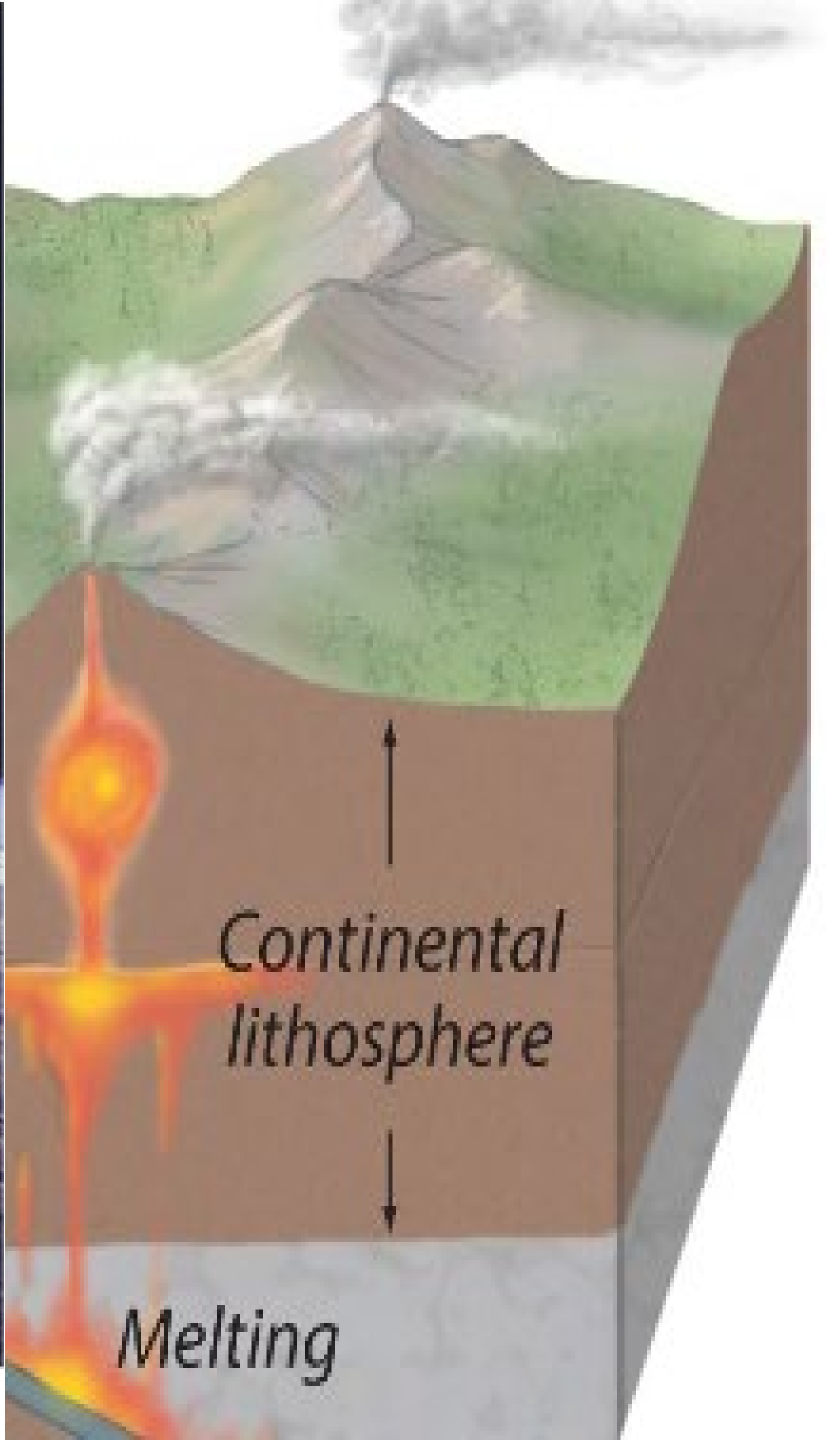




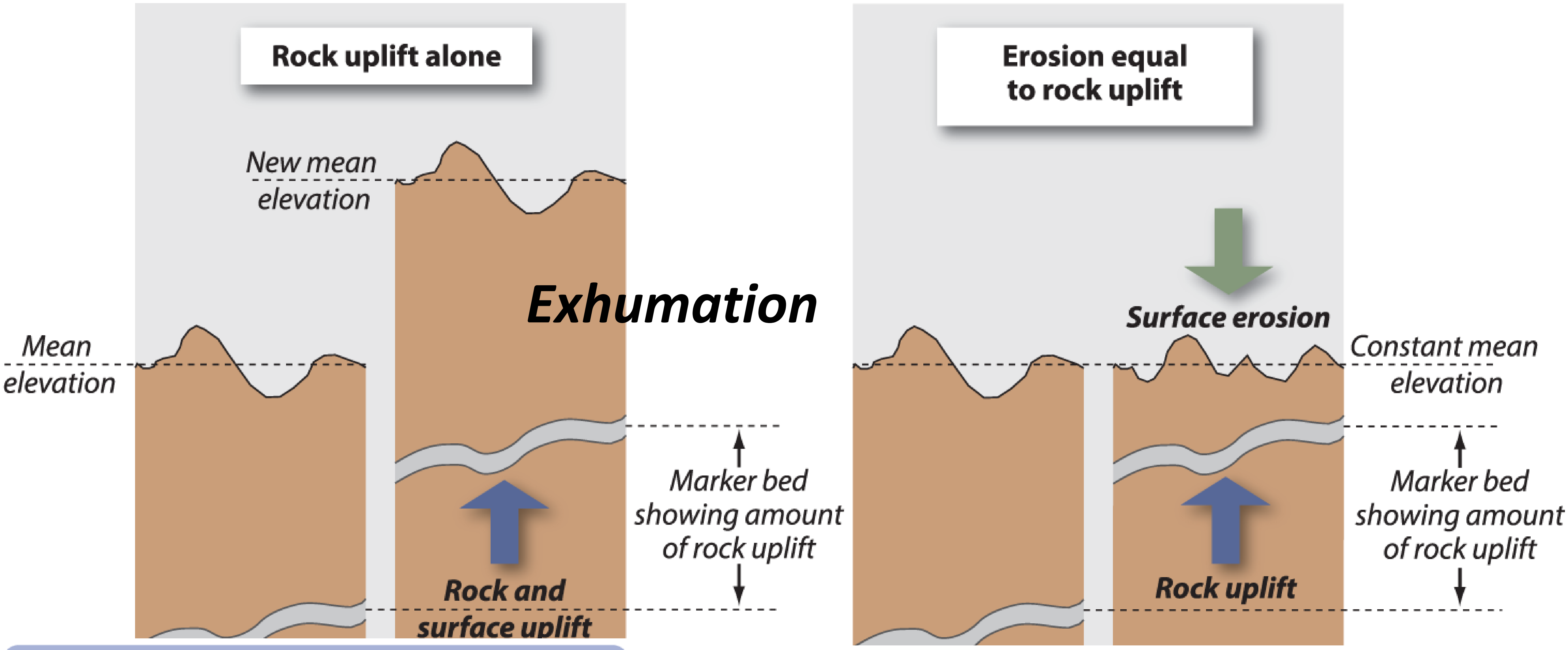
Map Symbol	Explanation
	Strike & Dip
	Vertical strata
	Horizontal strata
	Anticline axis
	Syncline axis
	Plunging anticline axis
	Plunging syncline axis
	Strike-slip fault


Himalaya
Tibetan Plateau
Plains of India

NASA

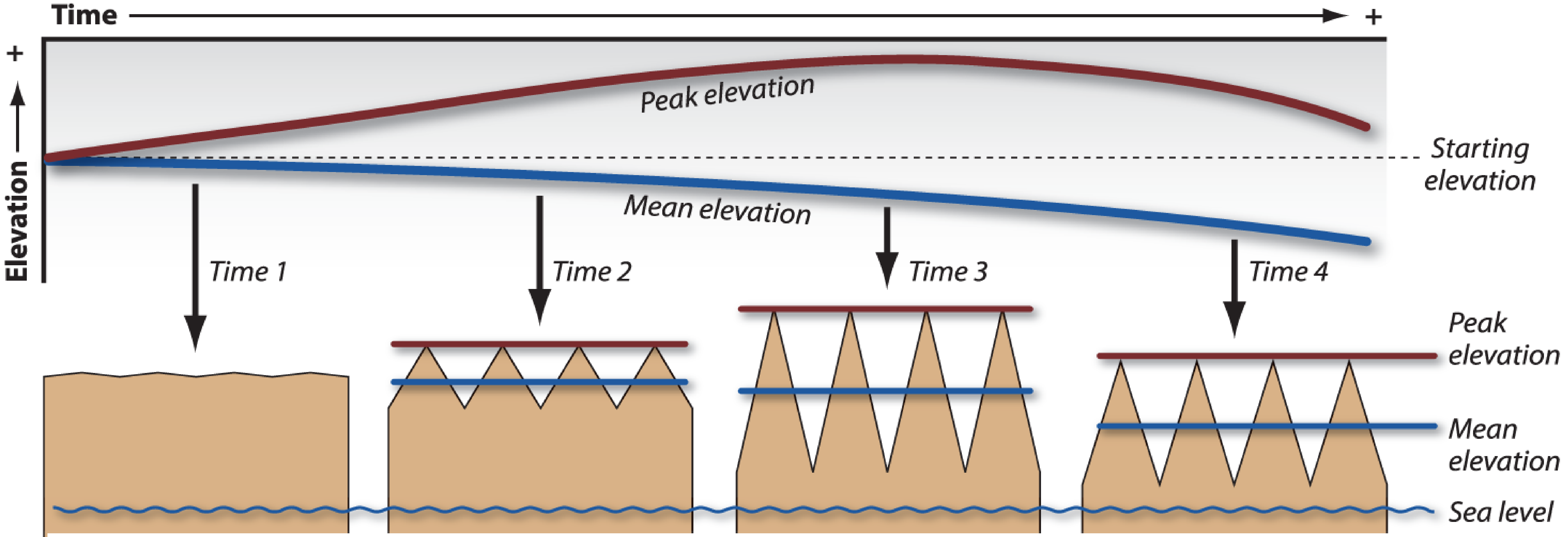

Continental lithosphere
Melting


Exhumation



Rock uplift without surface erosion results in net surface uplift, raising the mean elevation of the landscape and raising marker beds relative to sea level but not changing their depth below ground.

When surface erosion matches rock uplift, the mean elevation of the landscape remains constant. This causes exhumation (unroofing) of rocks, bringing once deep-seated rocks closer to the ground surface.



A low-relief surface is uplifted by tectonic forces to an elevation above sea level.

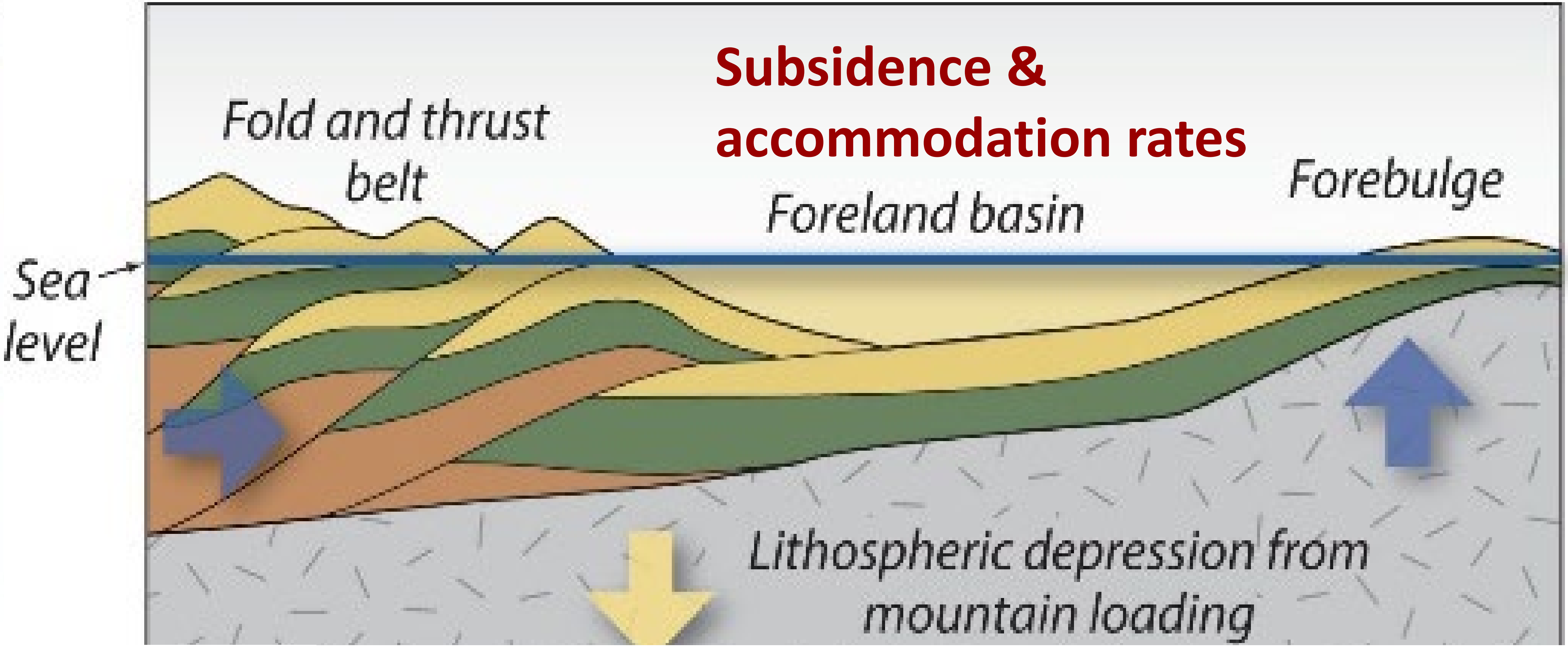
Because the effective base level has fallen, rivers begin to dissect the landscape, carving valleys.

Isostatic compensation triggered by deep river incision uplifts peaks as the erosion of deep valleys decreases mean elevation.

As the crust erodes and the crustal root thins, both mean elevation and peak elevation decrease.

Isostatic Mountain Uplift over time

Foreland basin

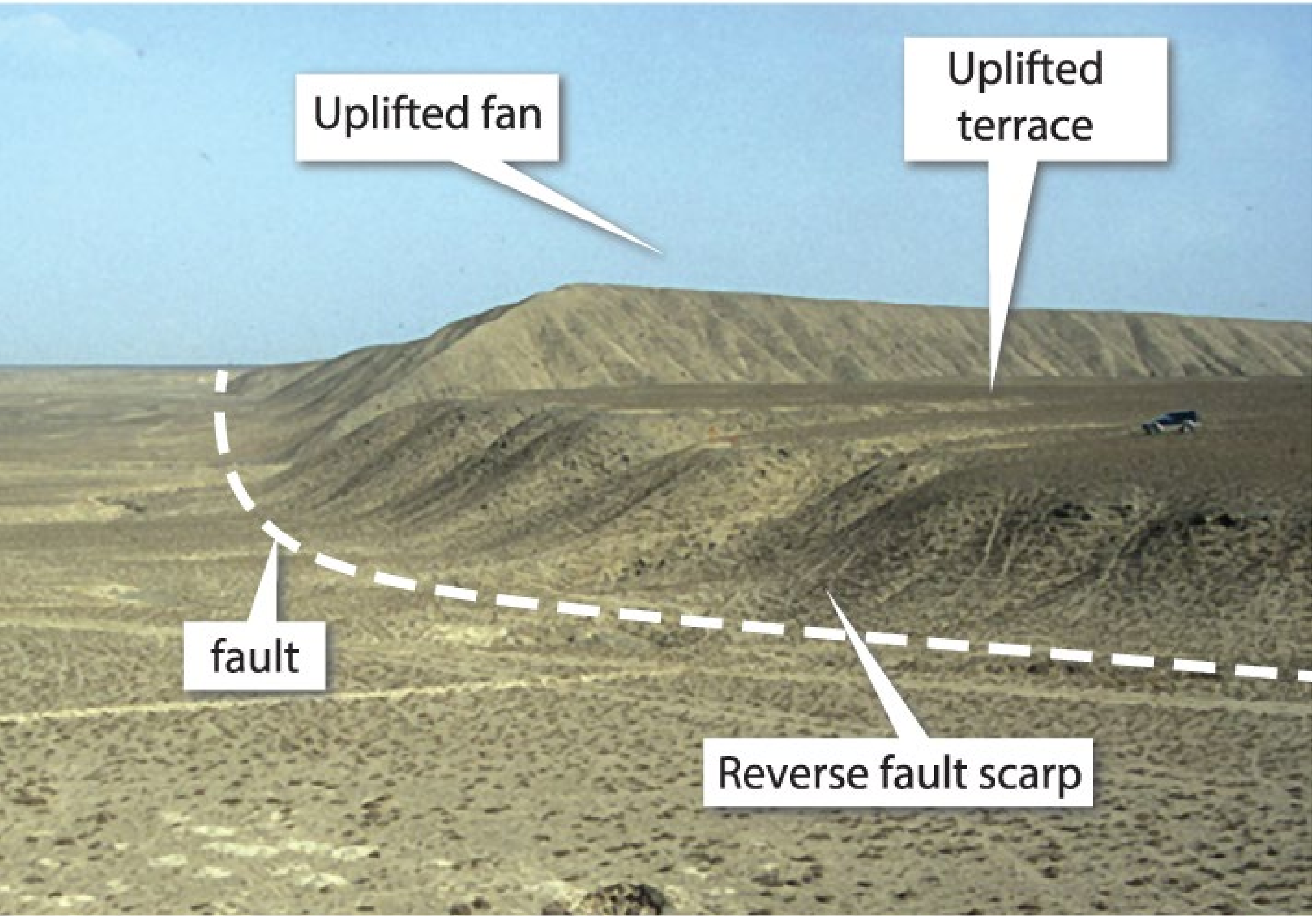


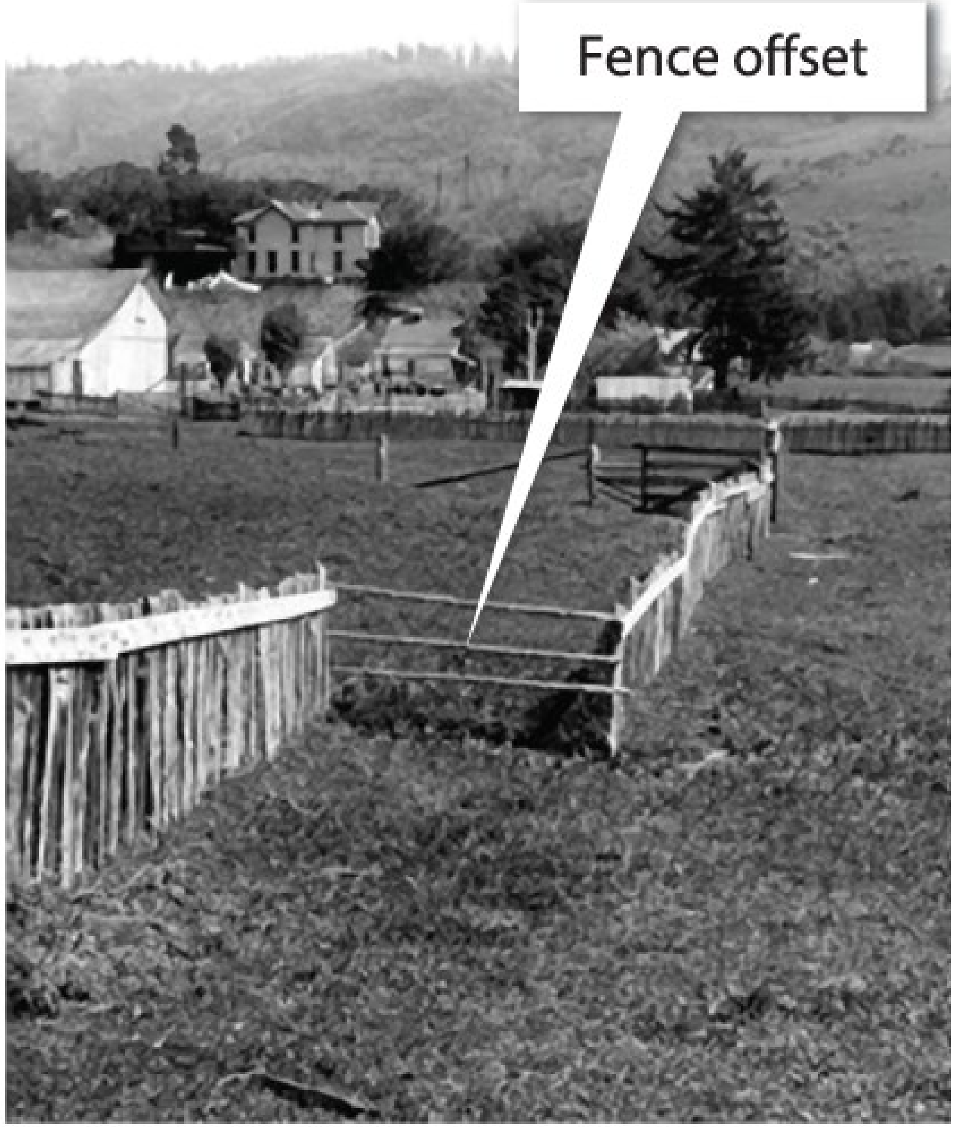
Sequence Stratigraphy

Sedimentary deposits Bound by Unconformities

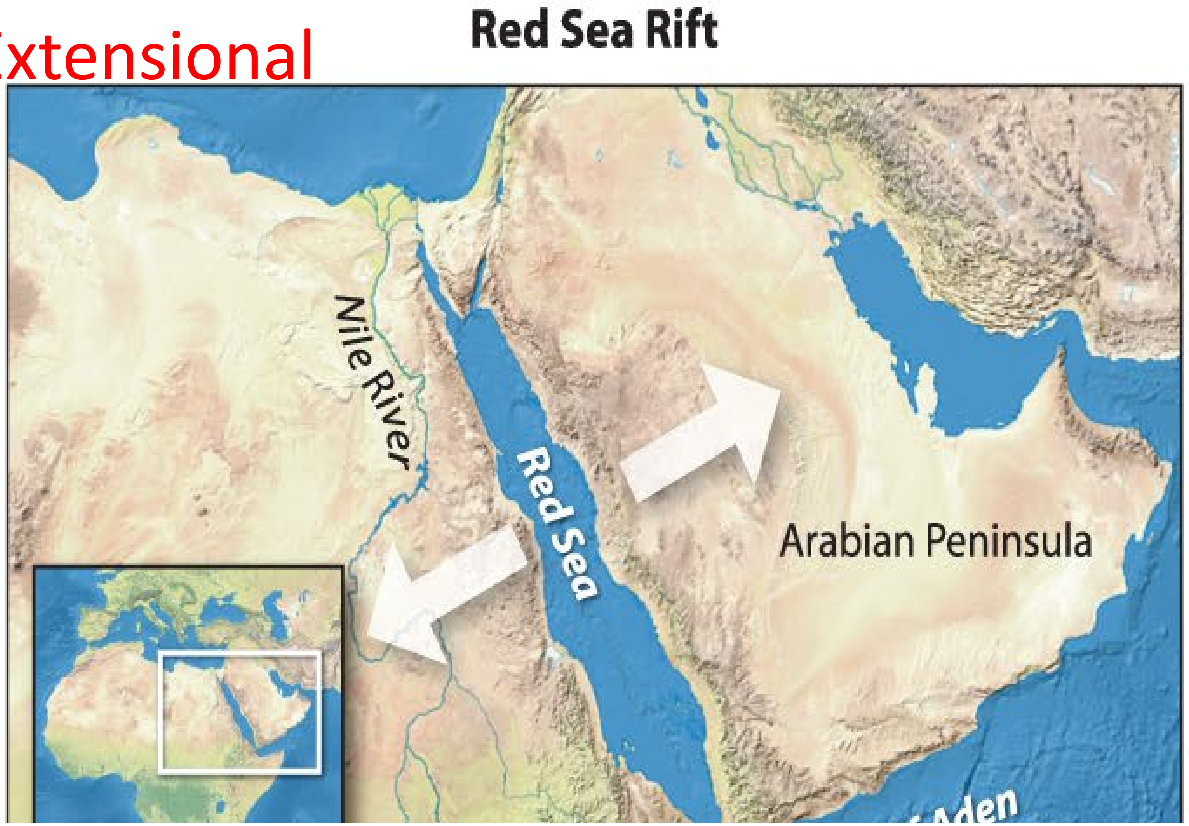
Sediment supply variations/ accommodation space changes

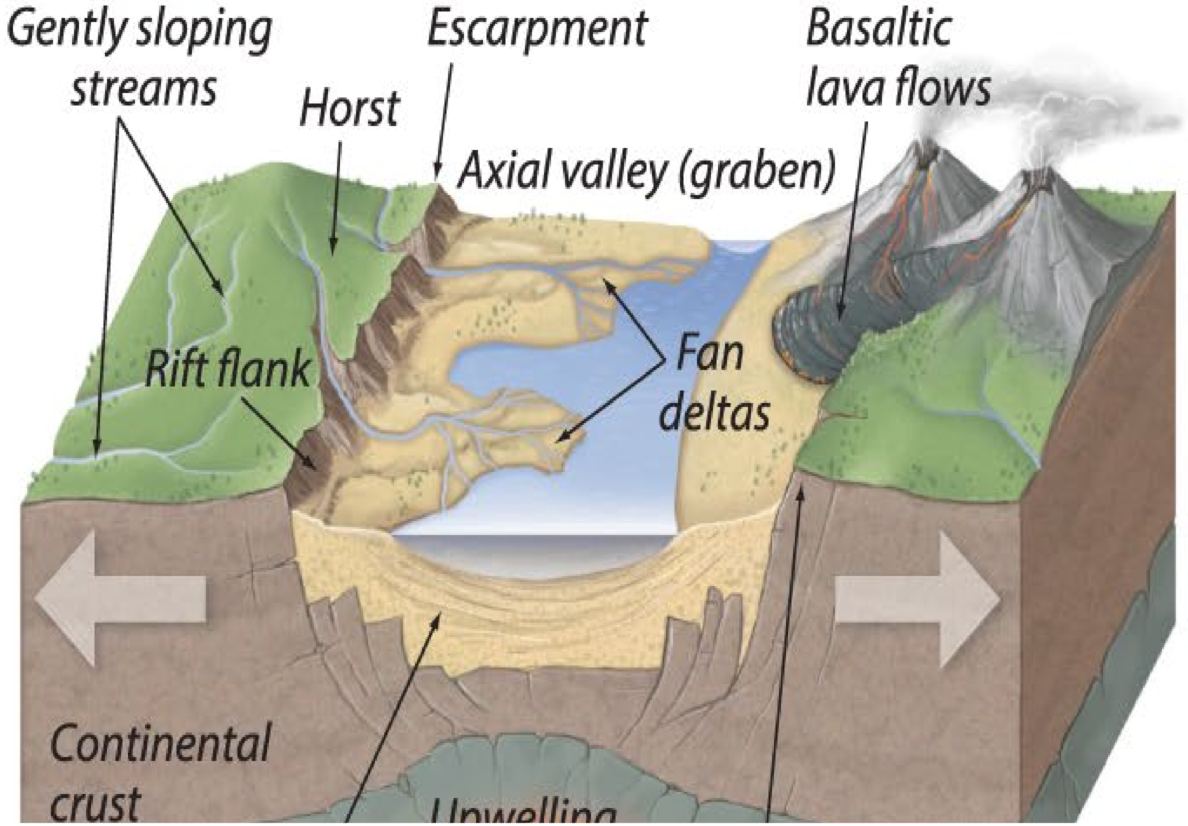
Fault Landforms



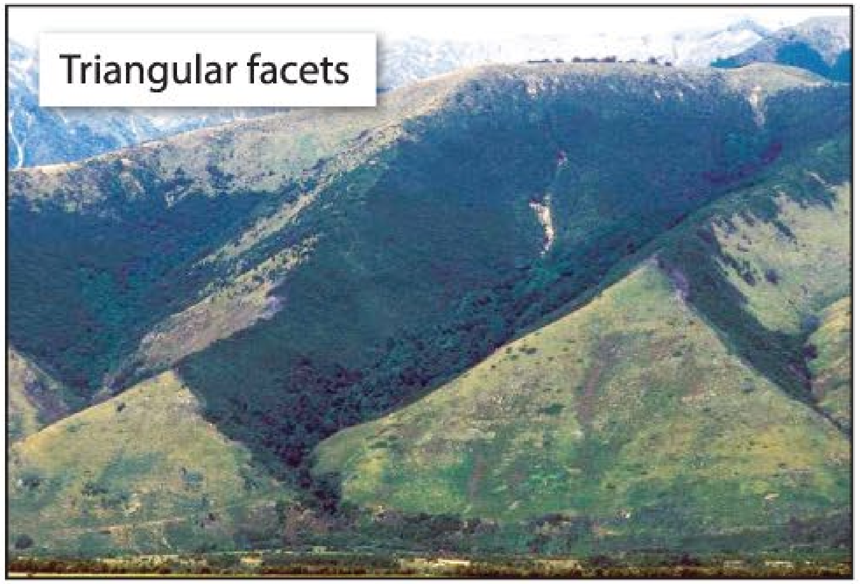


Extensional

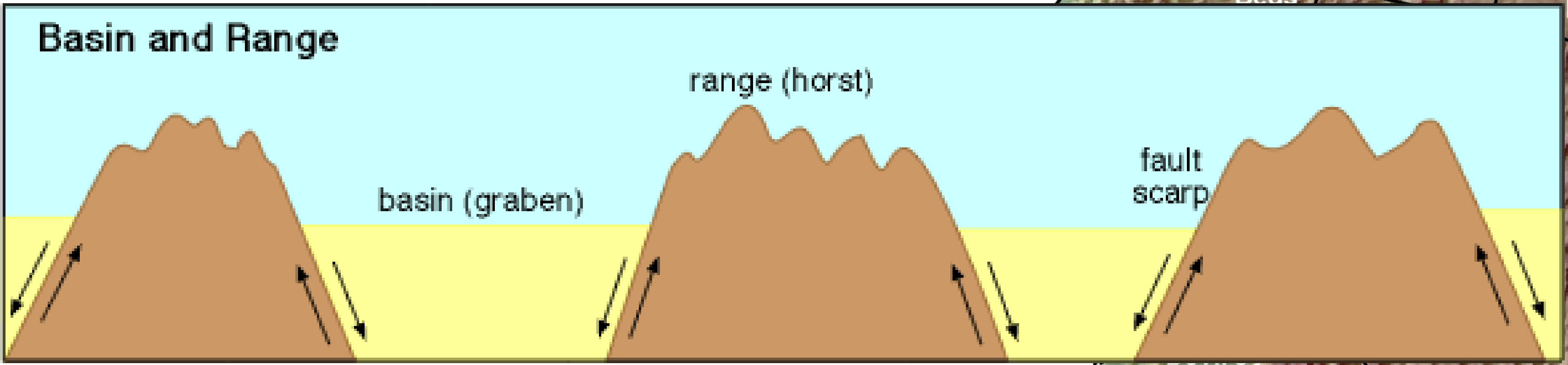


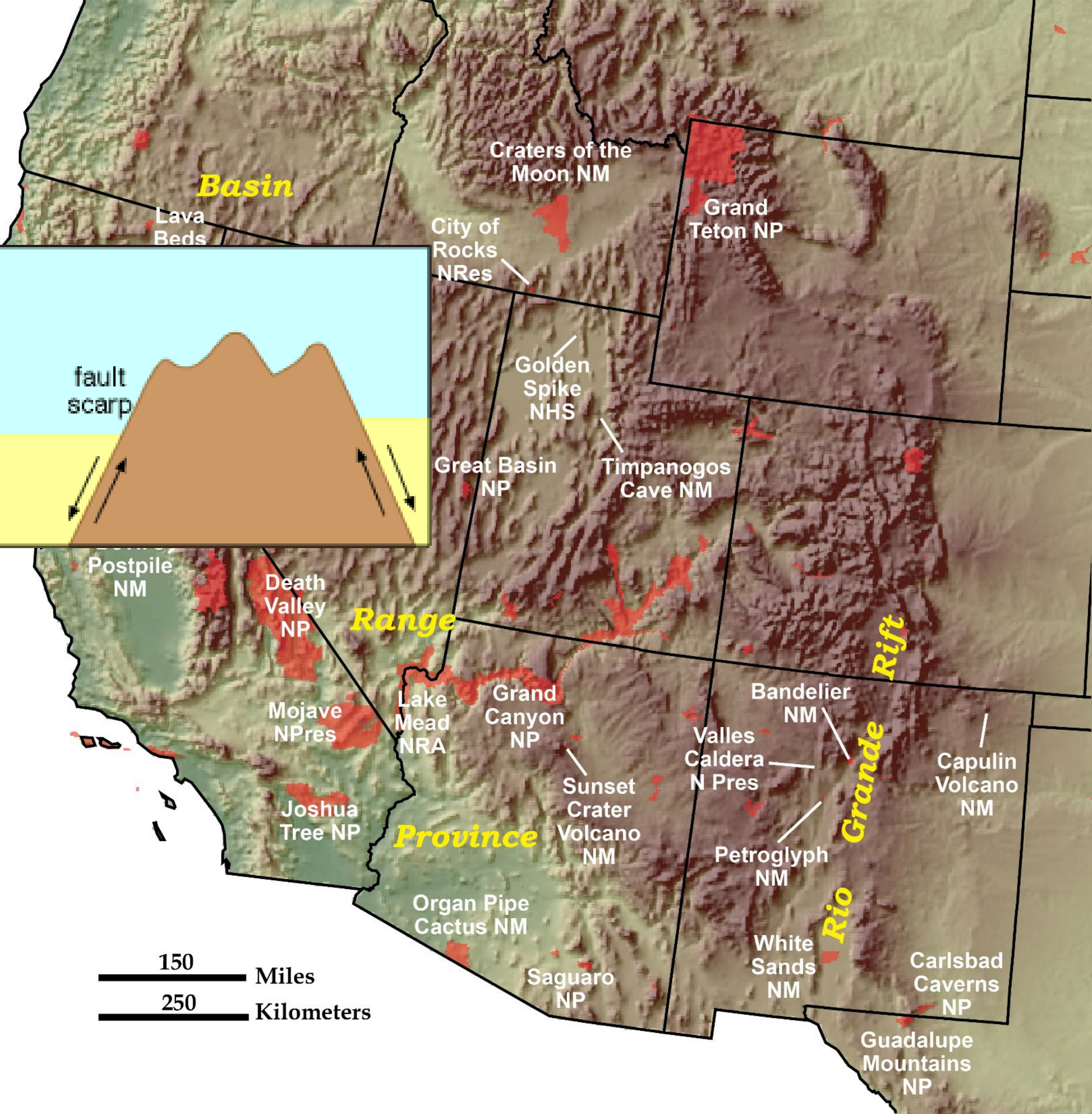


Extensional zones contain diagnostic normal faults that delineate range fronts, can offset alluvial fans, and form triangular bedrock facets that represent the exhumed fault surface. Hourglass-shaped valleys extend into the range front between the facets.

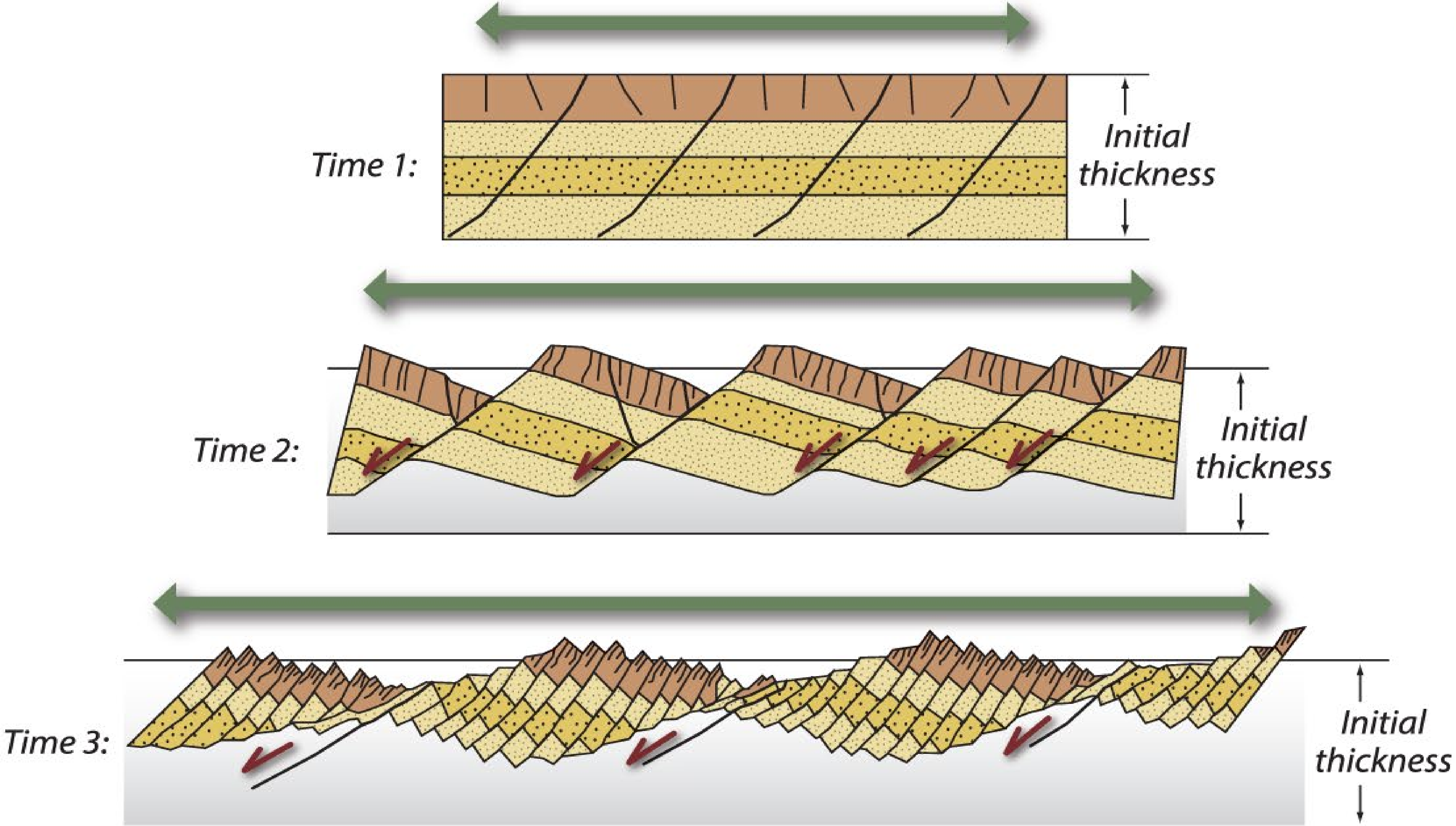


Basin and Range



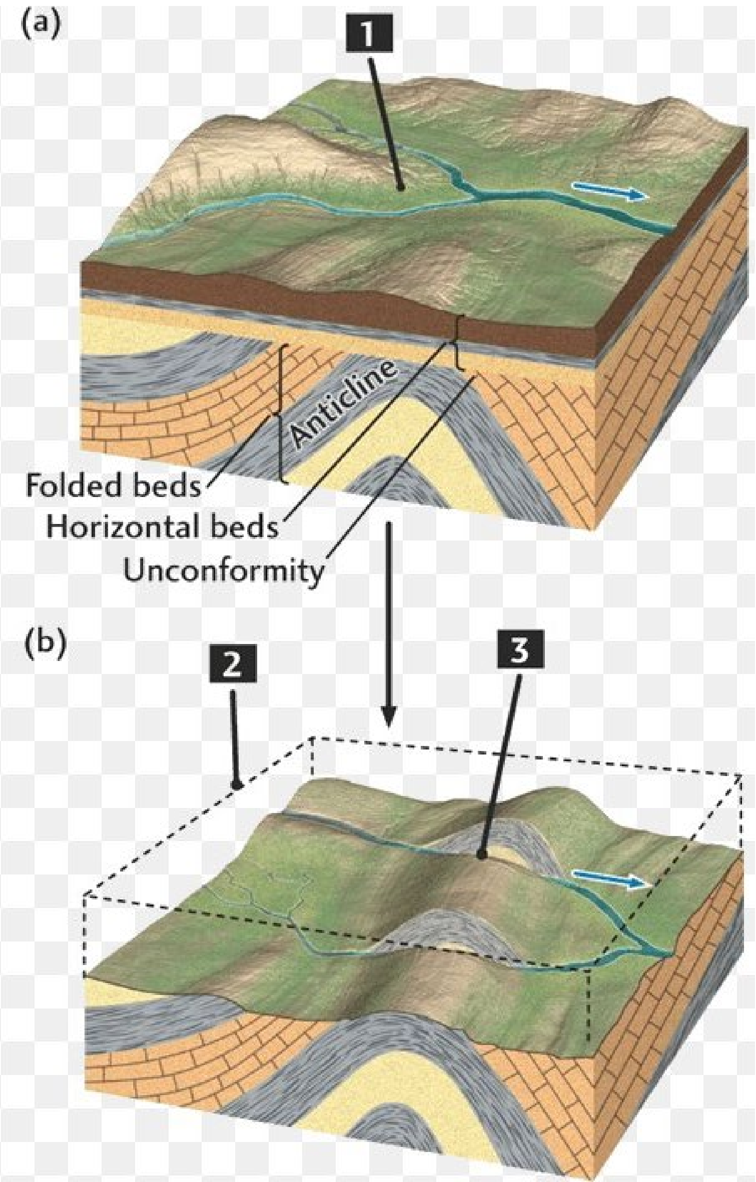


The Basin and Range physiographic province extends from the Rocky Mountains to the Sierra



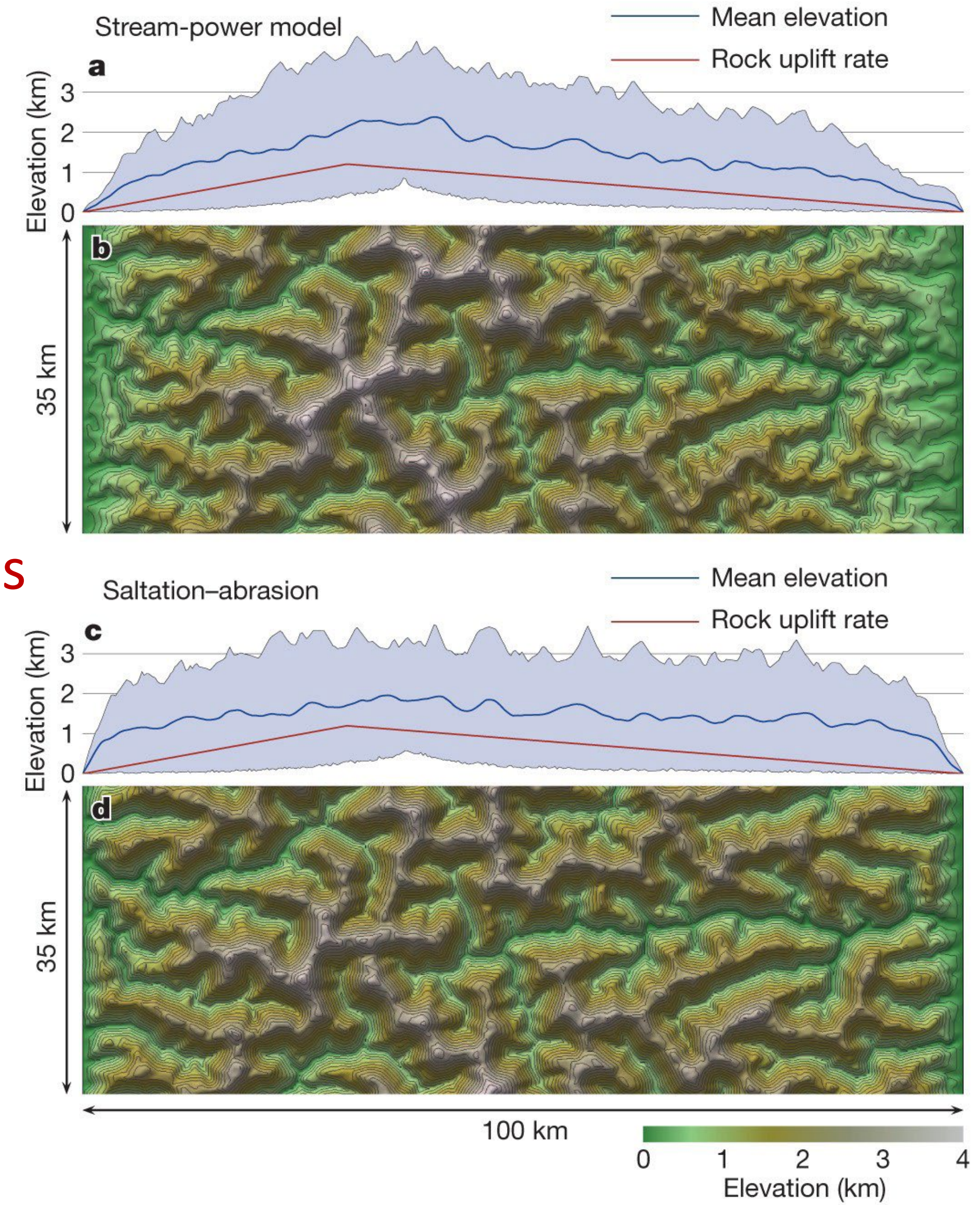
Extension of an initial high-elevation plateau along sets of nested normal faults has resulted in a fallen-down block structure in the Basin and Range. Alternating series of down-dropped basins and uplifted ranges reflect rotational deformation along a complex set of deep-seated regional normal faults and result in a landscape of fault-controlled, alternating valleys and mountain ranges.

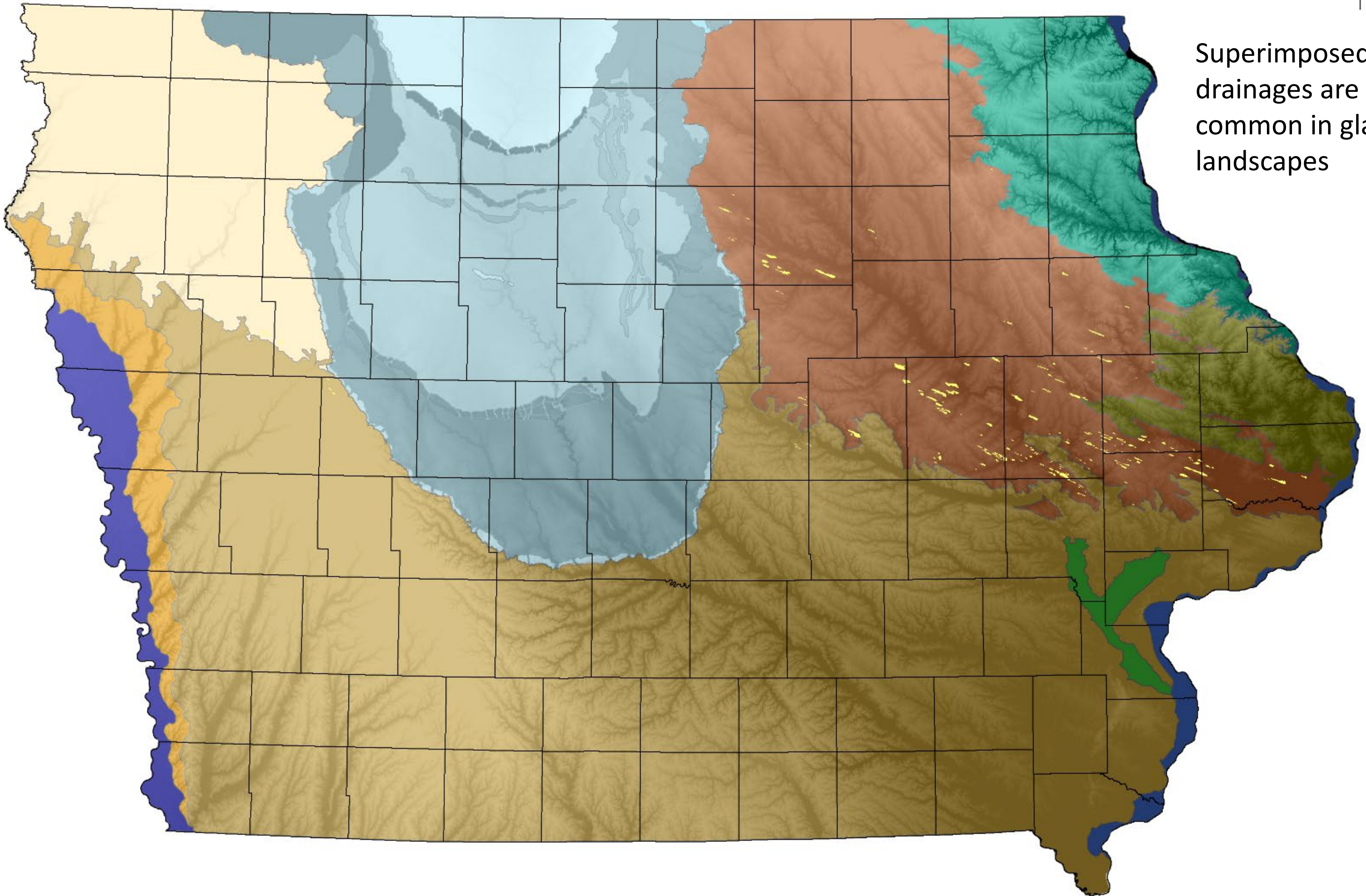
Differential Fluvial Erosion



Antecedent Drainages

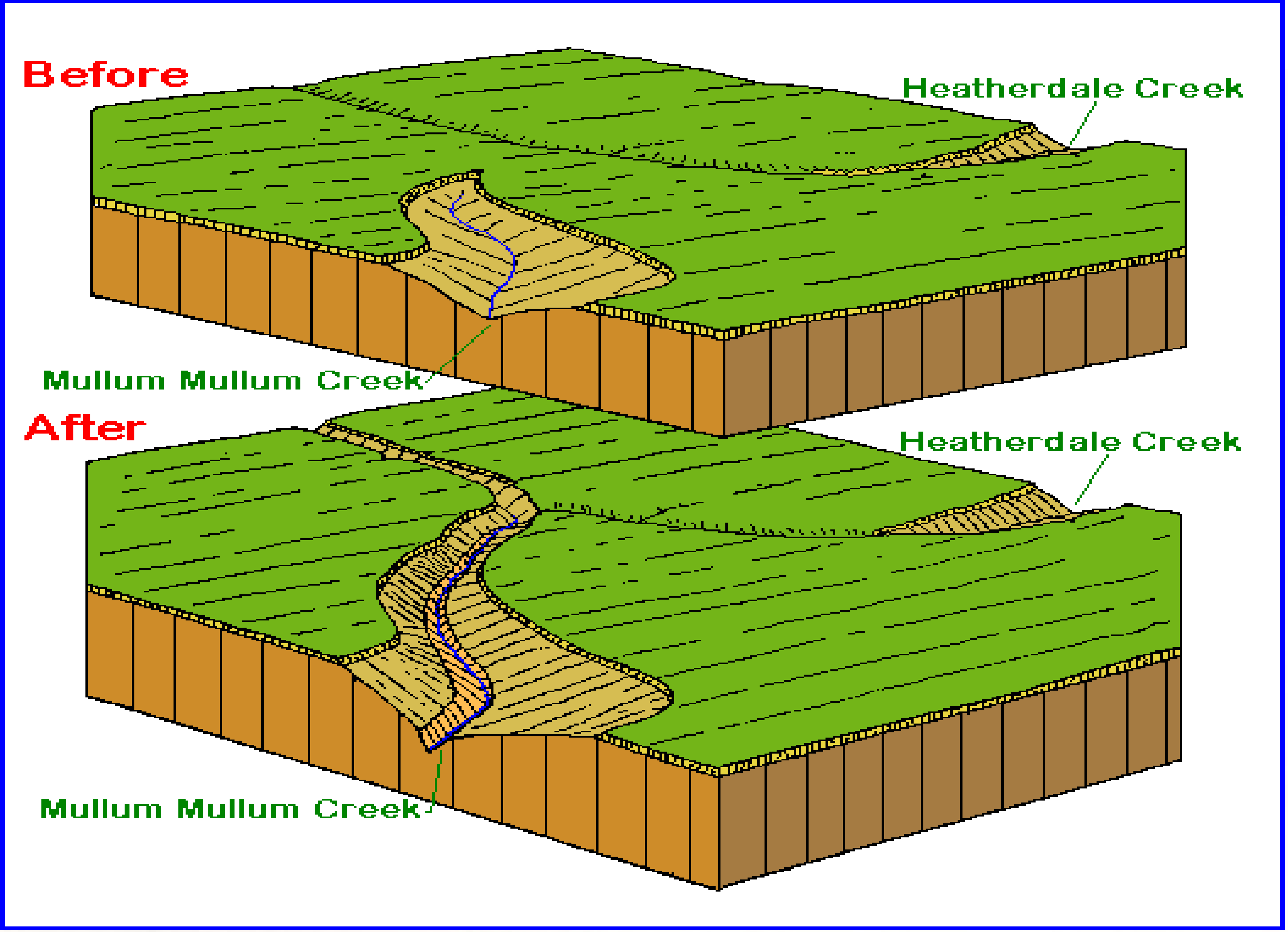
Drainage maintains valleys and flow before and after tectonism



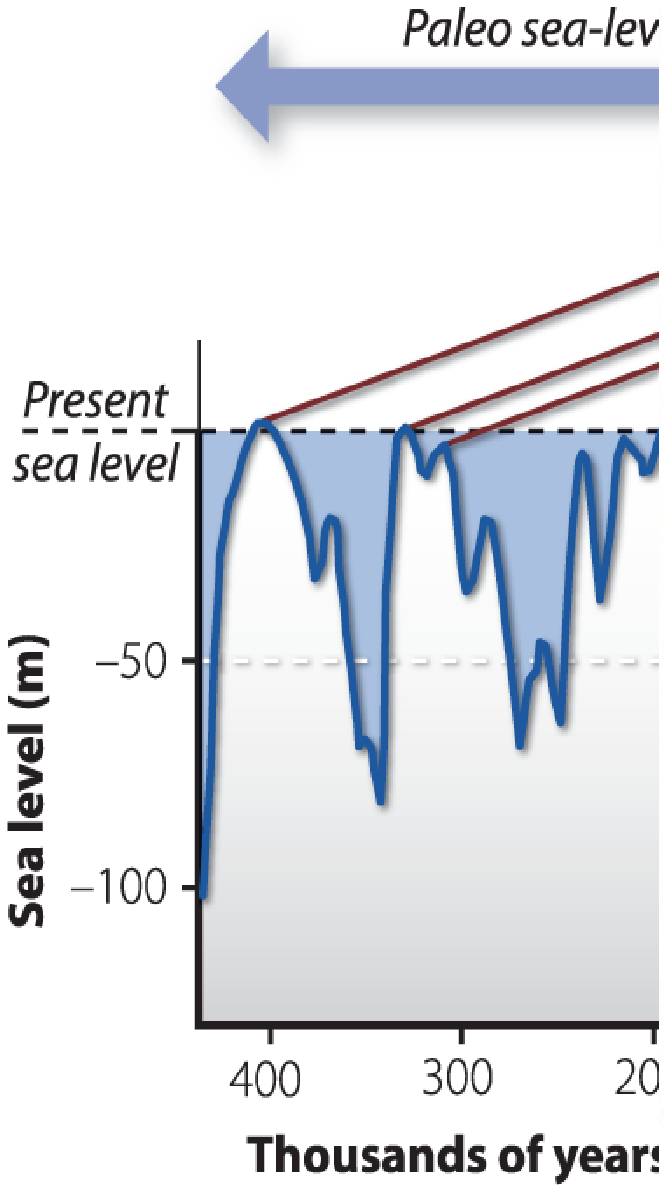


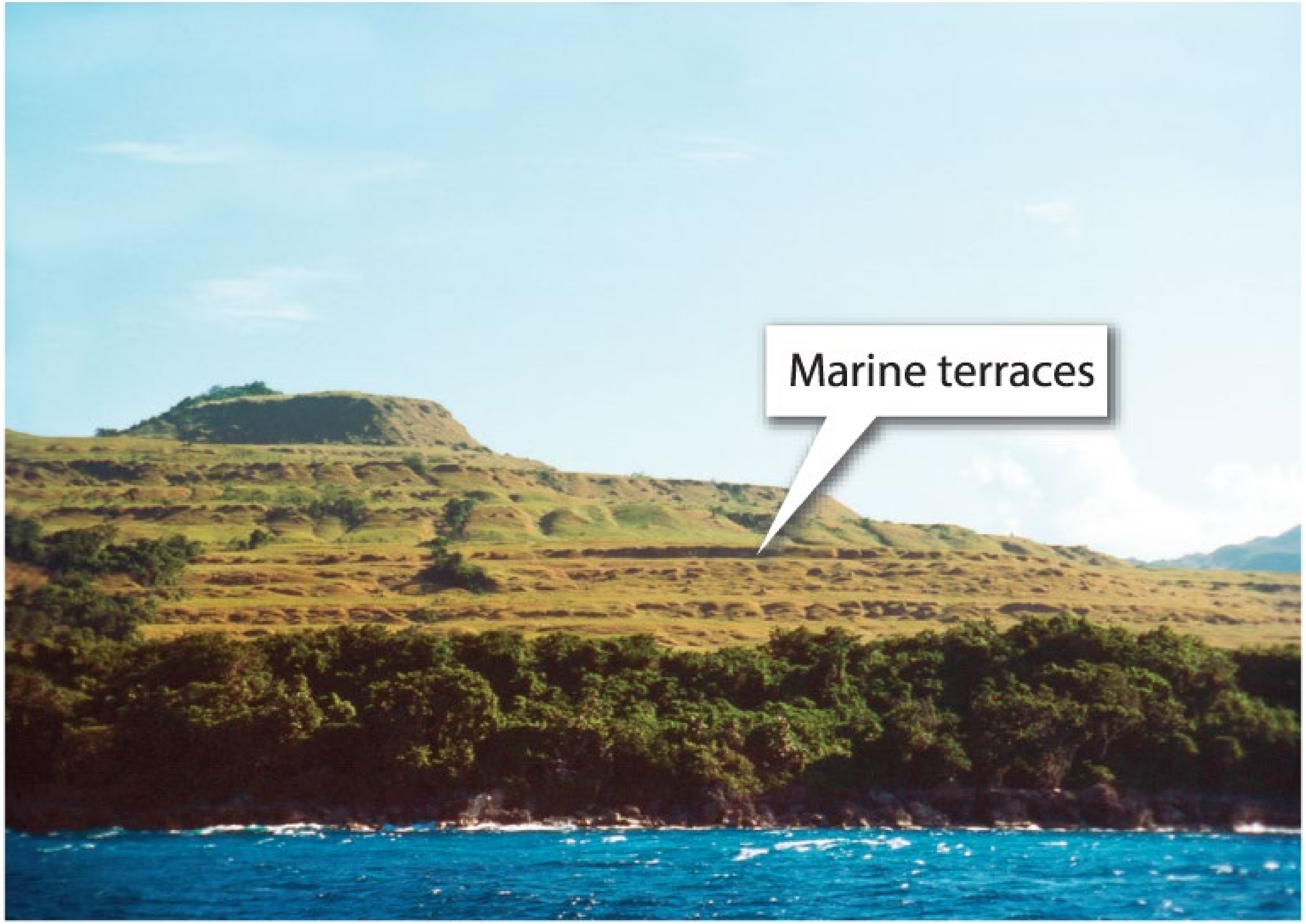
Superimposed drainages are very common in glaciated landscapes

Stream capture or piracy



Coastal uplift & subsidence





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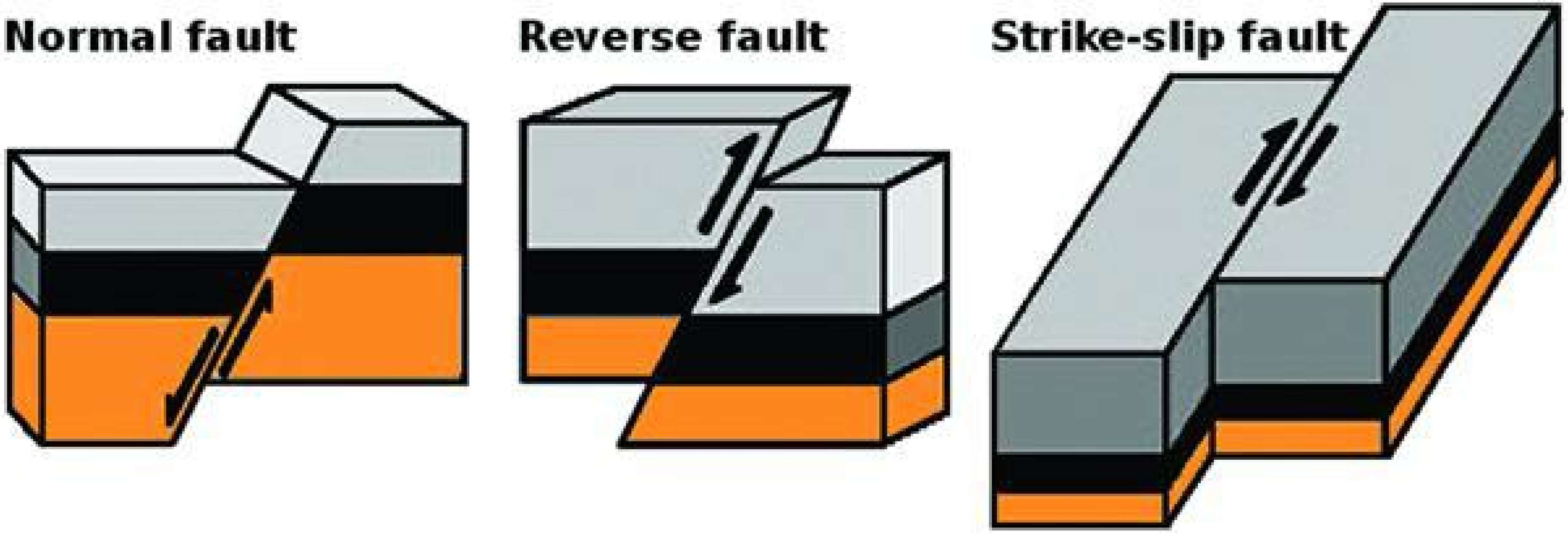
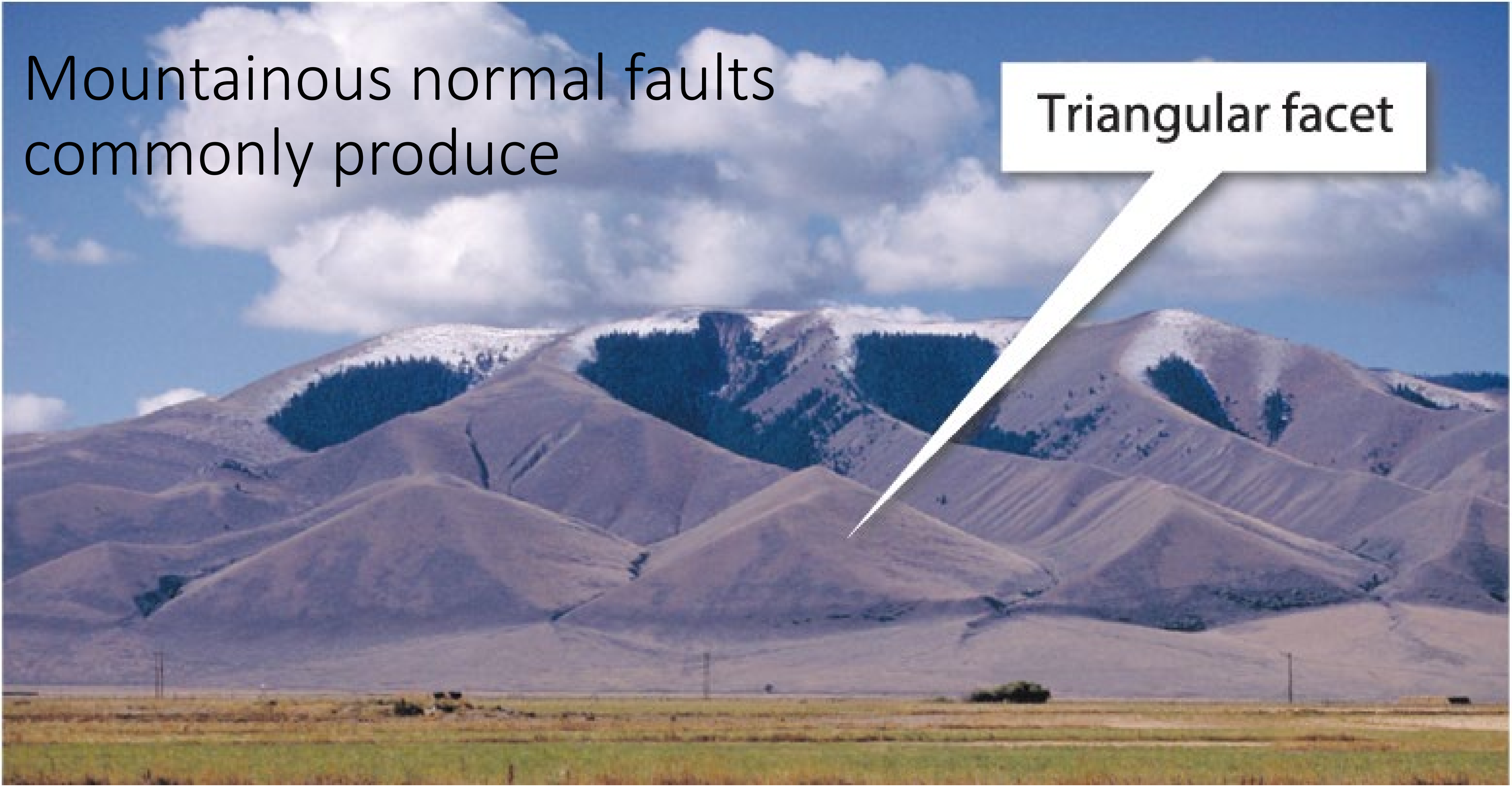
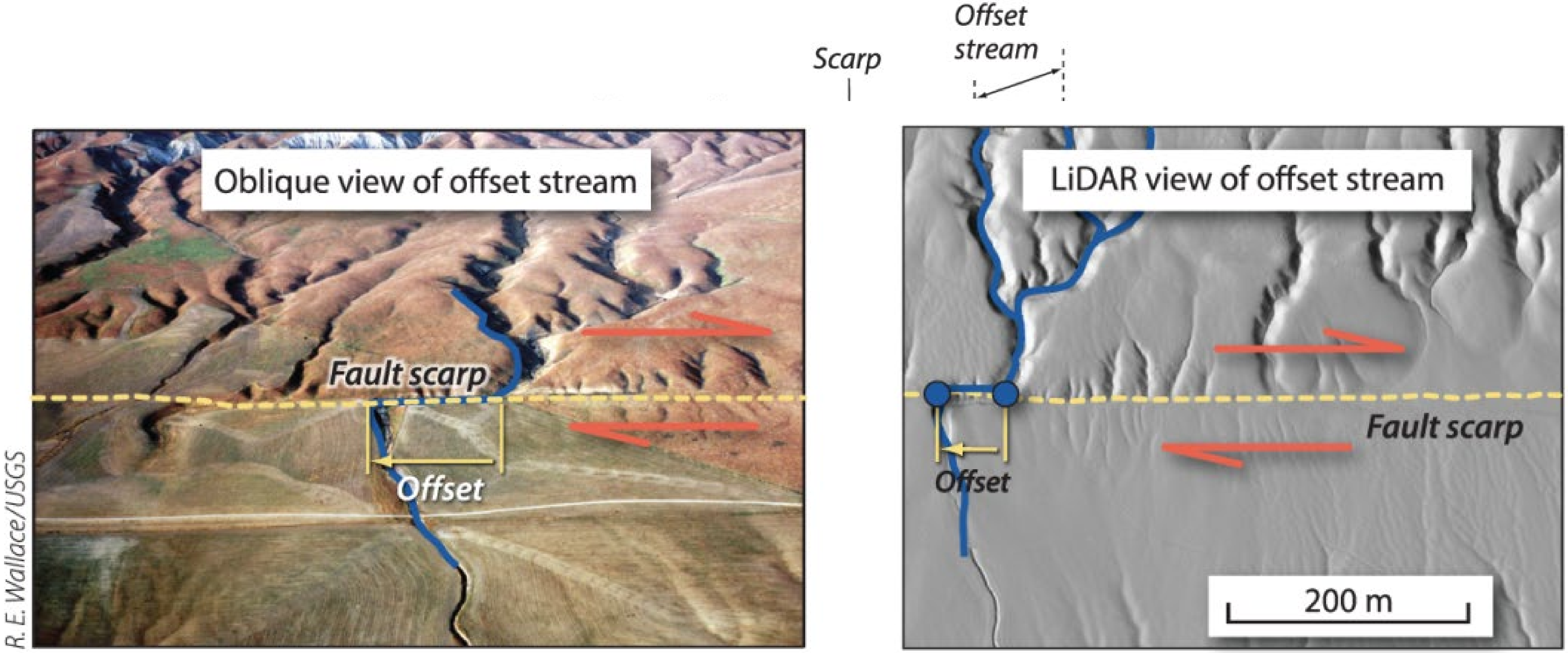
Faults

- Hanging wall
- Foot wall
- Earthquakes



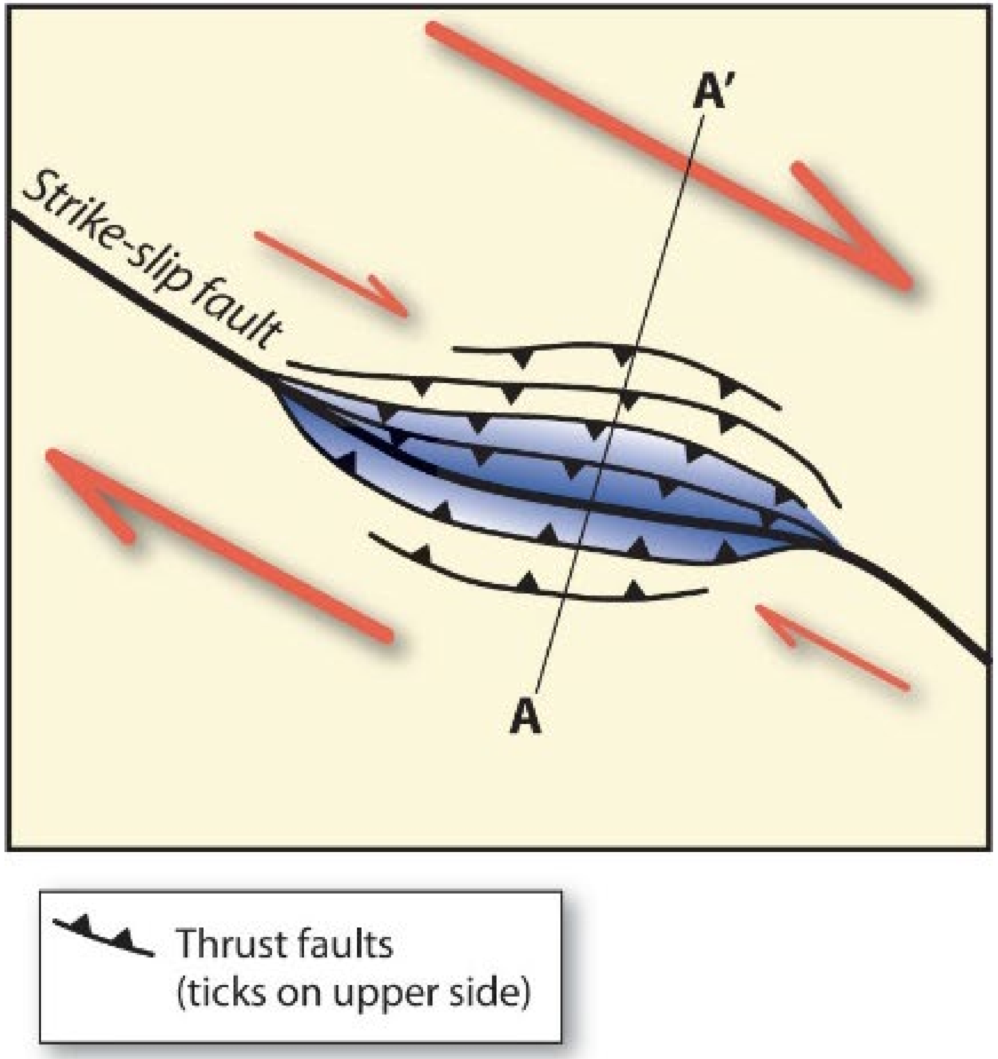
Mountainous normal faults commonly produce

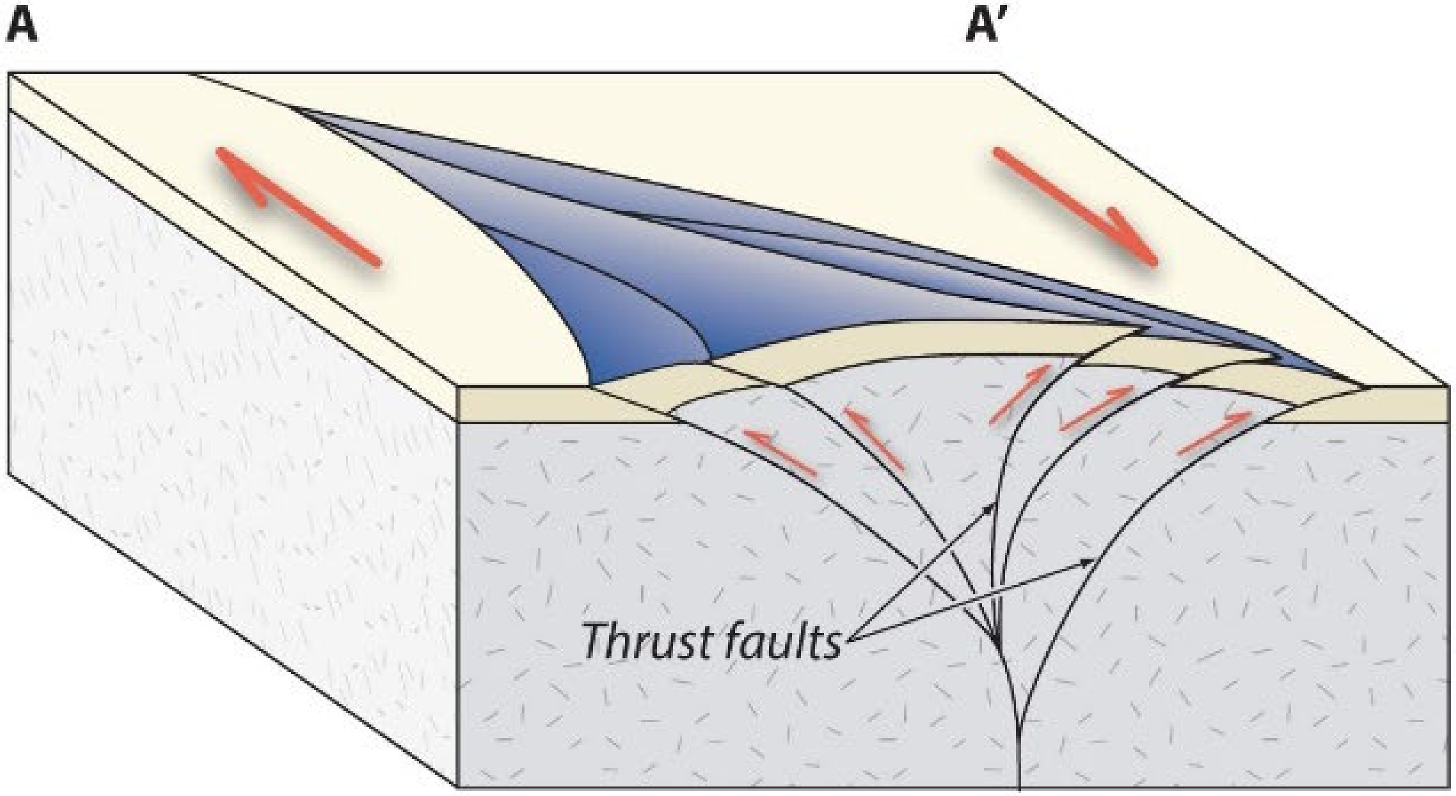




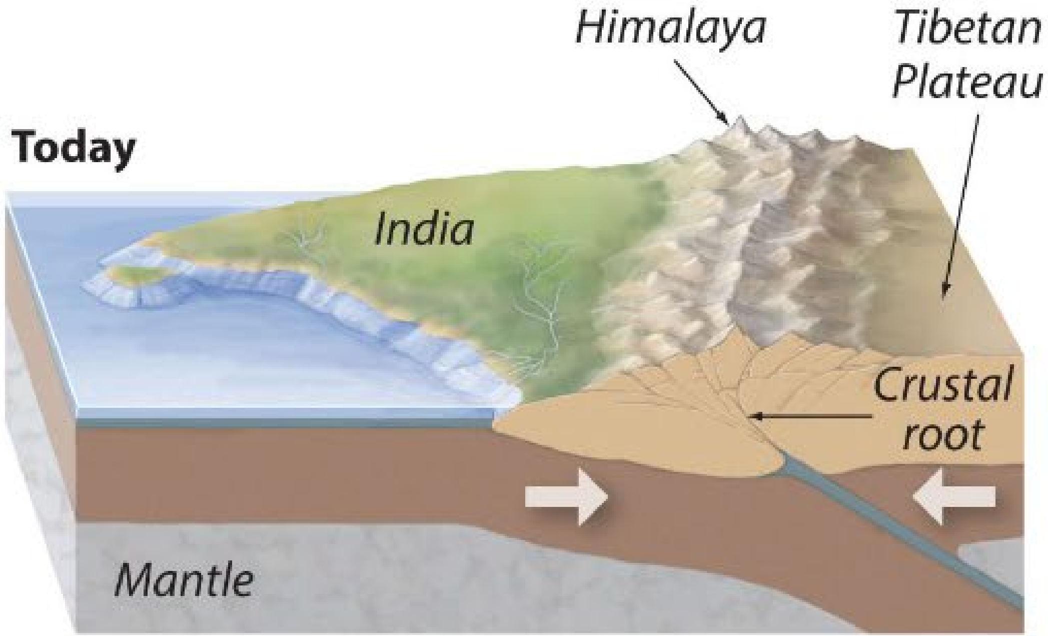
Strike-slip fault zones produce a characteristic suite of landforms that reflect both linear offset (beheaded streams, offset channels) and weakening of rock or tectonic extension near the fault (linear valleys, sag ponds). LiDAR and aerial photographs can reveal the location and amount of recent offset on strike-slip faults.

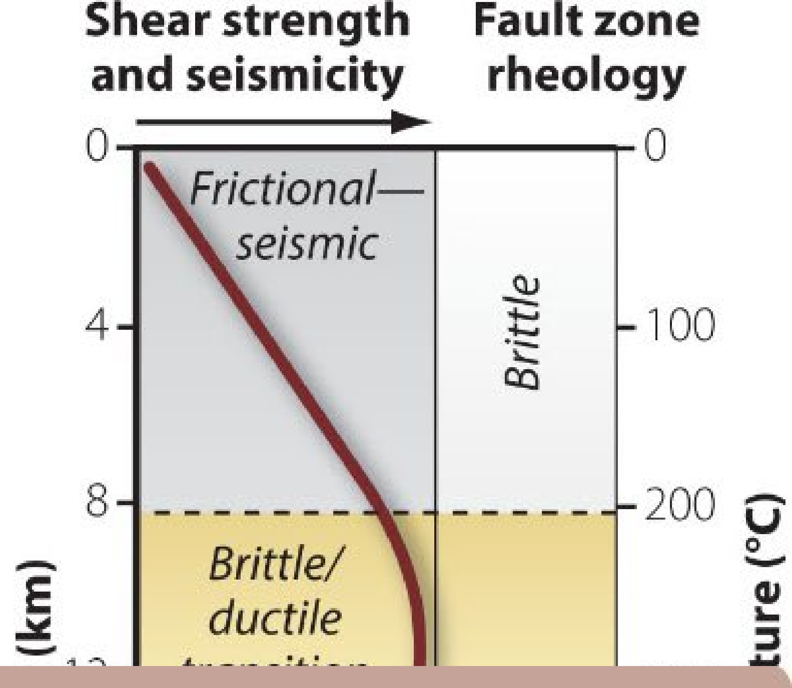
Restraining bend





As material is squeezed through a **restraining bend,** by movement along a strike-slip fault, compression results in surface uplift distributed along a nested set of thrust faults.

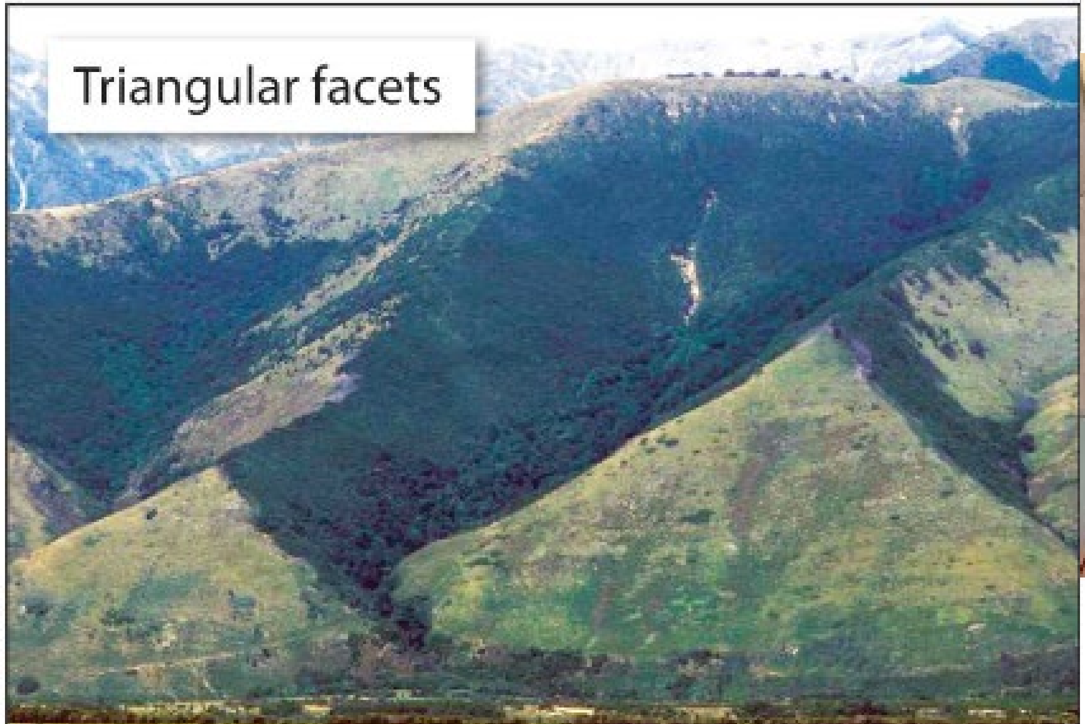


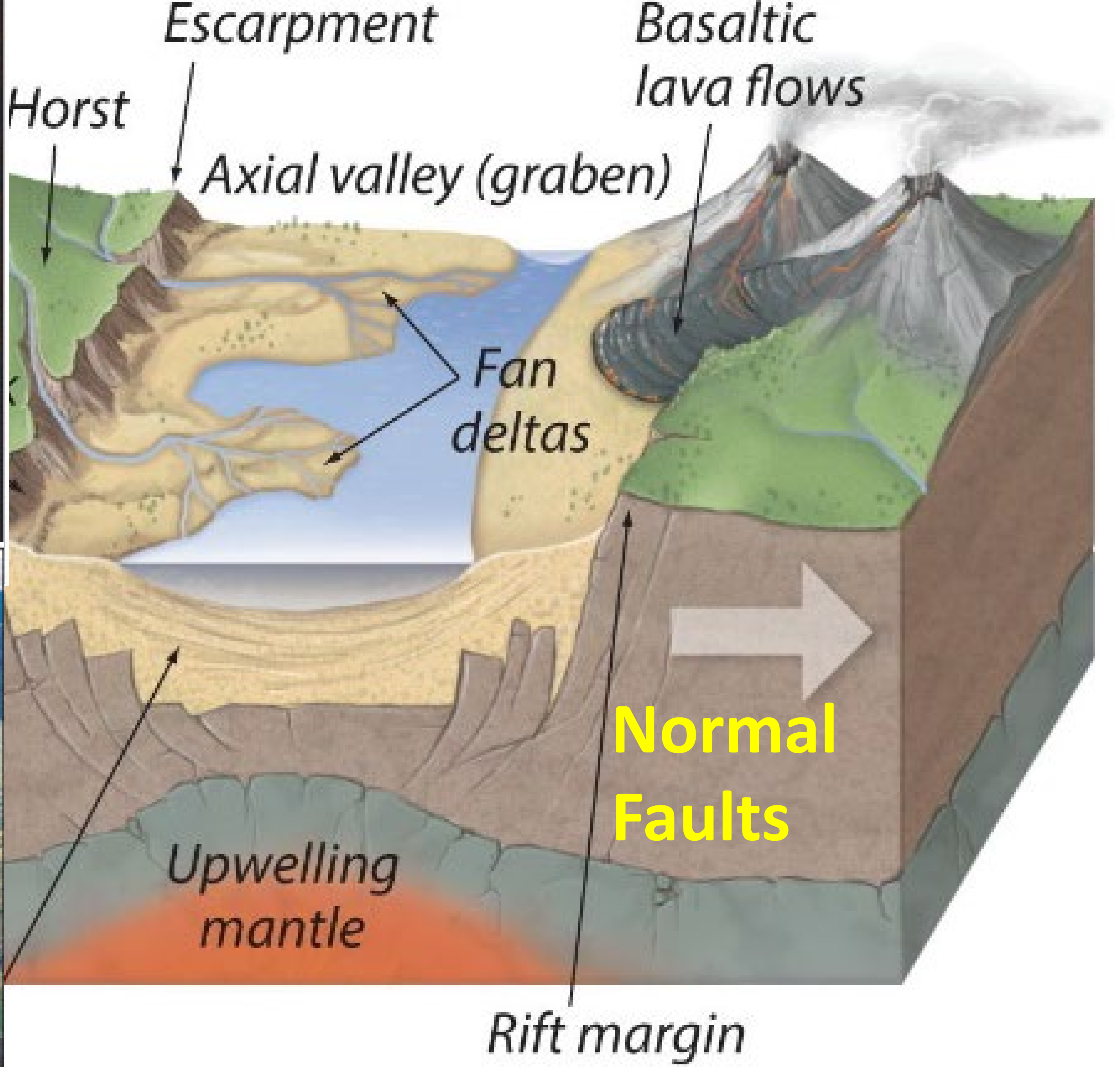


As India moved into Asia, the continental lithosphere of both continents was not dense enough to subduct and ongoing collision resulted in **crustal thickening.** Over time, the **crustal root** grew thicker and the Tibetan Plateau rose and, as the collision continues, it grows wider. The thickening crust, rising mountains, and high rates of erosion affect the shape and behavior of the Himalaya. Rapid erosion advects warm rock toward the surface, and the thickened crust causes rock at depth to cross the brittle/ductile transition. This change in the process and rate by which the rock deforms allows rock to more easily and rapidly extrude out the sides of the range, removing some of the mass brought in by continental collision and limiting the height of the Tibetan plateau.

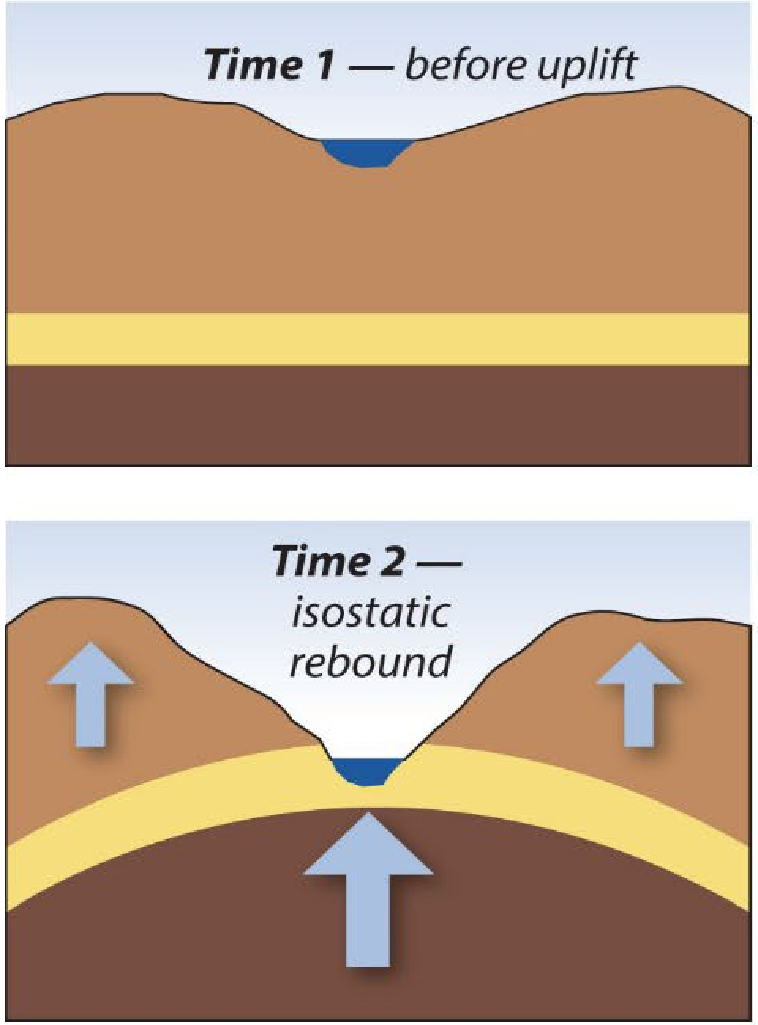
The shear strength and rheology (flow characteristics) of the lithosphere vary with depth due to the effects of increasing pressure and temperature. In the uppermost brittle crust, frictional strength increases to a depth of around 8 to 10 km. At higher pressures and temperatures below about 13 km depth, shear strength decreases and the crust becomes ductile, producing aseismic viscous flow. Tectonic convergence that produces exceptionally thick crust can lead to lateral flow of ductile material at depth.


Offset alluvial fan

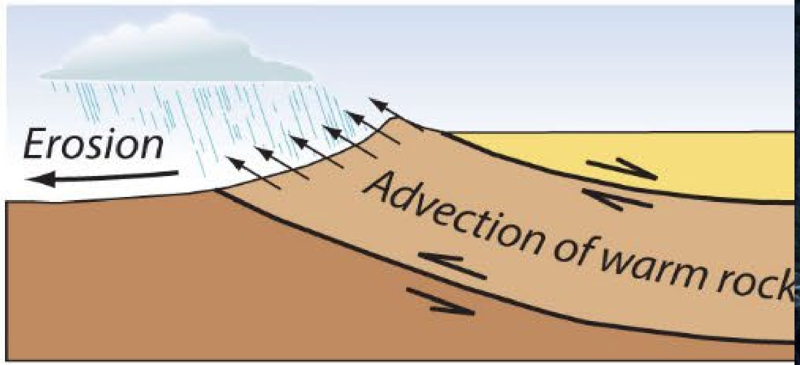

Triangular facets


Escarpment
Basaltic lava flows
Horst
Axial valley (graben)
Fan deltas
Normal Faults
Upwelling mantle
Rift margin

River anticline



Mountain front erosion

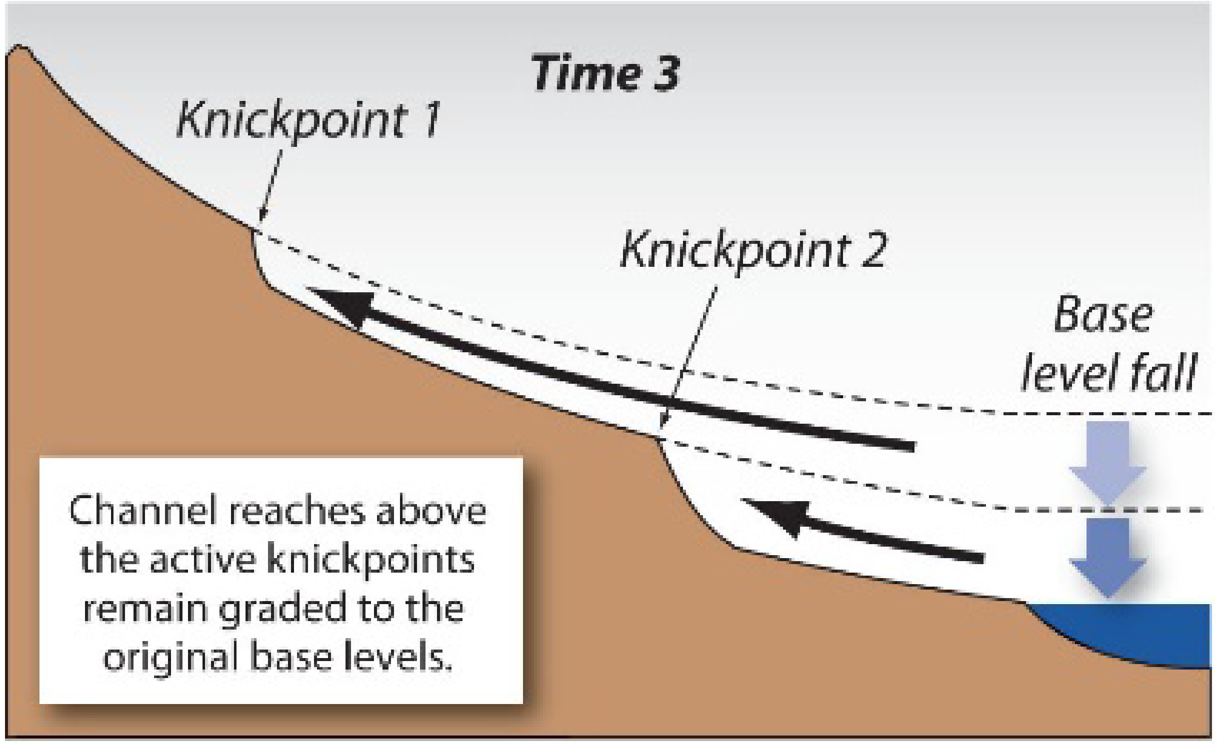


Heavy precipitation can drive rapid erosion on steep mountain fronts. This focused erosion can remove so much mass so quickly that warm rock from below the range flows (advects) to the mountain front in response to erosion. The end result is that erosion drives the movement of rock and can elevate rock of high metamorphic grade above lower grade rock.

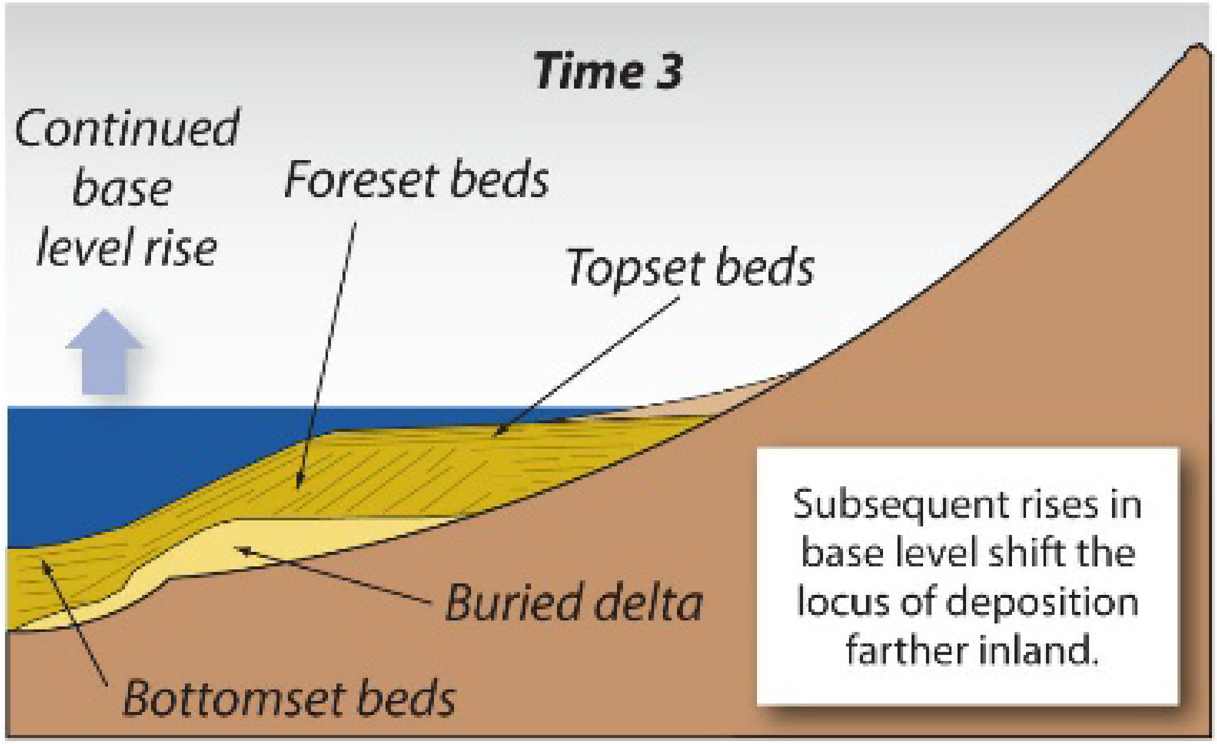
River anticlines form where mountain rivers, rapidly eroding into flexurally weak rock, remove enough mass that they catalyze focused exhumation and isostatic rebound. This focused rock uplift, driven by differential erosion, deforms rock, creating anticlines that run beneath some major rivers.

Affects the Graded Stream

Base level fall (fluvial incision)



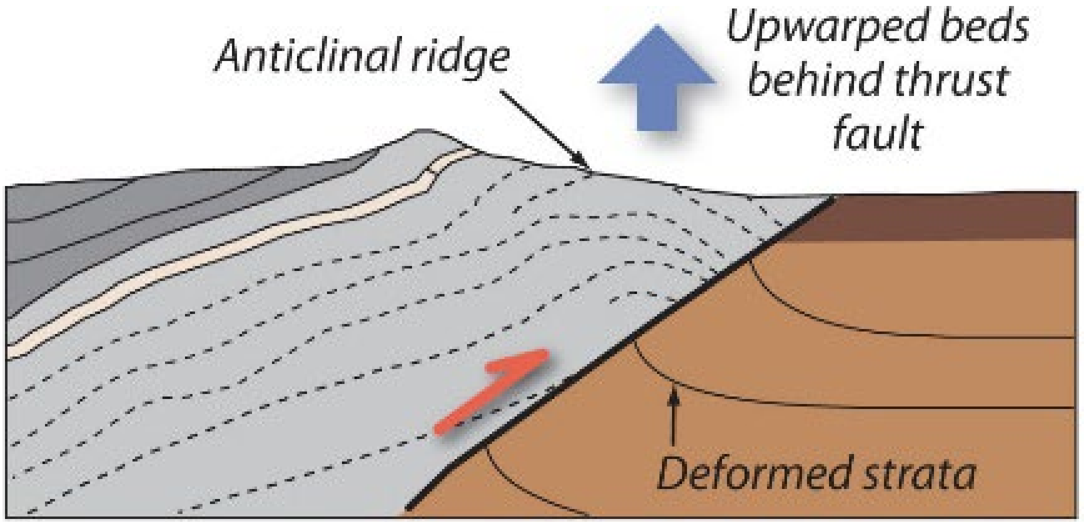
Base level rise (aggradation)

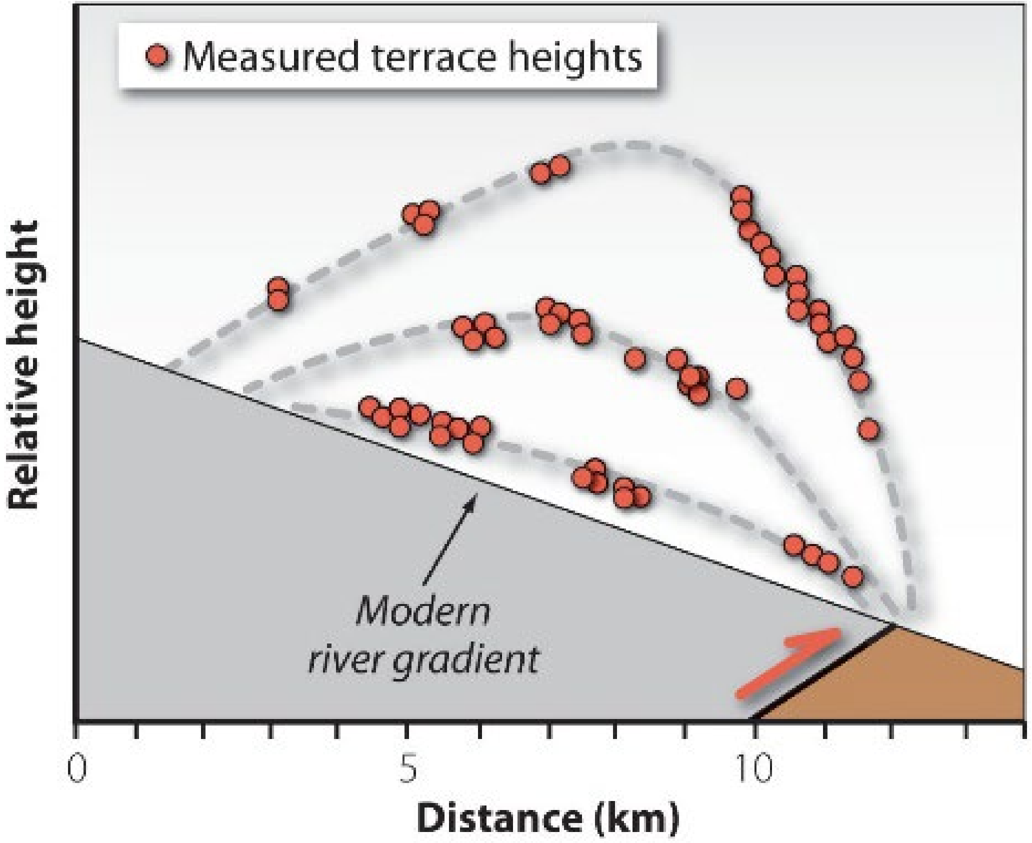


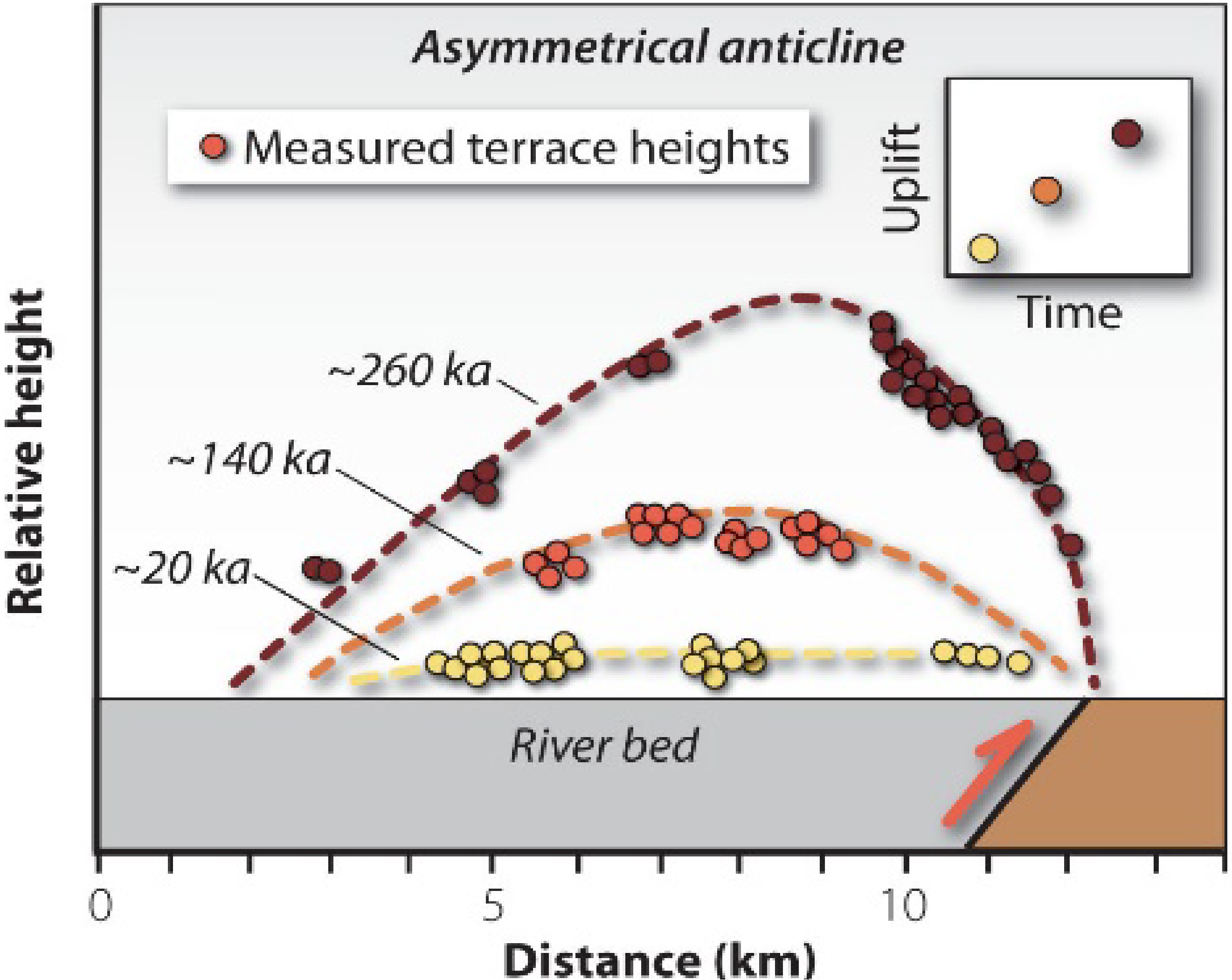
Base level fall steepens river slopes at the basin outlet, sending a **knickpoint** propagating upstream at a rate proportional to the upstream drainage area. Knickpoints can either maintain their relief or diminish as they propagate upstream.

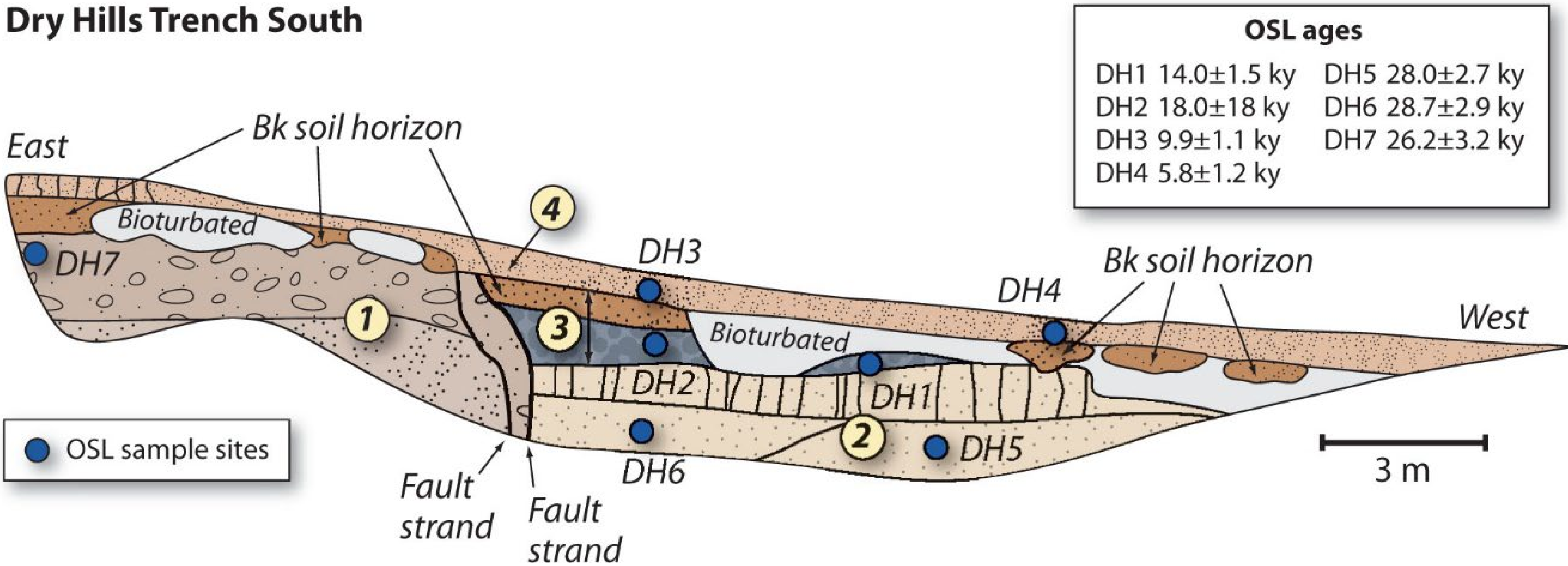
The influence of a rising base level shifts the locus of sedimentation inland, predominantly affecting estuarine and lowland river systems. The direct influence of a base level rise is restricted to aggradation in the downstream end of a river system as the system adjusts.

Geomorphology + Geochronology = uplift rates








Dry Hills Trench South
OSL ages
DH1 14.0±1.5 ky
DH2 18.0±18 ky
DH3 9.9±1.1 ky
DH4 5.8±1.2 ky
DH5 28.0±2.7 ky
DH6 28.7±2.9 ky
DH7 26.2±3.2 ky
East
Bk soil horizon
Bioturbated
DH7
4
1
3
DH3
Bk soil horizon
DH4
West
Bioturbated
DH2
DH1
2
DH5
DH6
OSL sample sites
Fault strand
Fault strand
3 m