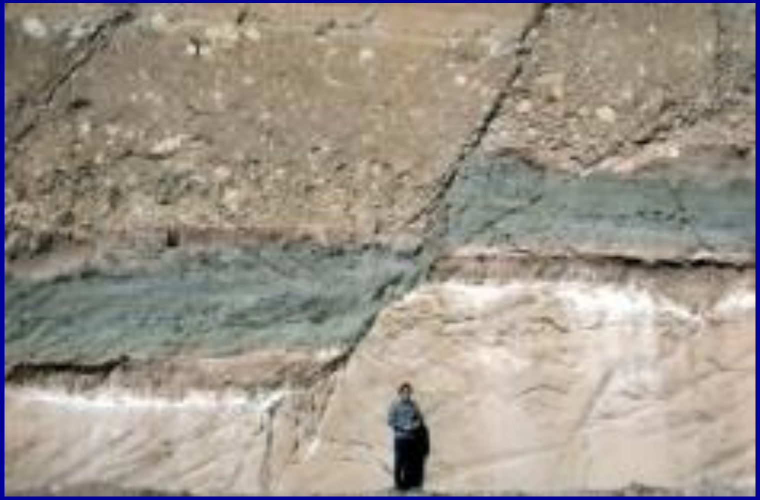
Geomorphology of Extensional Faulting: normal fault (poklesové zlomy

Zanjan. Iran



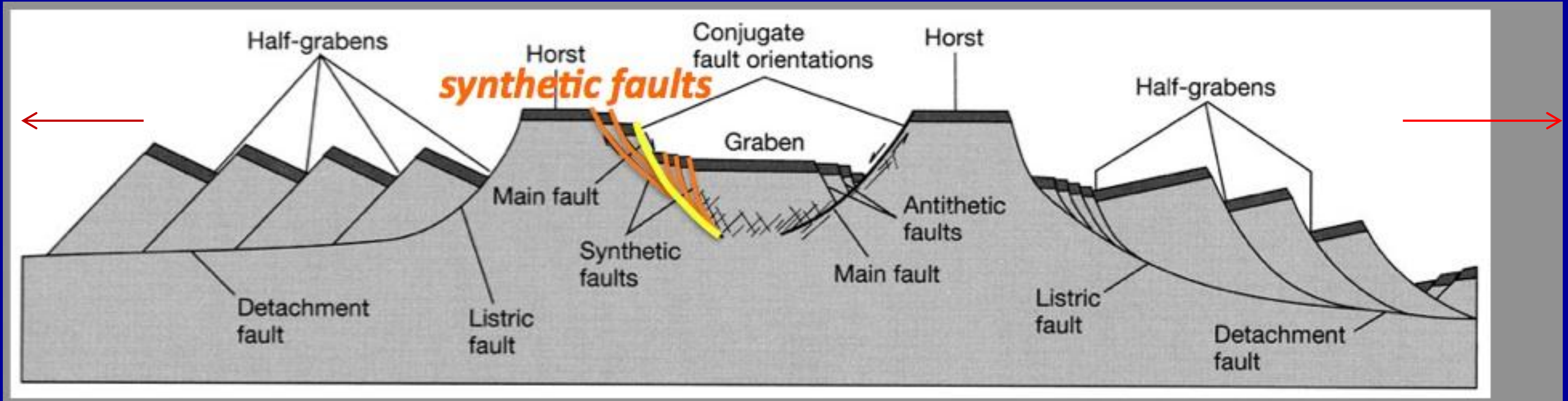
Extensional Faulting

Displacement accommodated in normal faults

- Single, Parallel synthetic, Antithetic

Primary normal fault (60-70°)

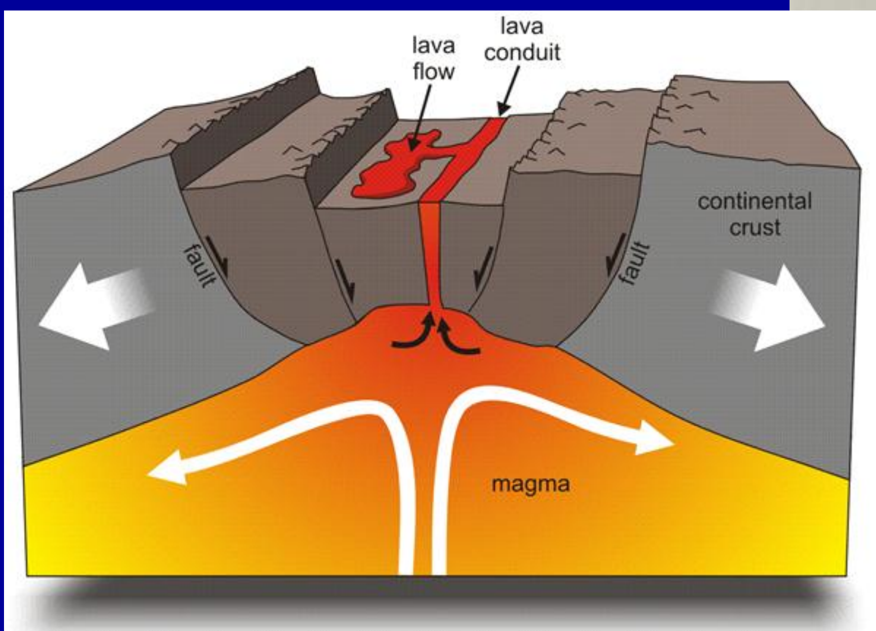
- Crustal penetrating fault
- Often has km of displacement
- Separates linear mt range from adjacent basin
  - Up-faulted block (horst)
  - Down-faulted block(graben)

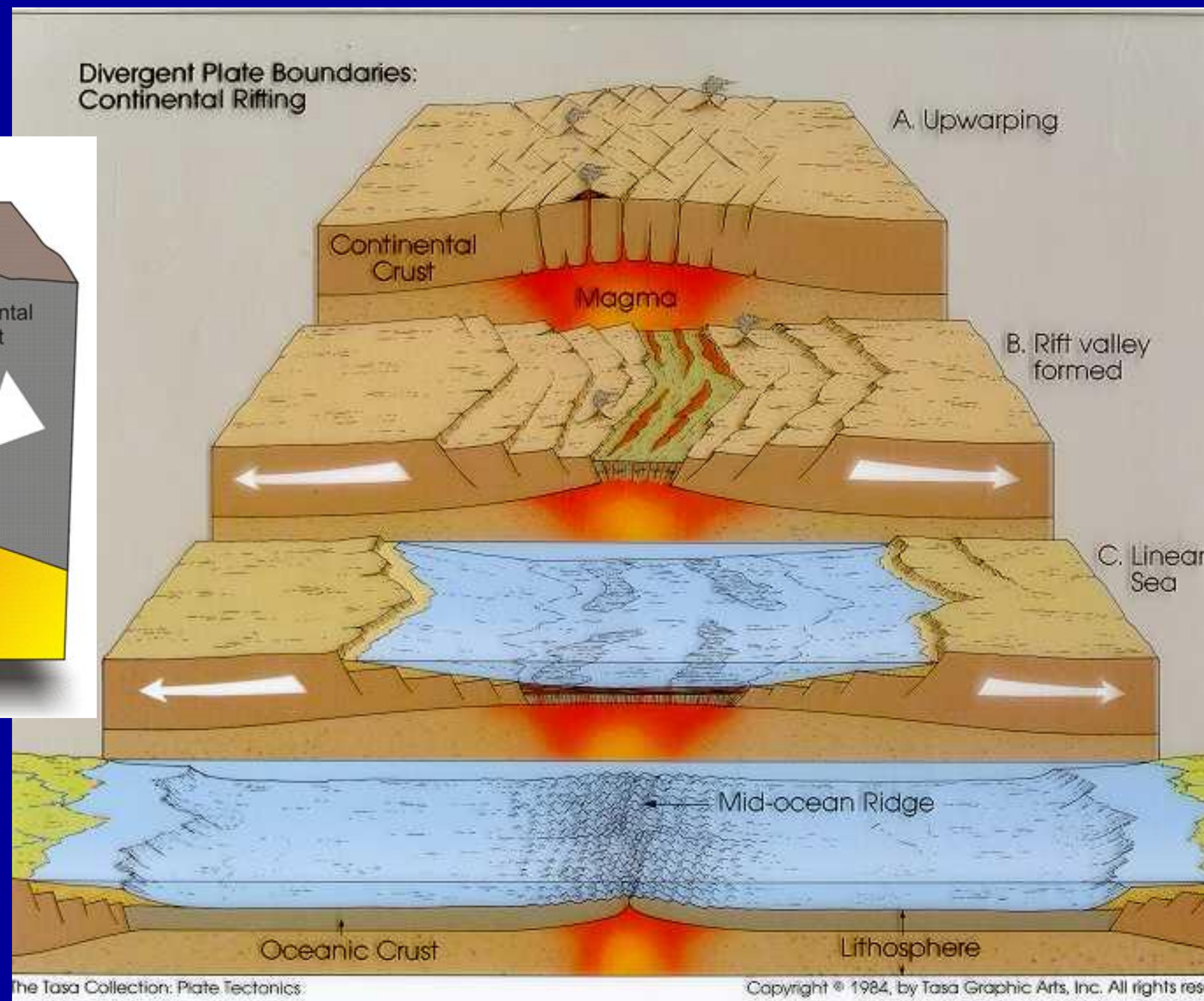


- Subsidiary faults dipping in the same direction as the major fault are <u>synthetic</u>. Those dipping opposite to the major fault are <u>antithetic</u>.

Crustal extension and normal faults – related to the most remarkable topography at regional scale

Rifts valleys

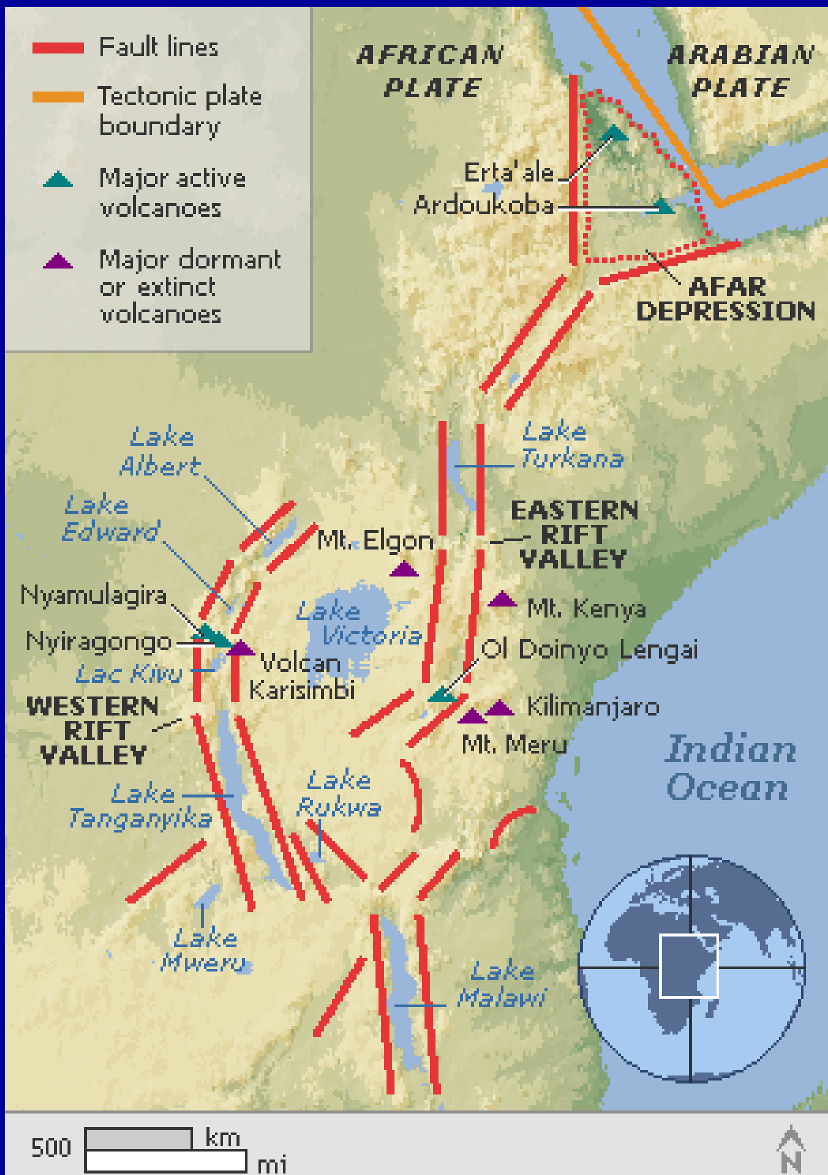


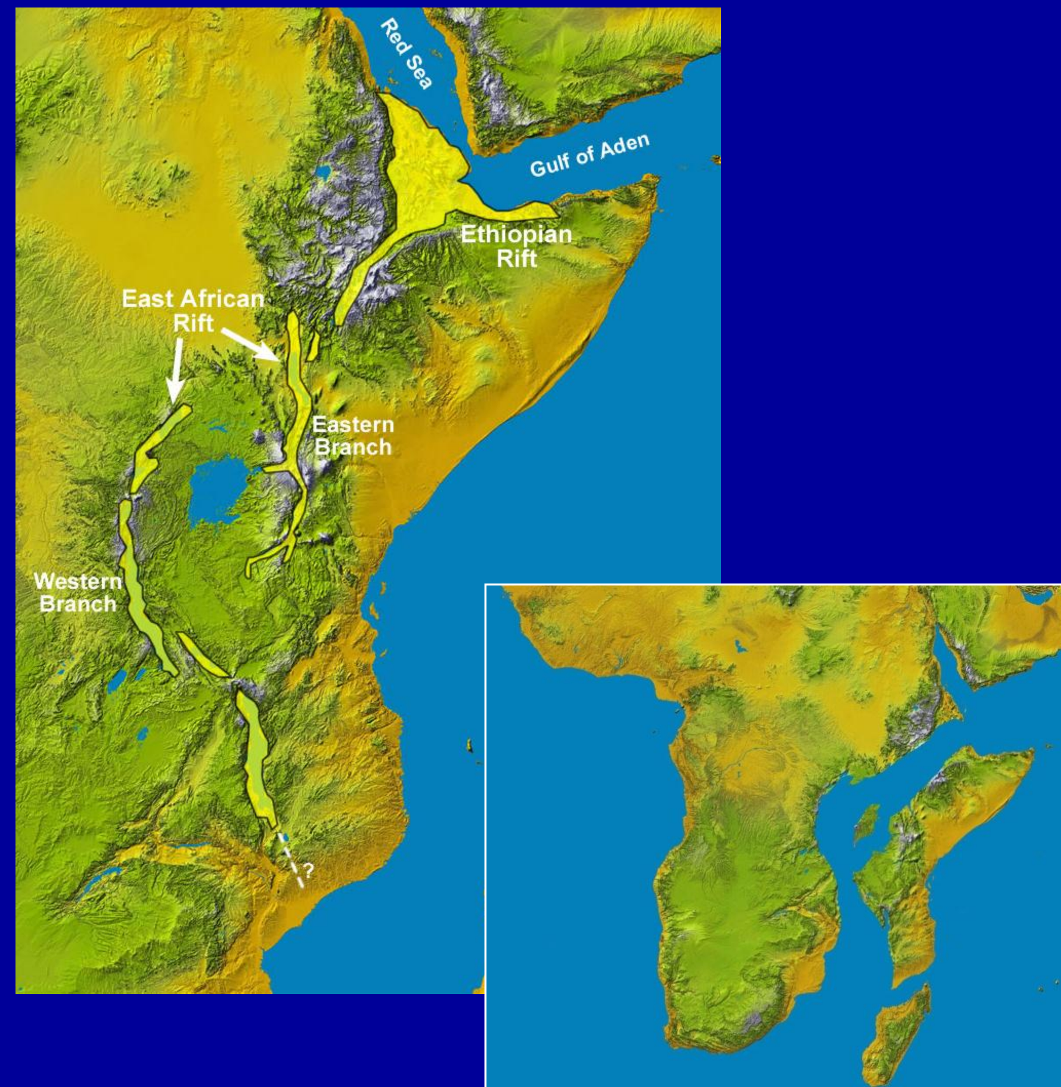


rift – elevated heatflow,
vertical compression,
horizontal extension

East African Rift Valley

active divergence, rift – numerous of normal faults





East African rift in 20 mil years

Hayli Gubbi, shield volcano, crater inside caldera, Afar region, Ethiopia

Normal faults disecting the volcanos, Afar

Massive fissure splits open in the Ethiopian Desert

Rift activity 2009

Escarpments

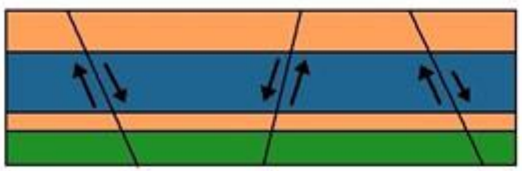
Rift Valley - Tanzania

Main Ethiopian Rift Valley

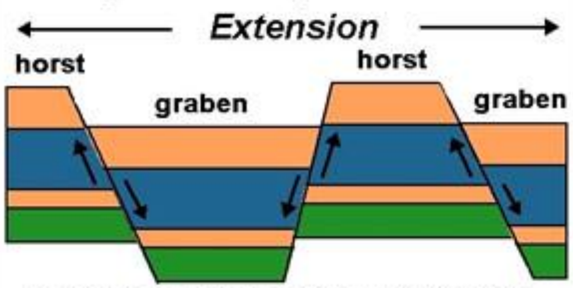
They has been formed during
million years by repeated EQs

Textbook horst and graben formation

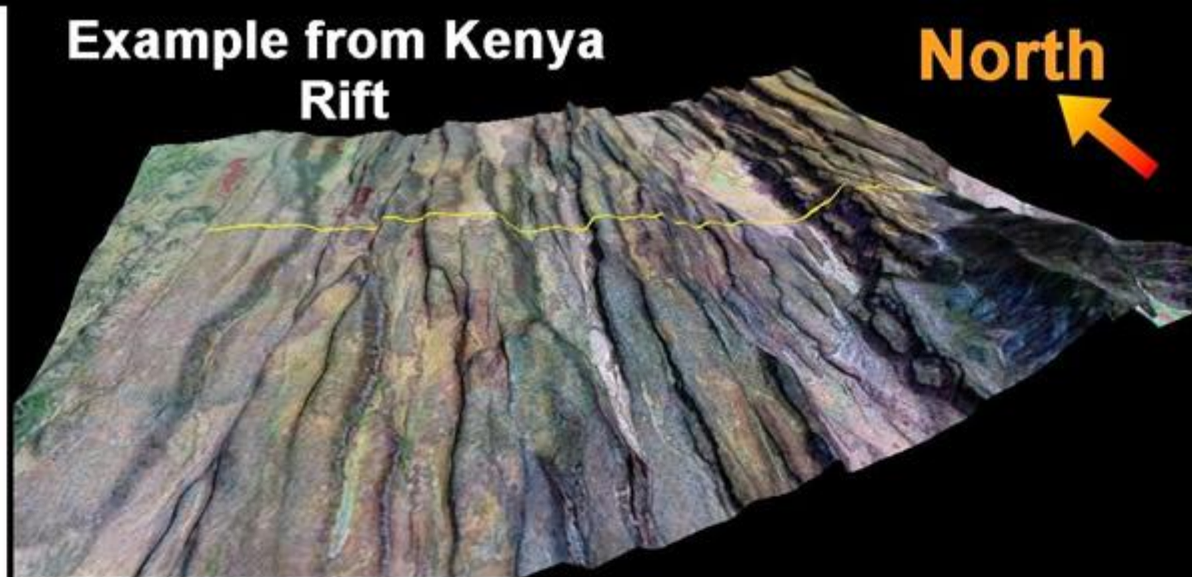
1. Layered rock units



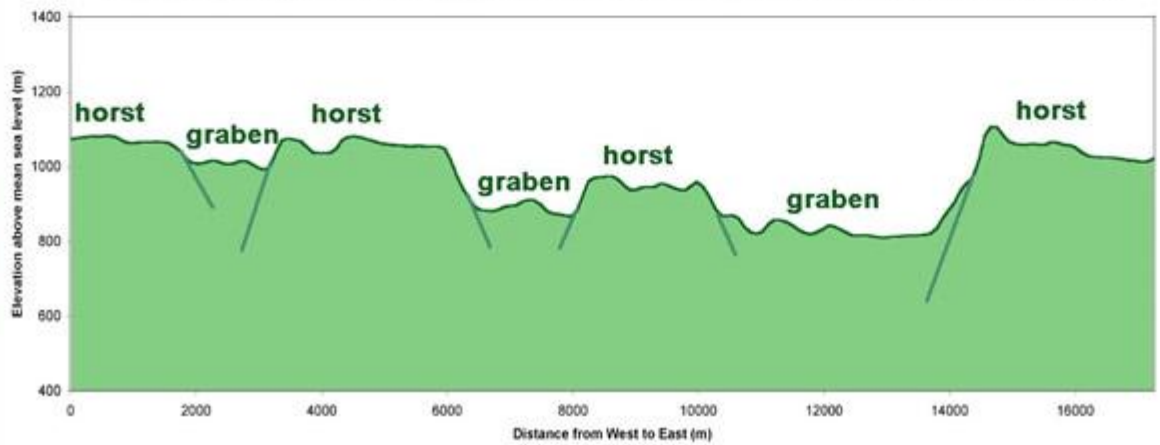
2. Layers are cut by normal faults



3. Down-dropped blocks are grabens, and upthrown blocks are horsts, note that the extension that occured.



Topographic profile along yellow line showing horst and graben structures

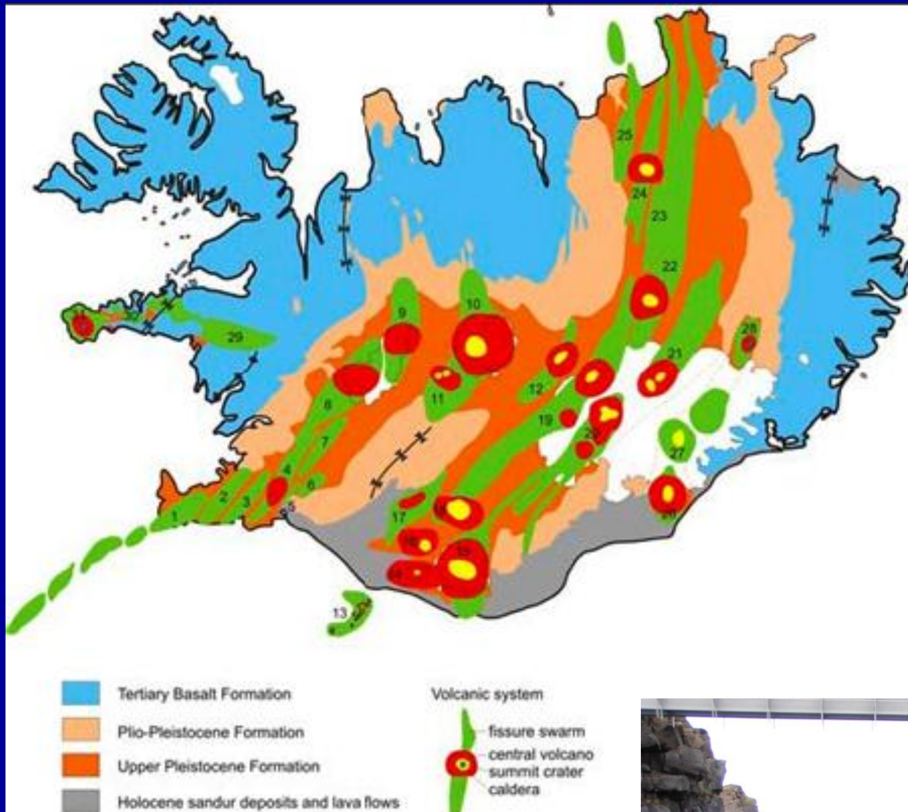


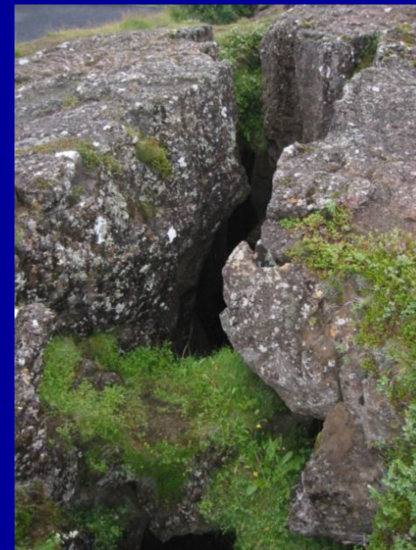
Iceland – Rift Valley

ridge represents submarine segments of the mid-ocean ridge

Image Source: http://commons.wikimedia.org/wiki/File:Iceland_Mid-Atlantic_Ridge_Fig16.gif

Iceland - shaded area shows the Icelandic Basalt Plateau, red points the migration of the hot spot and orange lines are the rifts, both active and inactive.

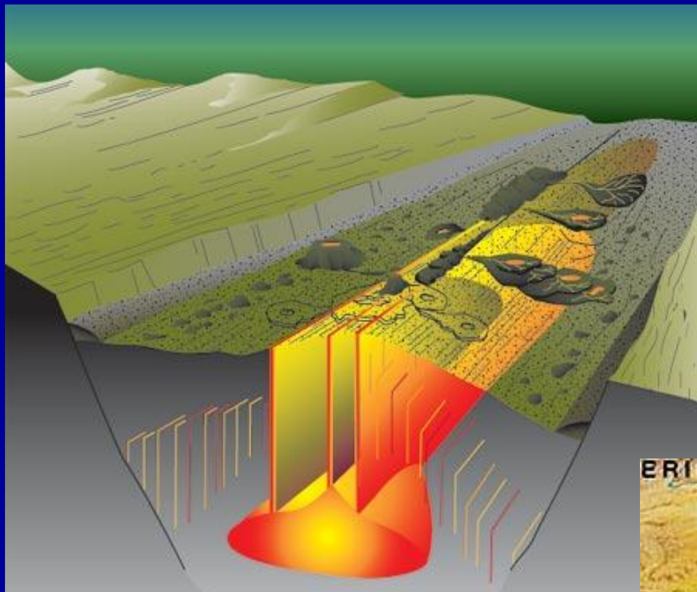




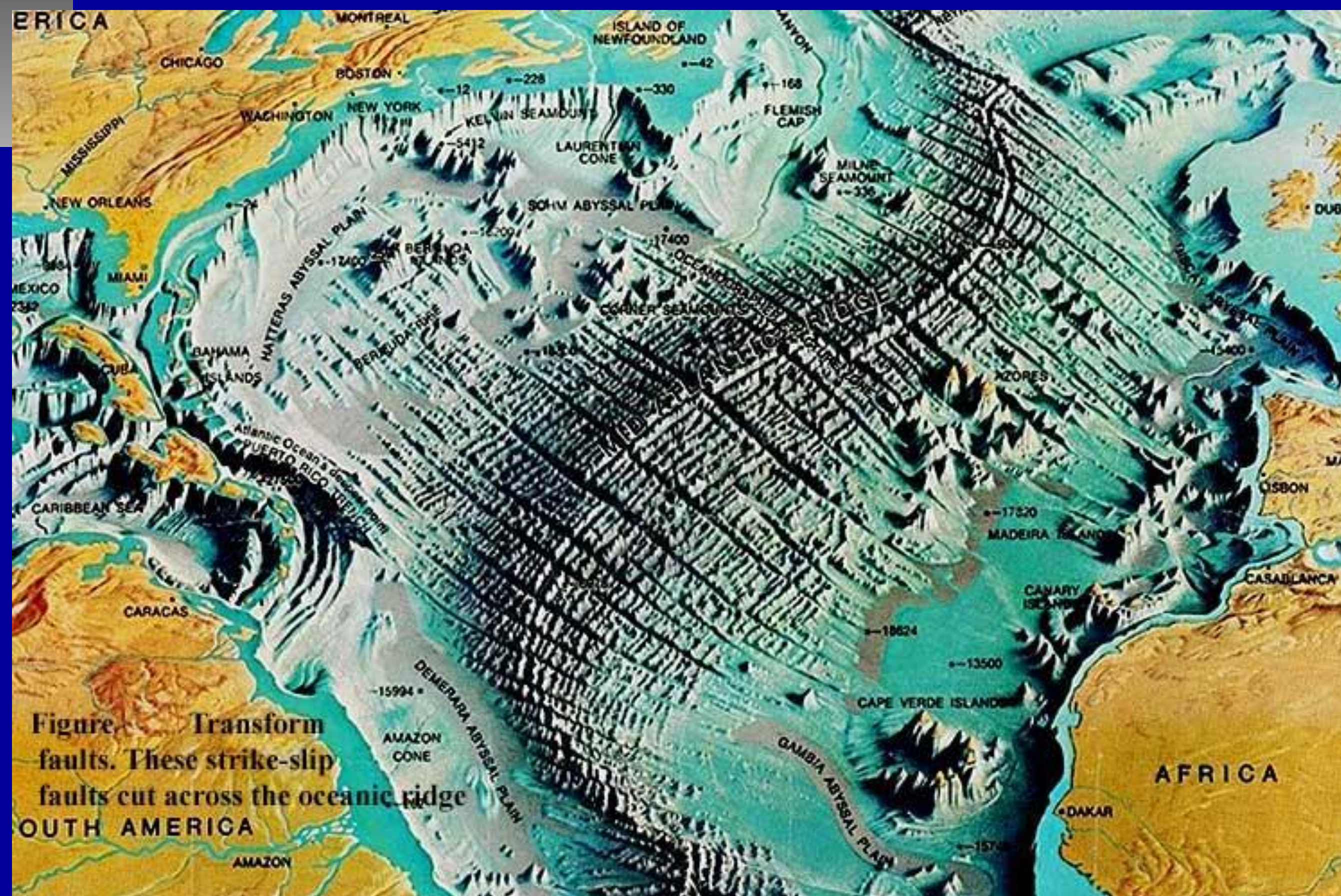
Geological map of Iceland - volcanic systems and volcanic zones and the division of the island into formations.

Each volcano with the typical lifetime of 0,5-1,5 my. Around 30 active volcanic systems in Iceland.

Rift valley, Thingvellir national park, Iceland



Ocean ridge – basaltic oceanic crust

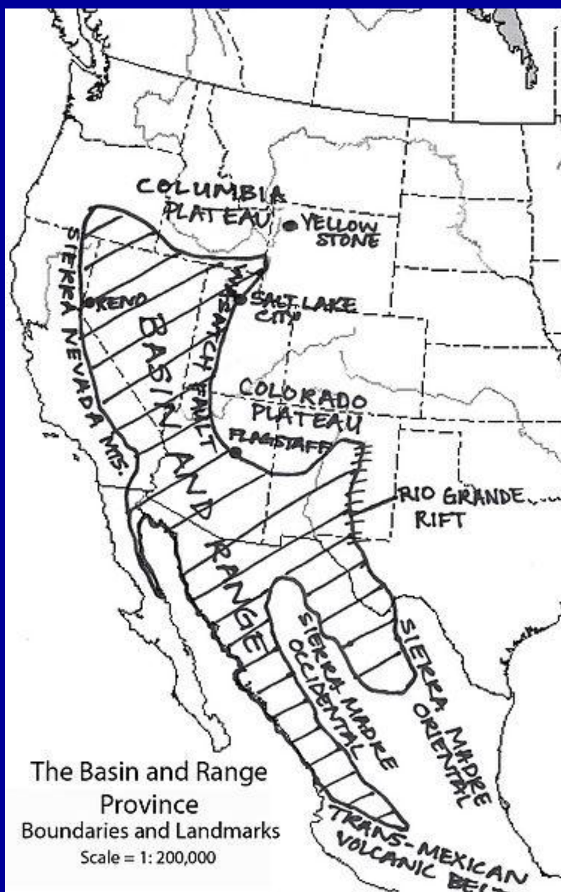


Mid-Atlantic oceanic ridge

Basin and Range topography

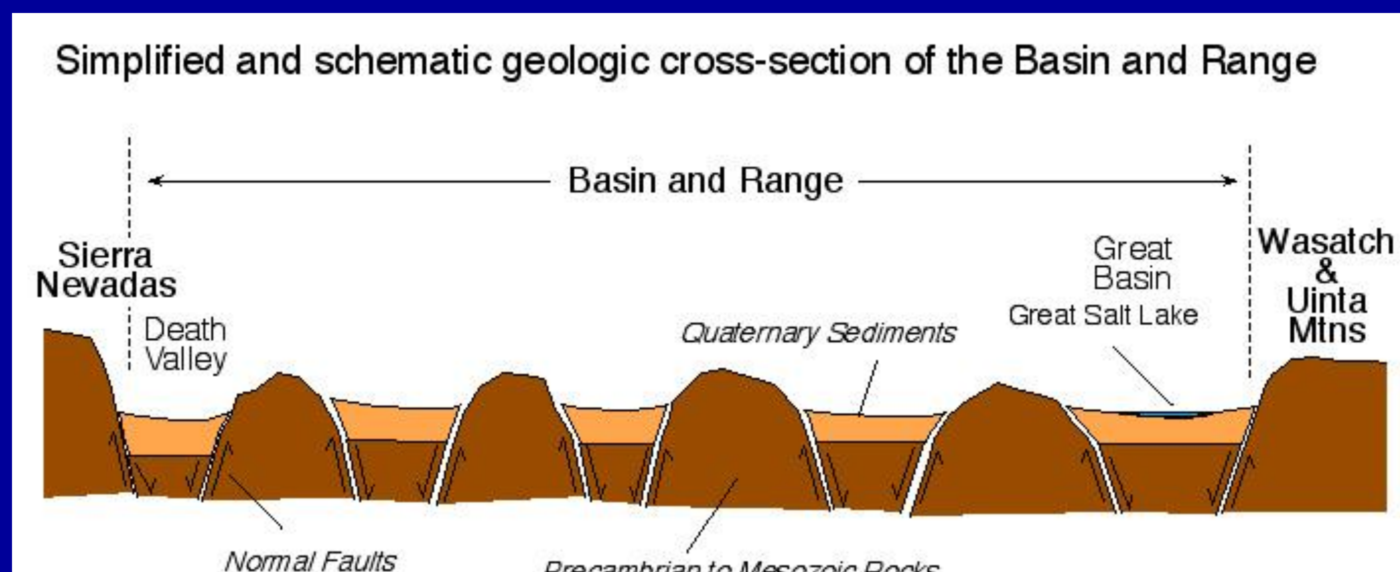
broad extensional faulting

Basin and Range Province



extension and thinning of the lithosphere, listric faults, grabens, horsts

elevated heat flow, geothermal energy

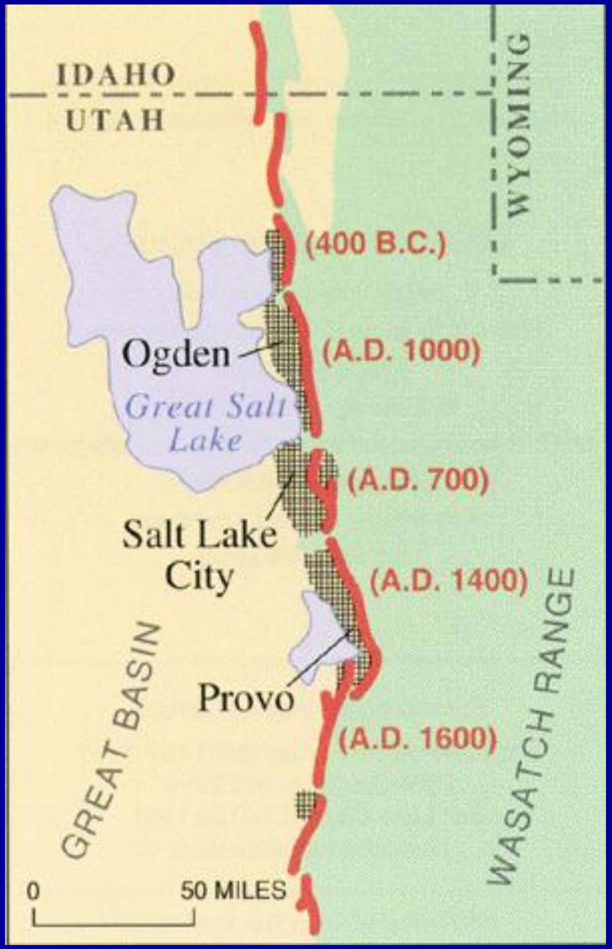


From Sierra Nevada to Wasatch Mts – 800 km

„Local scale„ normal faults

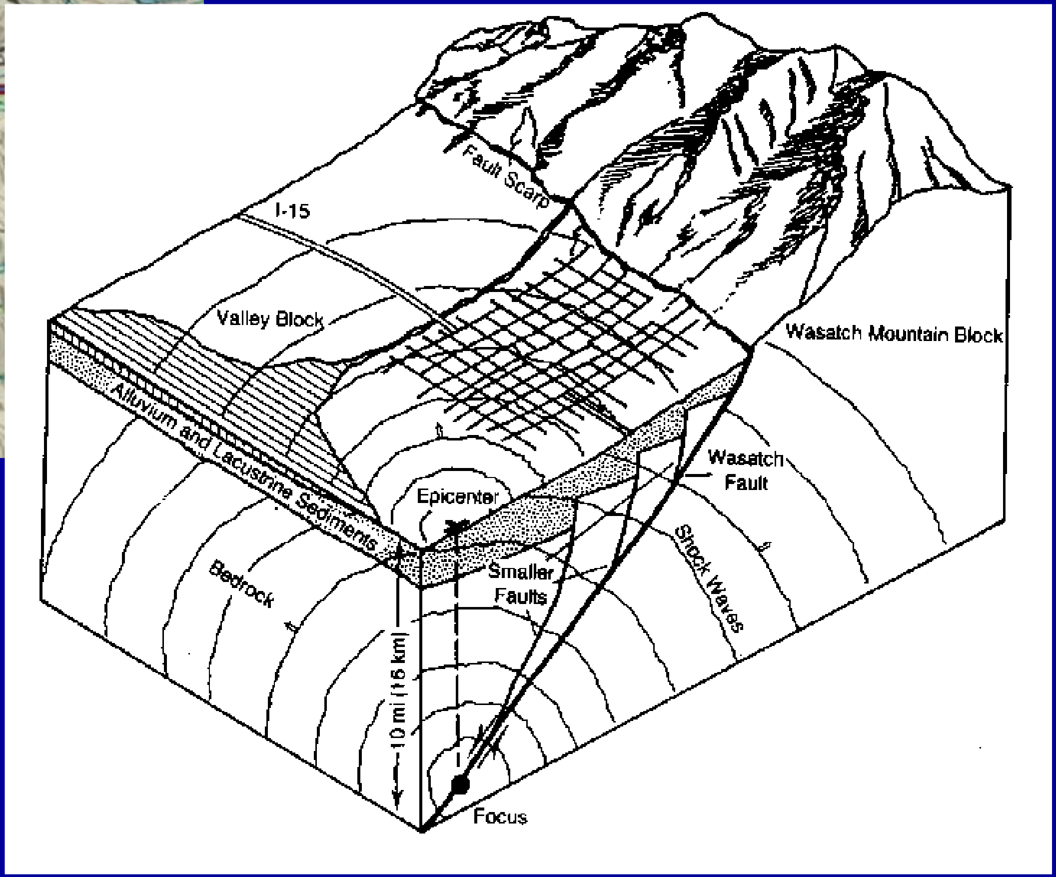
Fault trace of normal faults tends to be short 10-50 km

The **Wasatch fault**, forms the eastern boundary of the Basin and Range geologic province frontal fault are up to 400 km long, composed of separate faults or segments 30 – 60 km long, average of 40 km, each of which can independently produce earthquakes as powerful as local magnitude 7.5

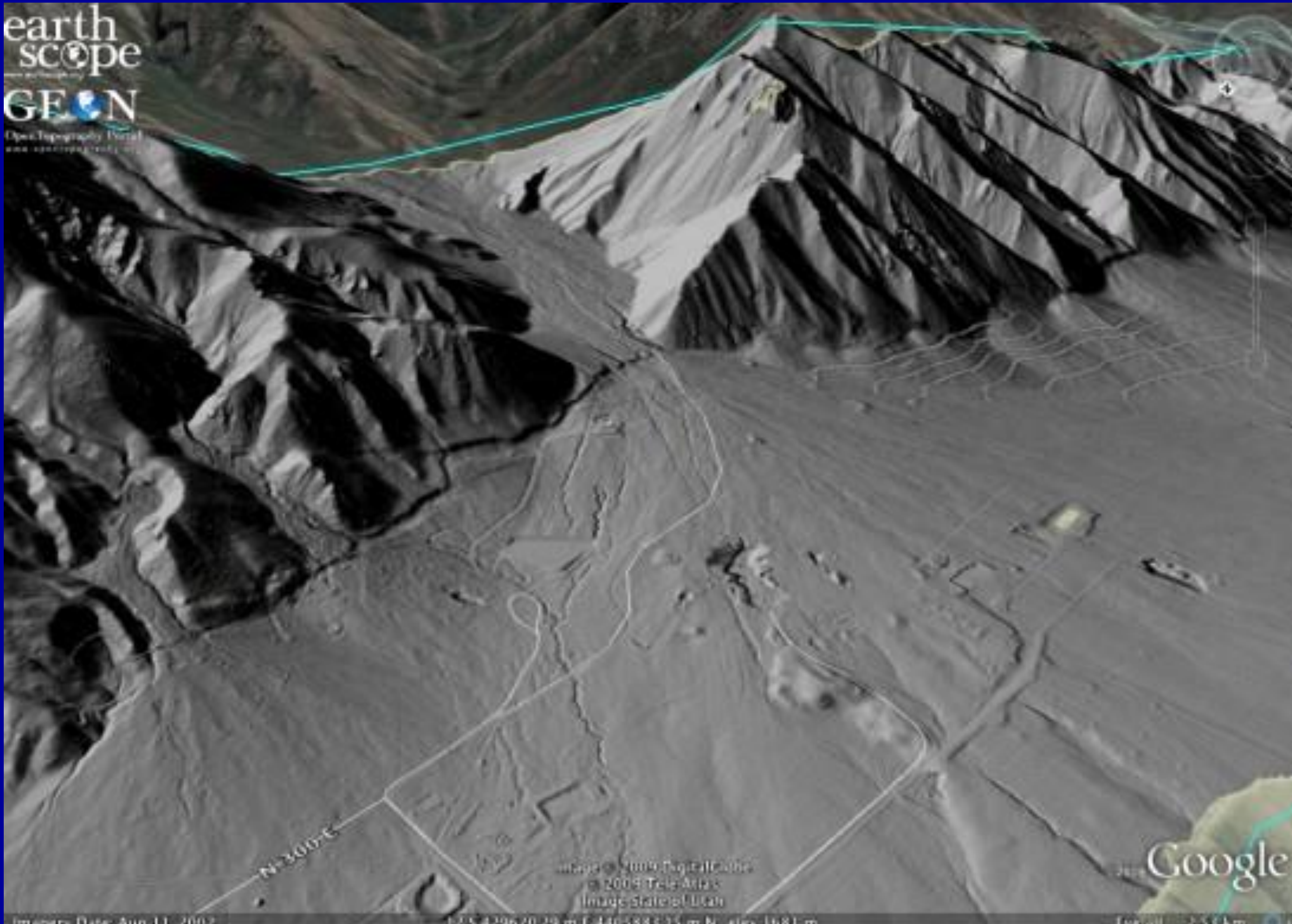


Linear mountain fronts

Linear mountaint front
- repeated earthquakes



The Wasatch Mountains have been uplifted and tilted to the east by movement of the fault. The average rate of uplift along the fault over its history is approximately 1 mm per year.



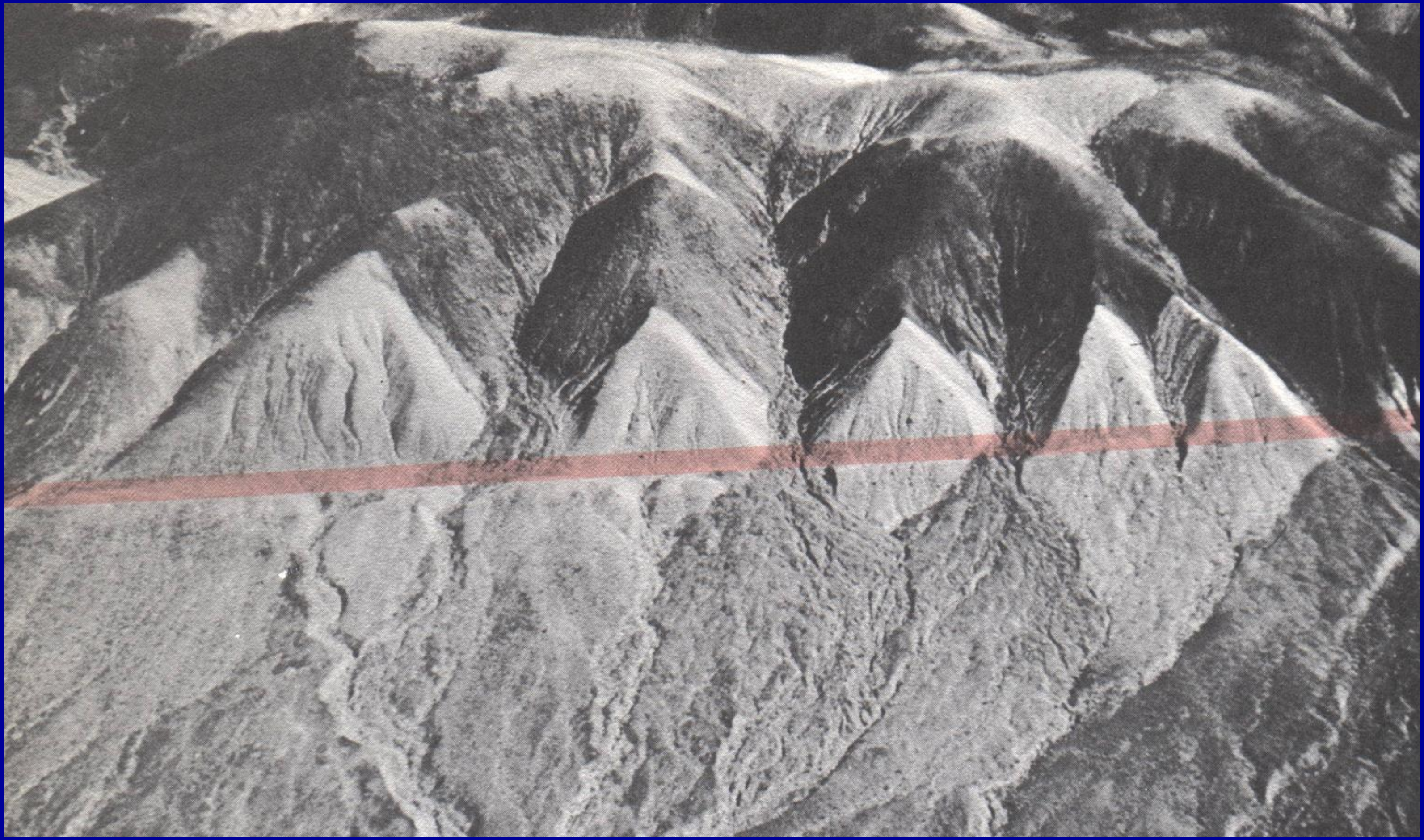
Scarp on the southern part of the Nephi strand of the Wasatch fault:

Wasatch fault

Multiple fault scarps (marked by arrows) cut across 16,000 to 18,000-year-old glacial moraines in Salt Lake County. Some of the scarps are 30 to 40m high, indicating they were formed by repeated large earthquakes (possibly as many as seven to ten events) in the past 18,000 years

Triangular (trapezoidal) facets

- dissected mountain front by rivers, setries of facets - „flatirons“

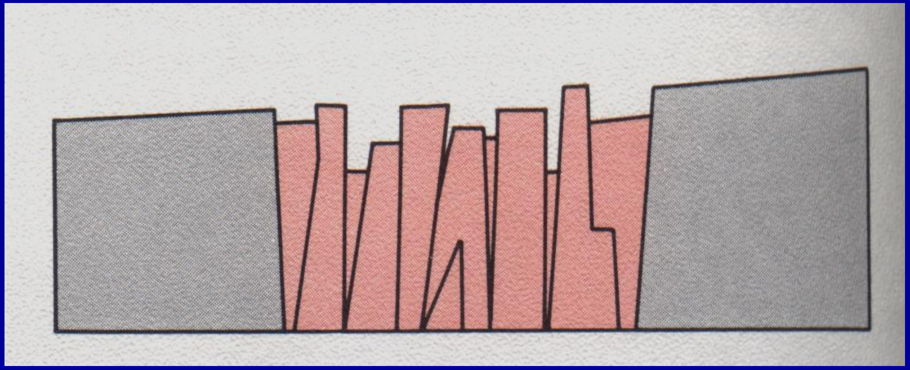


un-named fault in California, SE from Panamint Valley

Subsided blocks

Narrow block subsided between two ridges uplifted by strands of San Andrea Fault

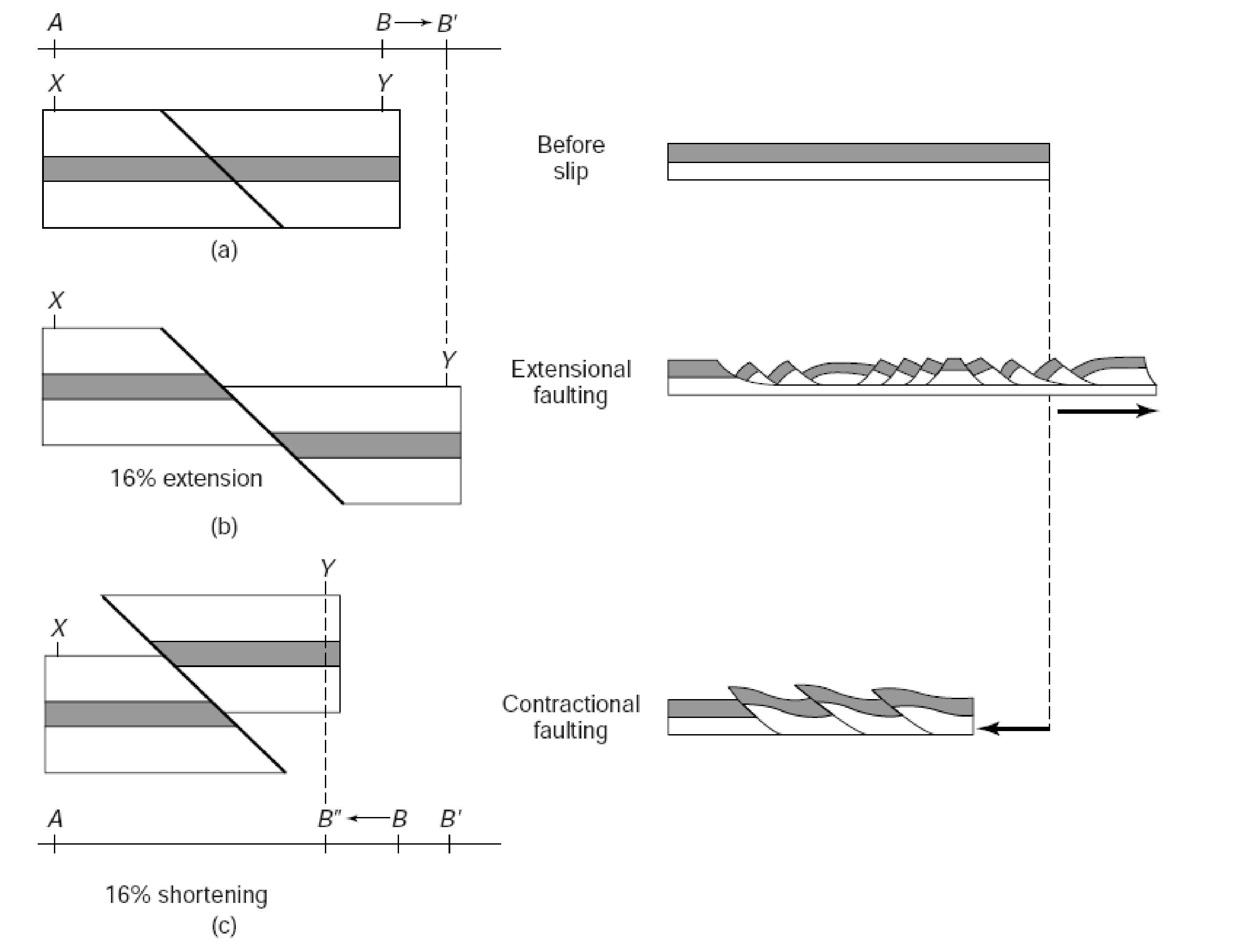
sags and ridges – by uneven blocks uplift



Crustal Shortening :
Reverse Faulting, Folding and Uplifting

Crustal shortening + thickening

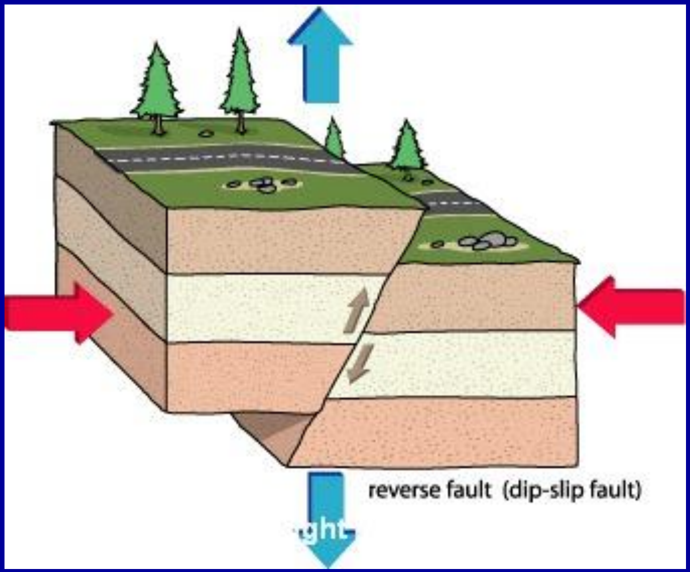
- Crustal shortening is the reduction of the size of the Earth's crust through convergent plate boundary (compression)



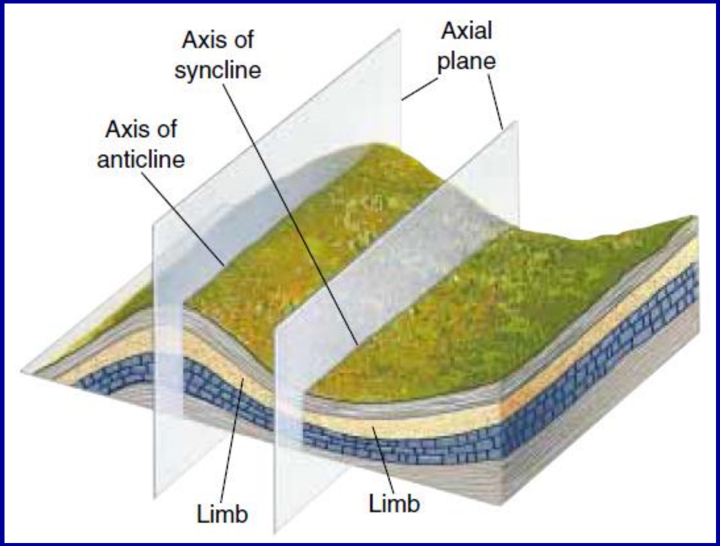
Crustal Shortening

- Implications :

  - Reverse/Thrust Fault

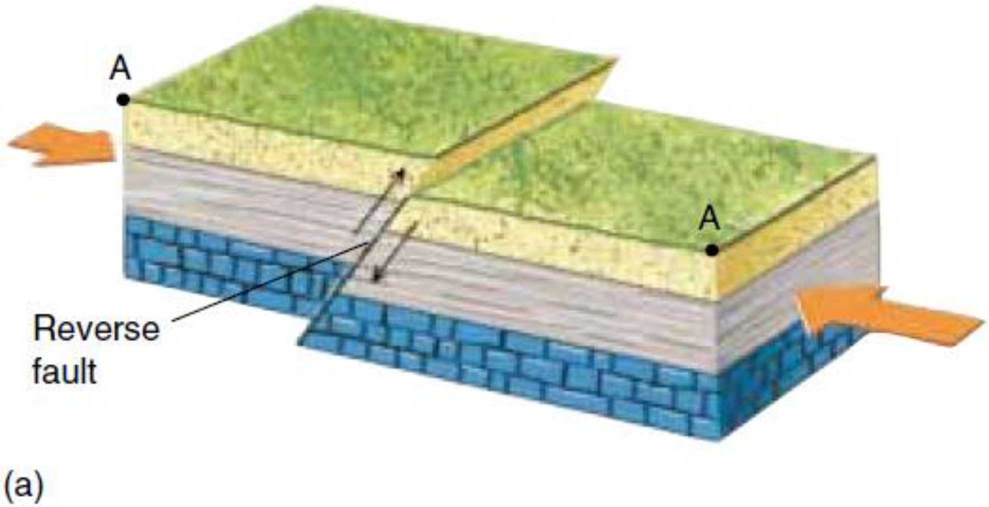


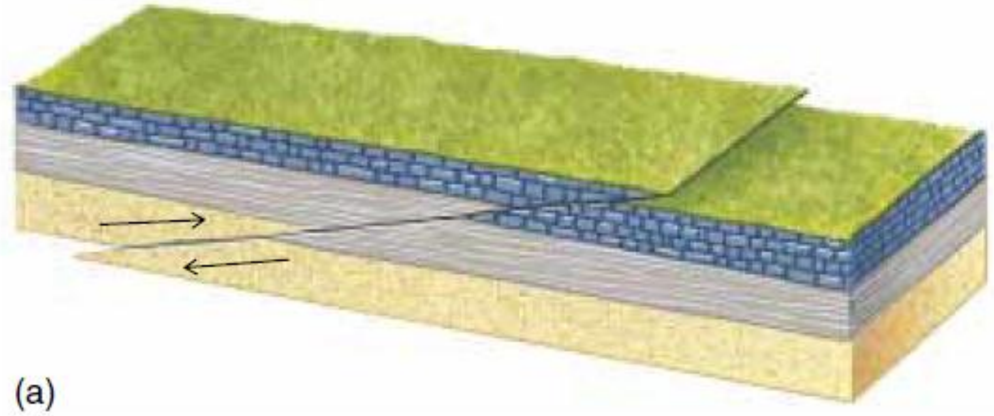
  - Fold



  - Uplift

Reverse – Thrust Fault





Reverse Fault : > 45^0

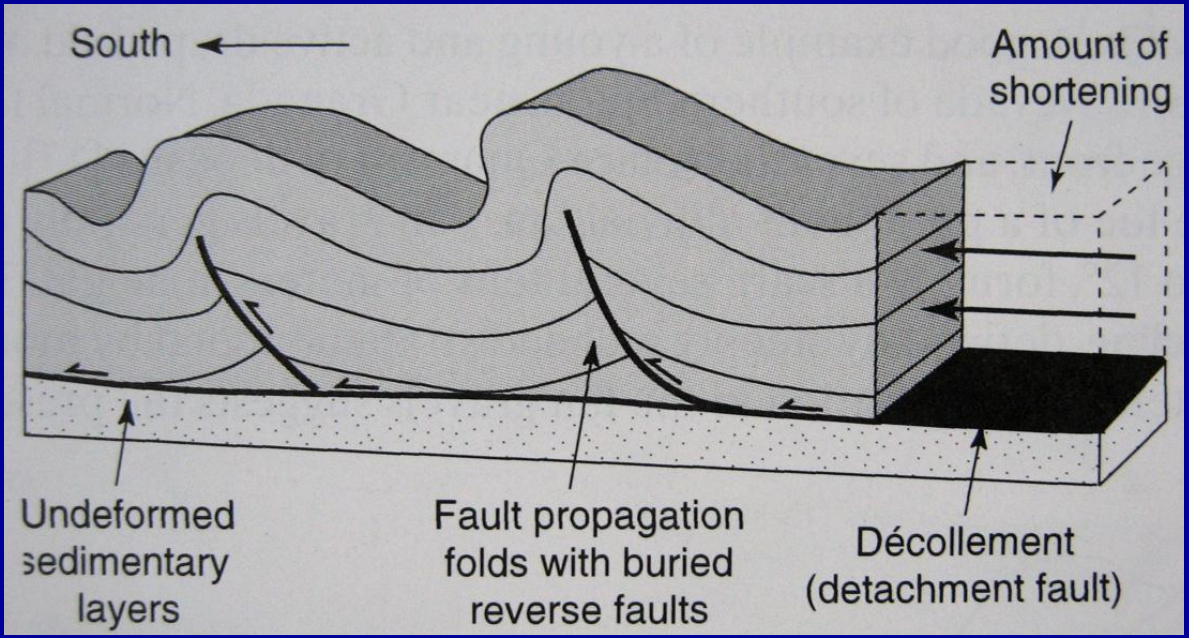
Thrust Fault : <45^0

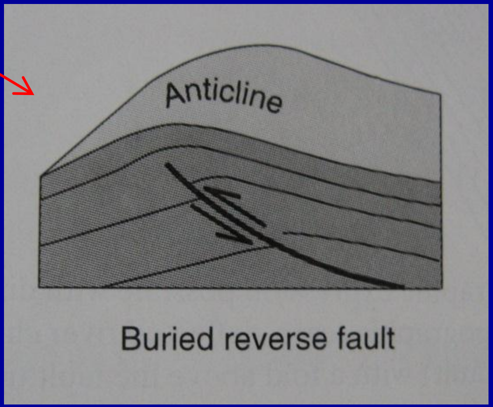
Thrust faults associated with subduction produce a variety of landforms –

- uplifted coastal terraces, anticlinal hills (upwarped) and synclinal lowlands (downwarped)

Thrust faults – often associated with fold - in **fold-and-thrust belts**

- some of the thrusts and reverse fault may **break the surface** or they remain **hidden** in the core of anticline – **blind reverse fault**





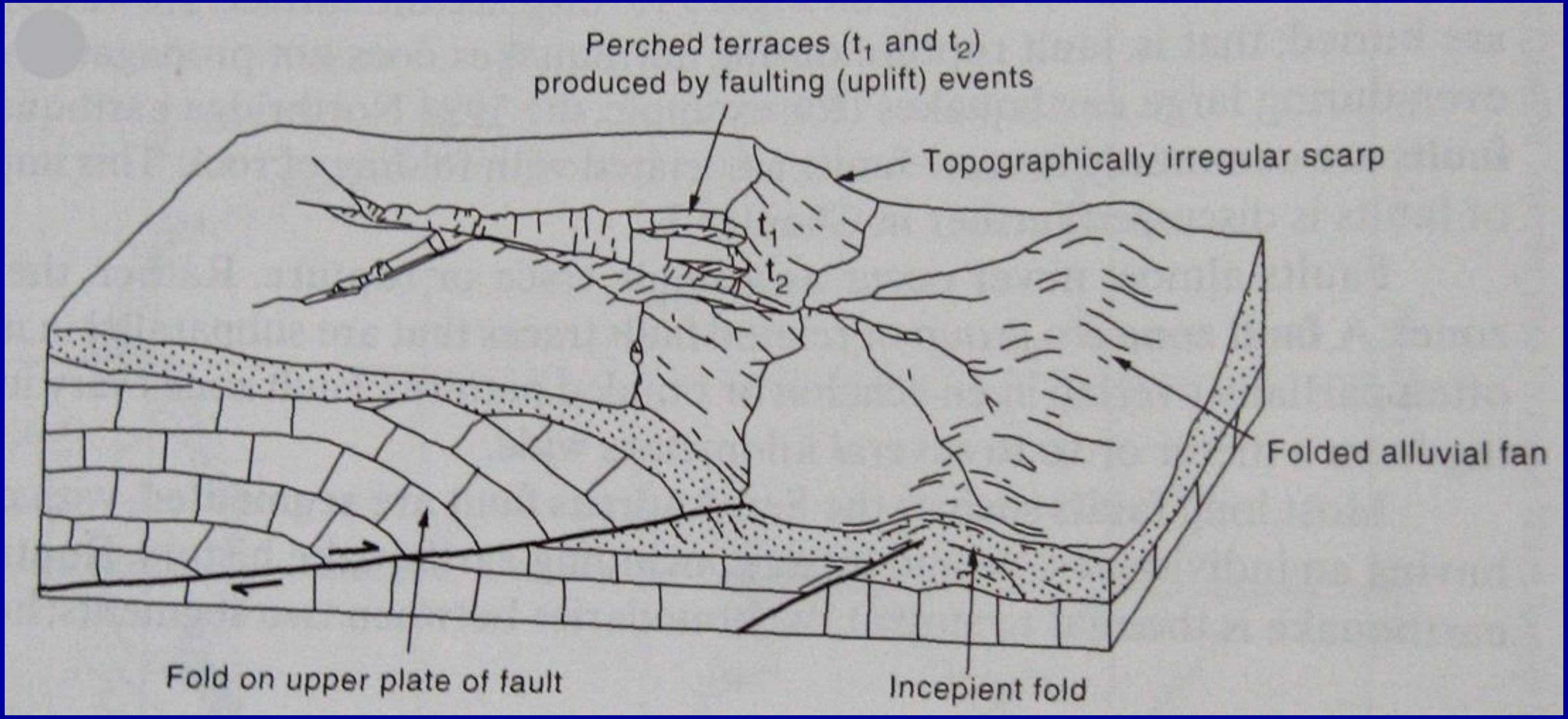
Asymmetric **fault-propagation fold** developed over a décollement

Reverse faults- closely related to folds

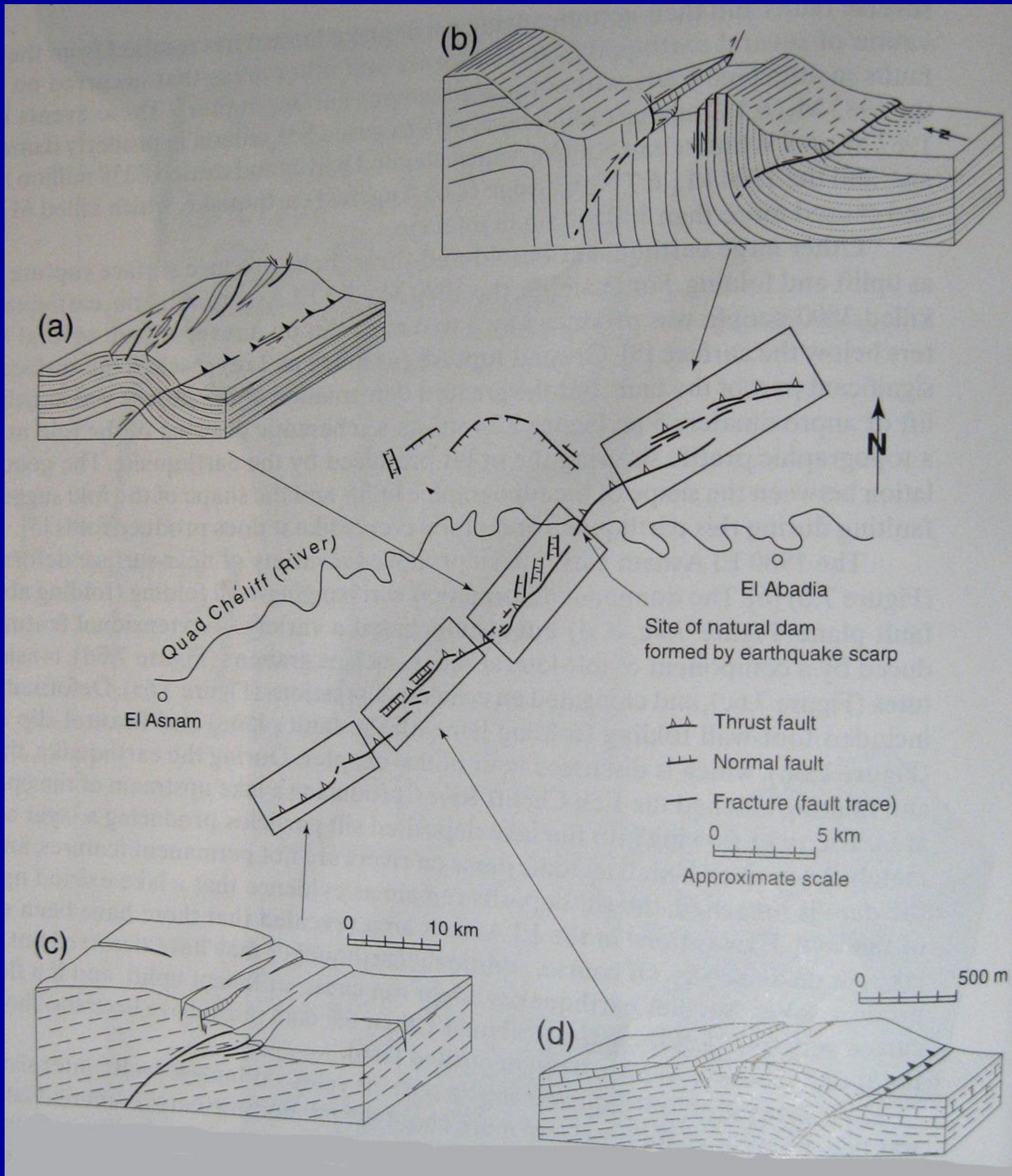
Rate of lateral propagation of faults and fold may be sveral times **higher than vertical slip rate** of the fault

Landforms associated with reverse faulting

steep mountain fronts, fault scarps, fold scarps, extensional features, and landslides

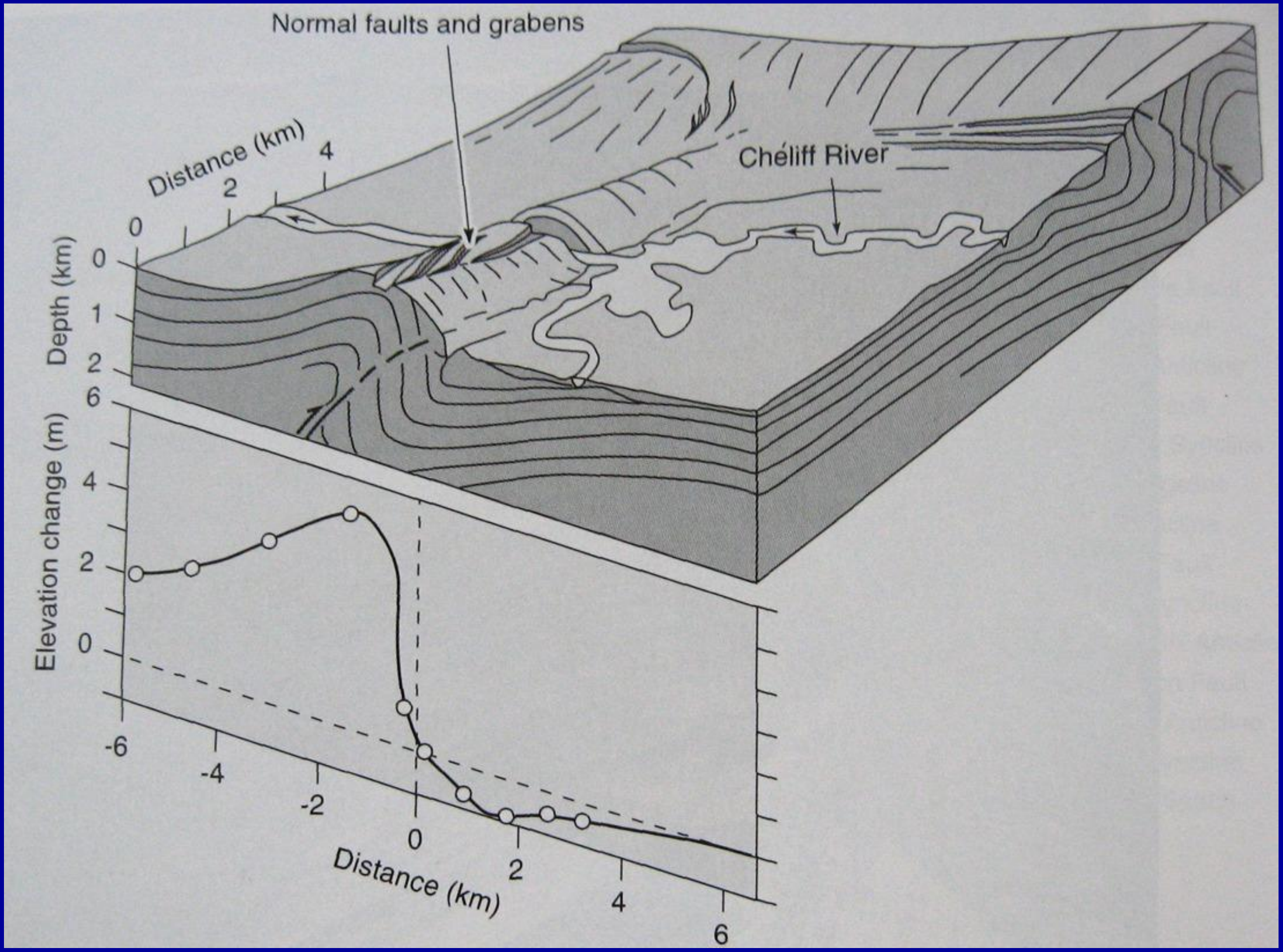


1980 EL Asnam M=7.3, Algeria – fold-and-thrust belt



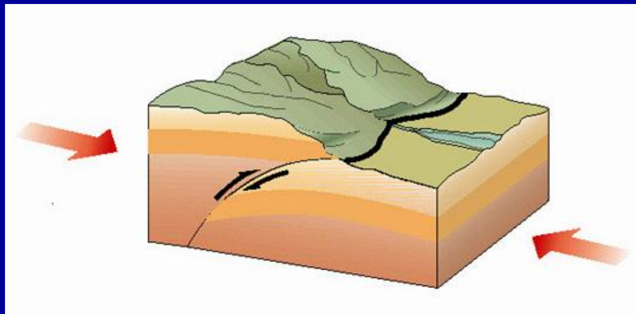
3-6 m slip on reverse fault at the depth, surface rupture - 2m
mostly anticlinal uplift of 5m
– **seismic folding**

a),b),c) hanging-wall folding
d) extensional features produced by component of left-lateral shear
c) tension fractures
a) elongated en echelon depressions
b) footwall folding and flexural-slip faulting



Graph of surface uplift produced by 1980 El Asnam EQ.
The fold was produced by repetaed earthuqakes

Bolcked river – formation of a lake with deposition of 0.4 m



Fault scarps

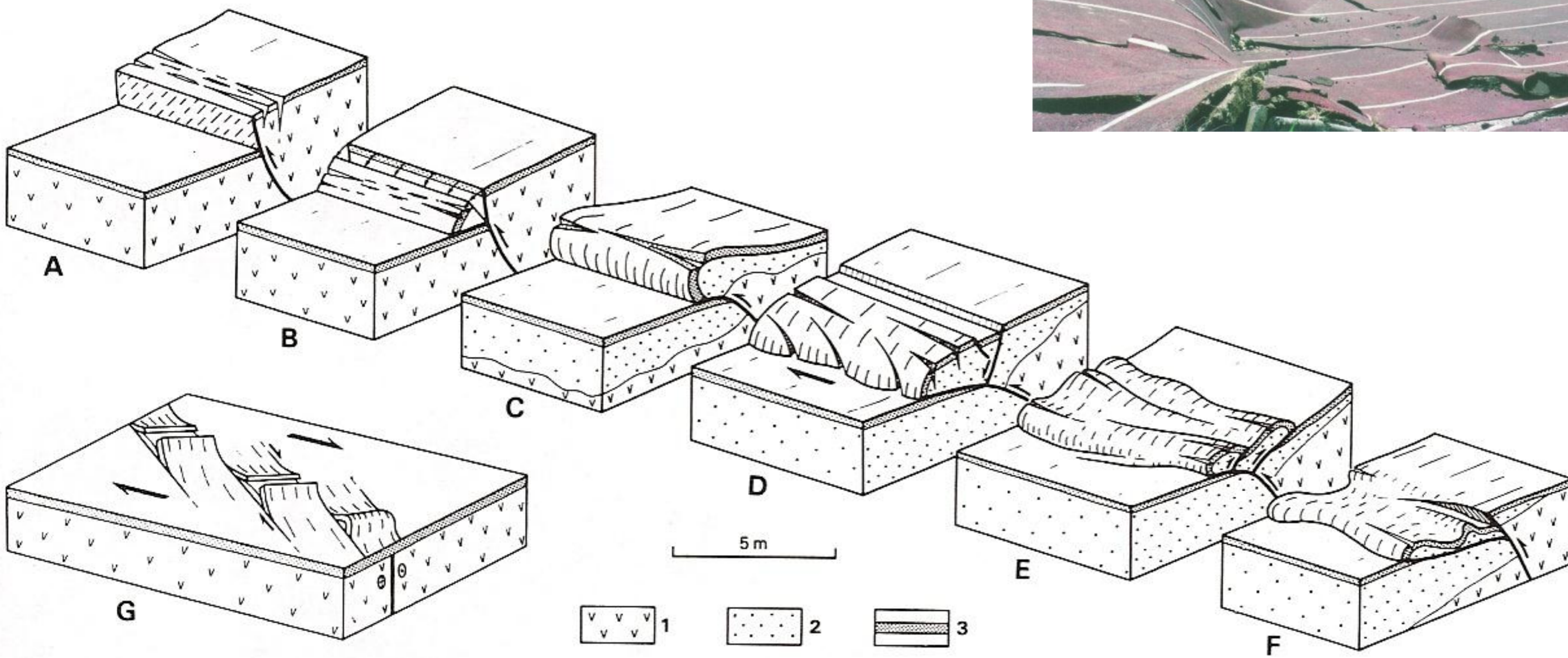


Figure 10–53. Fault-scarp features along the Spitak fault, Armenia. (a) simple thrust scarp; (b) hanging-wall collapse scarp; (c) simple pressure ridge; (d) dextral pressure ridge; (e) back-thrust pressure ridge; (f) low-angle pressure ridge: (g) en échelon pressure ridges. 1, bedrock; 2, soft Quaternary sediment; 3, turf. After Philip et al. (1992).

Fold

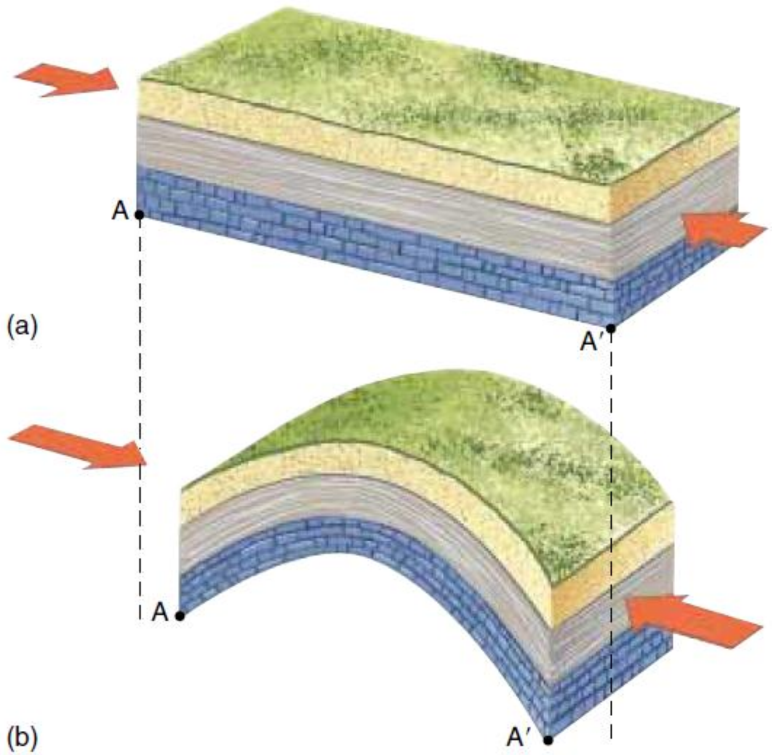
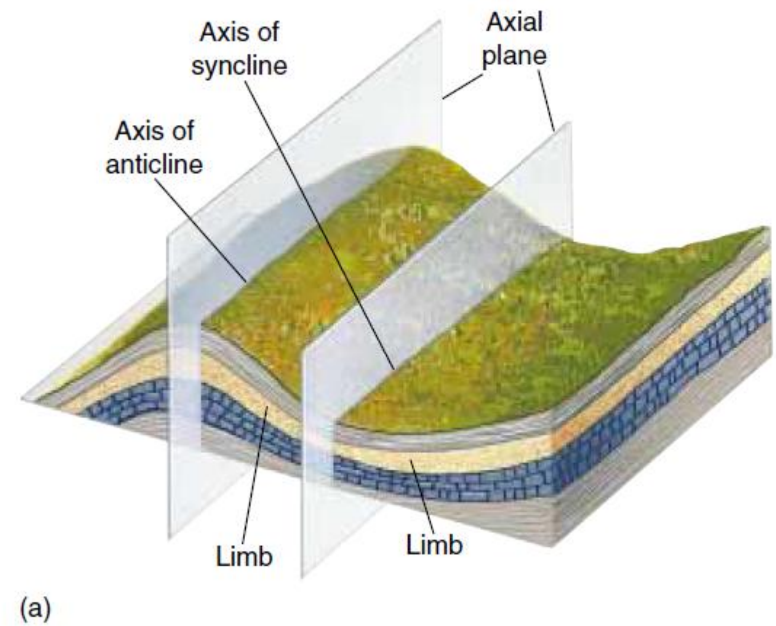
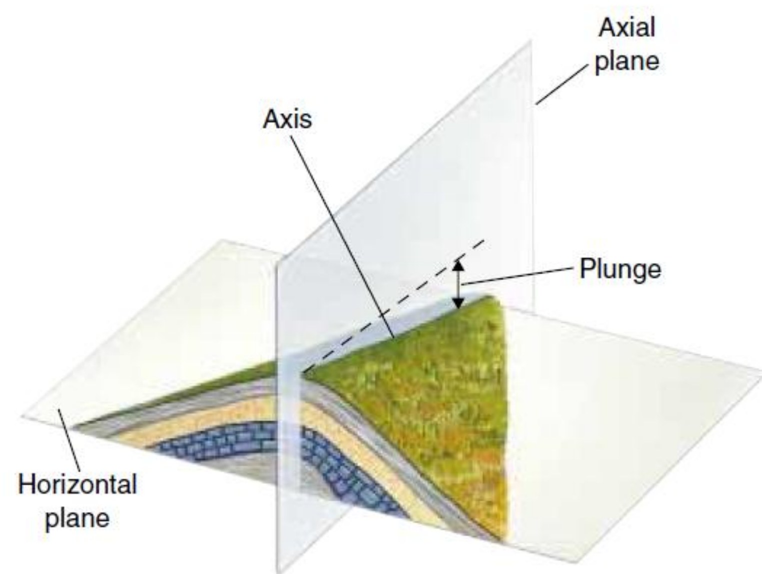
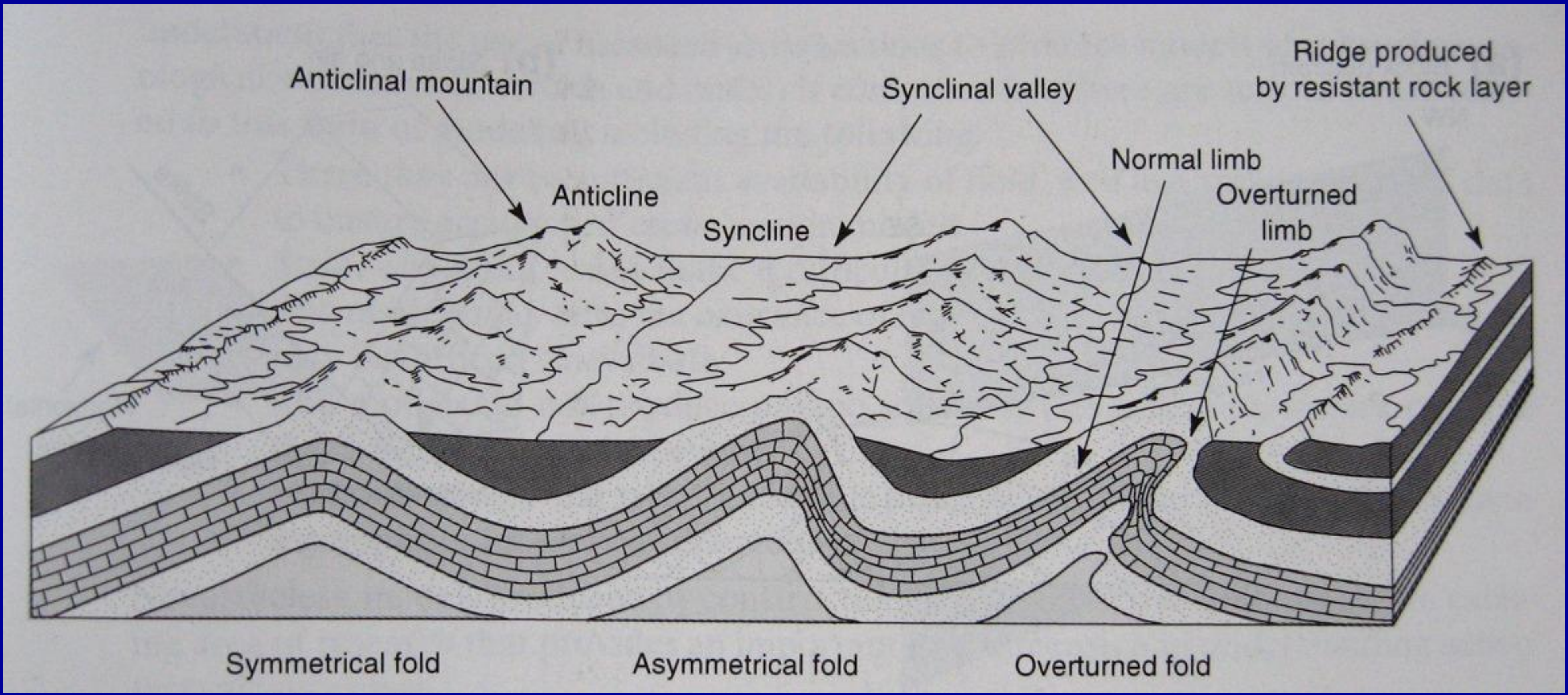


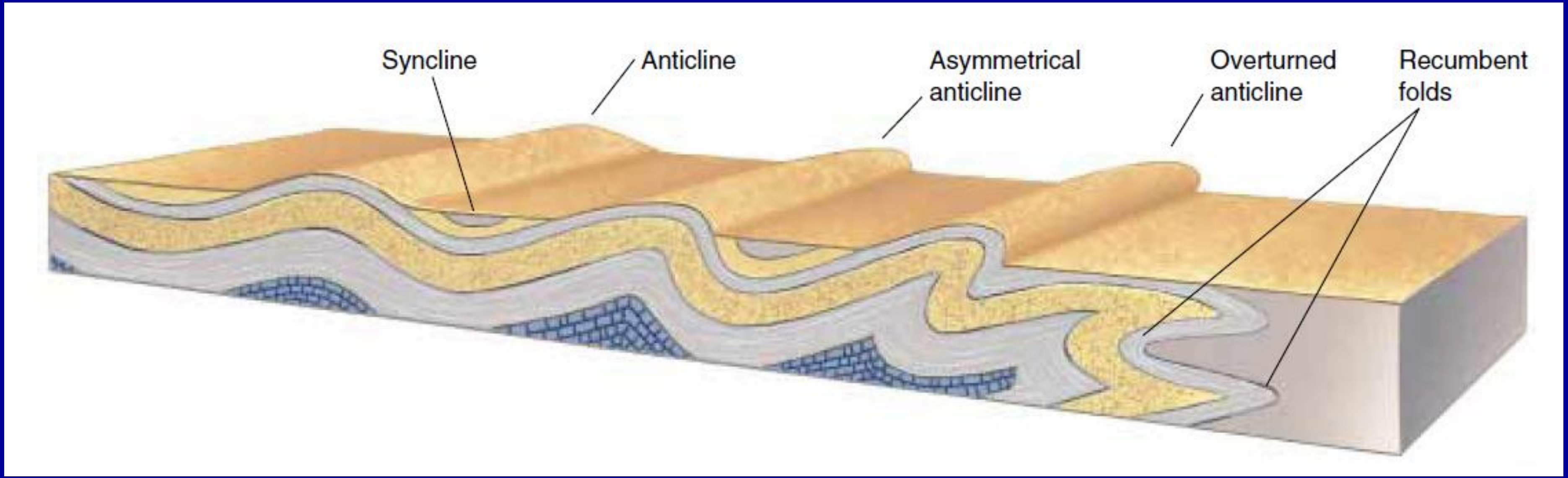
Figure 12–5 (a) Horizontally layered sedimentary rocks. (b) A fold in the same rocks. The forces that folded the rocks are shown by the arrows. Notice that points A and A′ are closer after folding.

1. Folding usually results from compressive stress. For example, tightly folded rocks in the Himalayas indicate that the region was subjected to compressive stress.
2. Folding always shortens the horizontal distances in






Anticlinal mountain
Synclinal valley
Ridge produced by resistant rock layer
Anticline
Syncline
Normal limb
Overturned limb
Symmetrical fold
Asymmetrical fold
Overturned fold


Syncline
Anticline
Asymmetrical anticline
Overturned anticline
Recumbent folds

Thompson and Turk, 1998

FIGURE 10.7 An asymmetric, plunging fold (the Sheep Mountain Anticline in Wyoming, USA).