Tvary reliéfu na základě různých typů pohybů

Změny v reliéfu vyžadují změny v reliéfotvorném procesu (např. náhlé zvýšení sklonu - ? Tektonický nebo sedimentologický proces??)

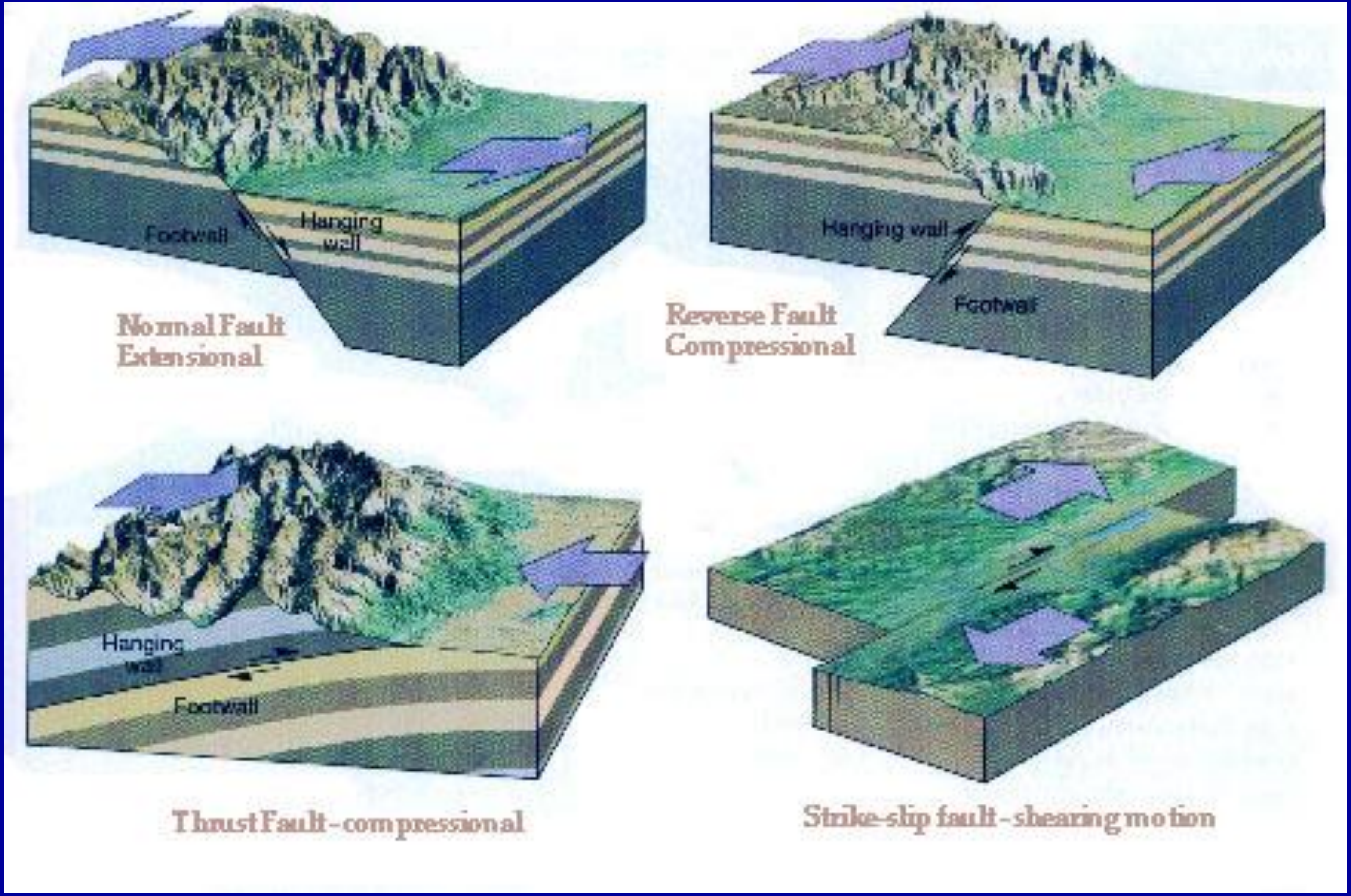
Tektonická geomorfologie - hledání **morfologických anomálií** – deformace vyklenutí povrchu, úklon povrchu, porušení trhlinami,

Některé charakteristiky indikují přítomnost zlomů, ale málo říkají o jeho aktivitě či typu pohybů

Lineární uspořádání vegetace, pramenů, zlomových svahů, ostatní lineamenty

Zlomy

3 typy zlomů – v různých napěťových režimech: poklesové zlomy (normal fault), přesmykové zlomy (reverse fault), zlomy s horizontálním posunem (strike-slips);



Opakovaná zemětřesení nebo creep – vytváření reliéfu

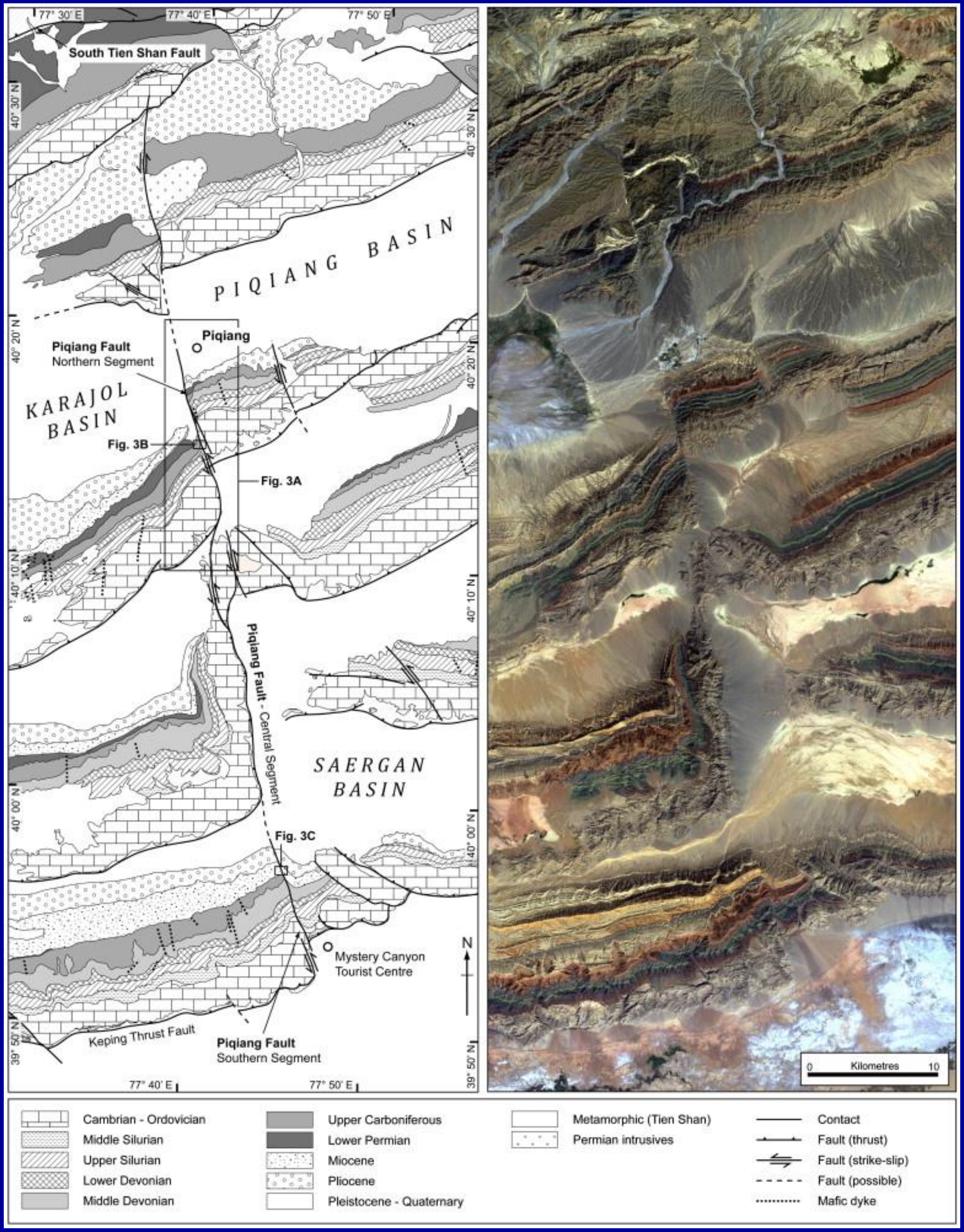
video

normal fault (pokles)

thrust fault (násun)

reverse fault (přesmyk)

Strike-slips

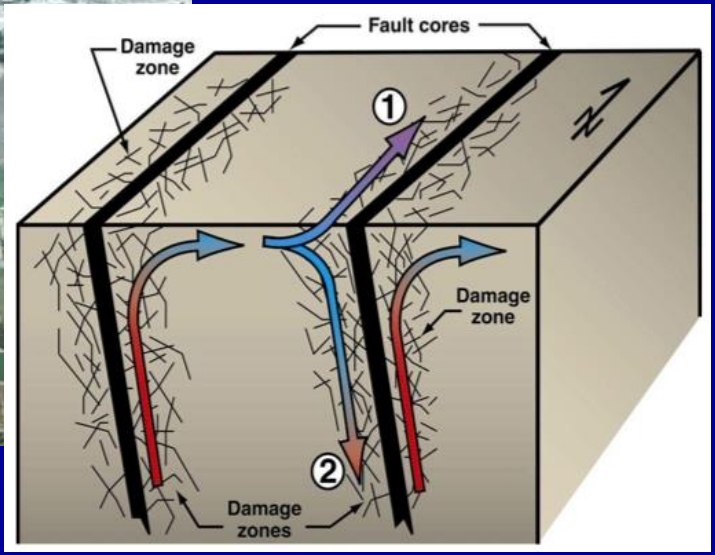


San Andreas fault

Piqing fault

Narušení toků podzemních vod - všechny typy zlomů

- Prameny – tektonický jíl (fault gouge) může být efektivní bariérou



Gilman Hot Springs, San Jacinto Valley

- Lineární uspořádání vegetace (aridní oblasti)

San Andreas Fault - Thousand Palms Oasis, Indio Hills, California

Zlomový svah (fault scarp) – všechny typy zlomů, všechna měřítka

Northward across Coyote Creek Fault, San Jacinto Fault Zone

Scarp on Strike-Slip (oblique slip)

Mladý scarp

Carboneras fault, Spain

Coyote Mts, Elsinore fault, CA

Scarp na poklesovém zlomu

Krupnik fault, Bulgary, 1904 M=7,8

Scarp na přesmyku

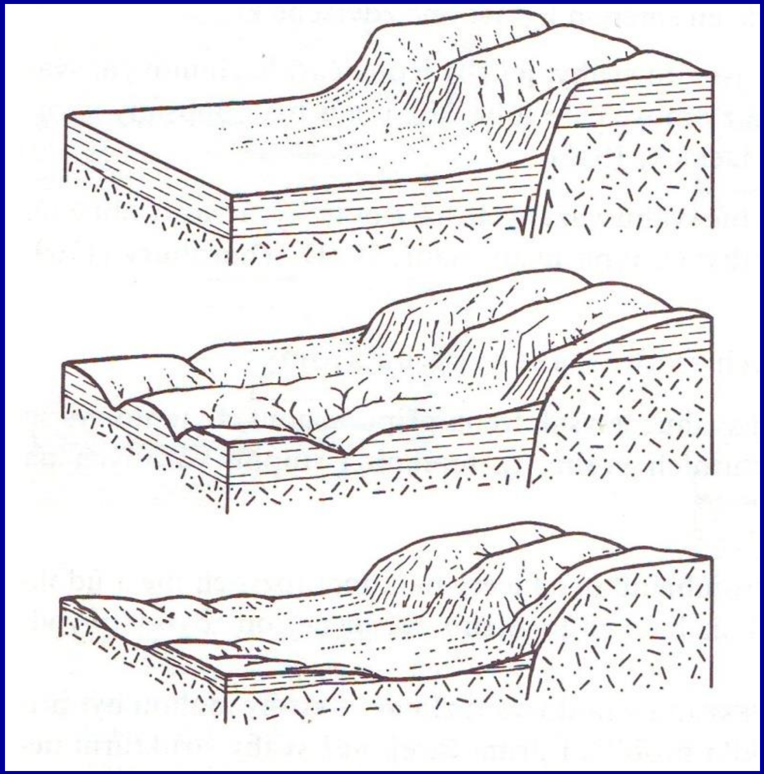
Chichi earthquake 1999, Taiwan

Aktivní nebo neaktivní?

- Selektivní zvětrávání podél neaktivních zlomů může produkovat tvary připomínající tvary na aktivních zlomech
  - Lineární uspořádání vegetace,
  - Lineární údolí
  - Scarps / stupně ve svahu

“**Fault-Line Scarps**”

(svah na zlomové čáře)



Někdy tyto tvary jsou vázané na selektivní erozi na zlomu a nikoliv na aktivní pohyby

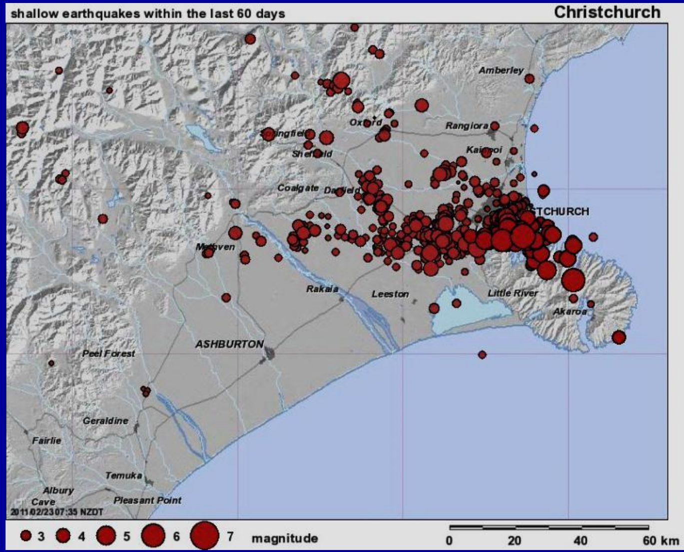
Některé tvary reliéfu jasně indikují **mladou aktivitu** (svrchní pleistocén - holocén)

•Tvary reliéfu vázané na pohyb na zlomu stále vidět v morfologii,
- pravděpodobně aktivní zlom (pokud nevznikl selektivní erozí)

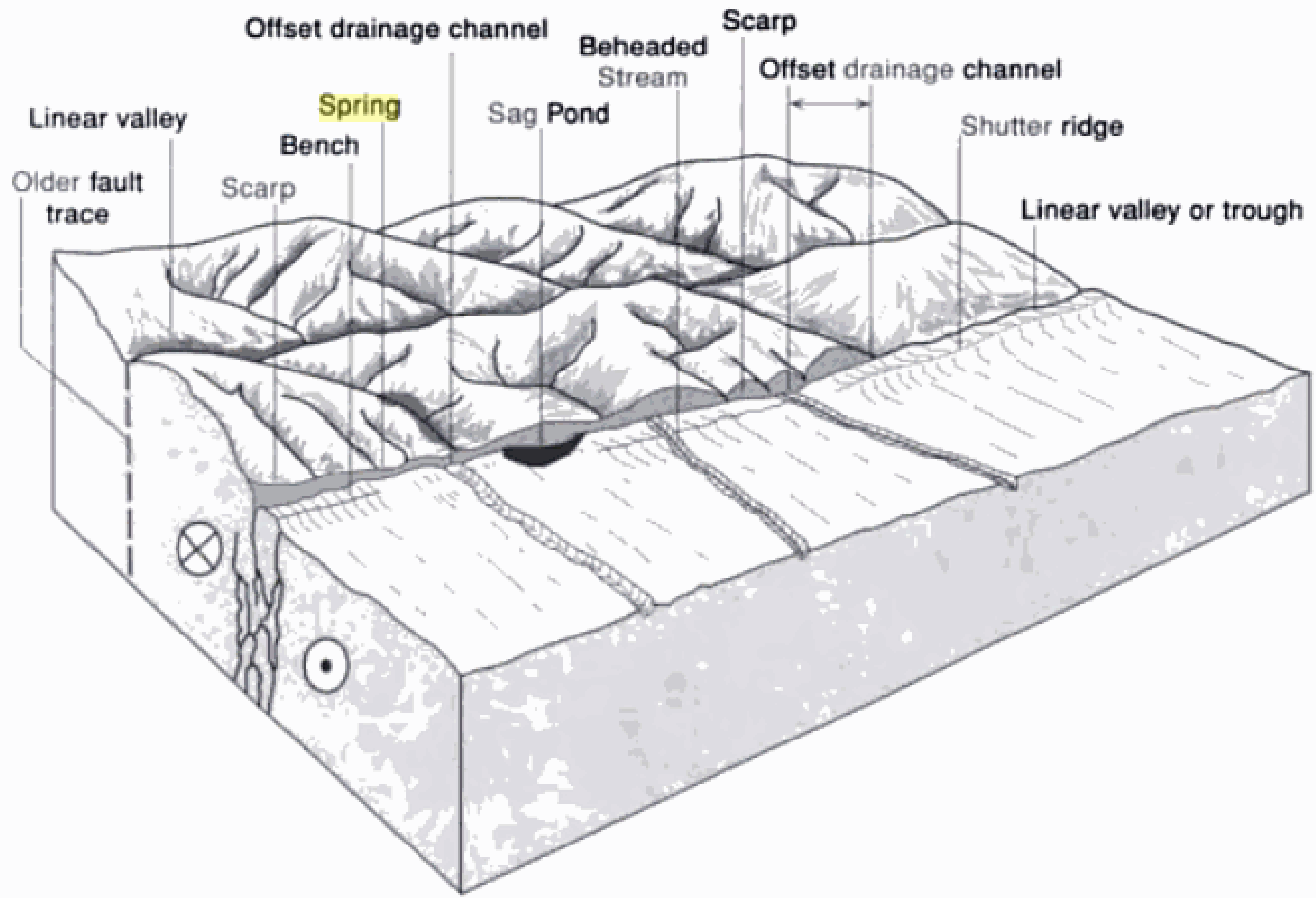
- scarps v aluviu, deflected drainages, sags, shutter ridges, side-hill bench

Obecné pravidlo – aktivní zlomy produkují aluvium, které tak zlomy pohřbívá, lokálně doklady aktivity maskovány

Christchurch EQ 21.2. 2011, M = 6.3, NZ
-**neznámý zlom, výzdvih Jižních Alp**
– 10mm/r = vysoká rychlost sedimentace, zamaskování průběhu zlomu



Aktivní strike-slipový zlom - tvary



A linear trough along fault, sag ponds, shutter ridges, offset ridges and drainages, springs, scarps and beheaded streams are typical geomorphic features indicative of strike-slip faulting. The older, abandoned fault trace displays analogous, but more erosionally degraded features. Modified after Wesson et al. (1975).

Burbank and Anderson, 2001

Účinky na údolích

Offsets

- Původně lineární, nyní zakřivený tok jako výsledek posunu (displacement/offset)
- Zakřivení toku musí být souhlasné se smyslem pohybu!

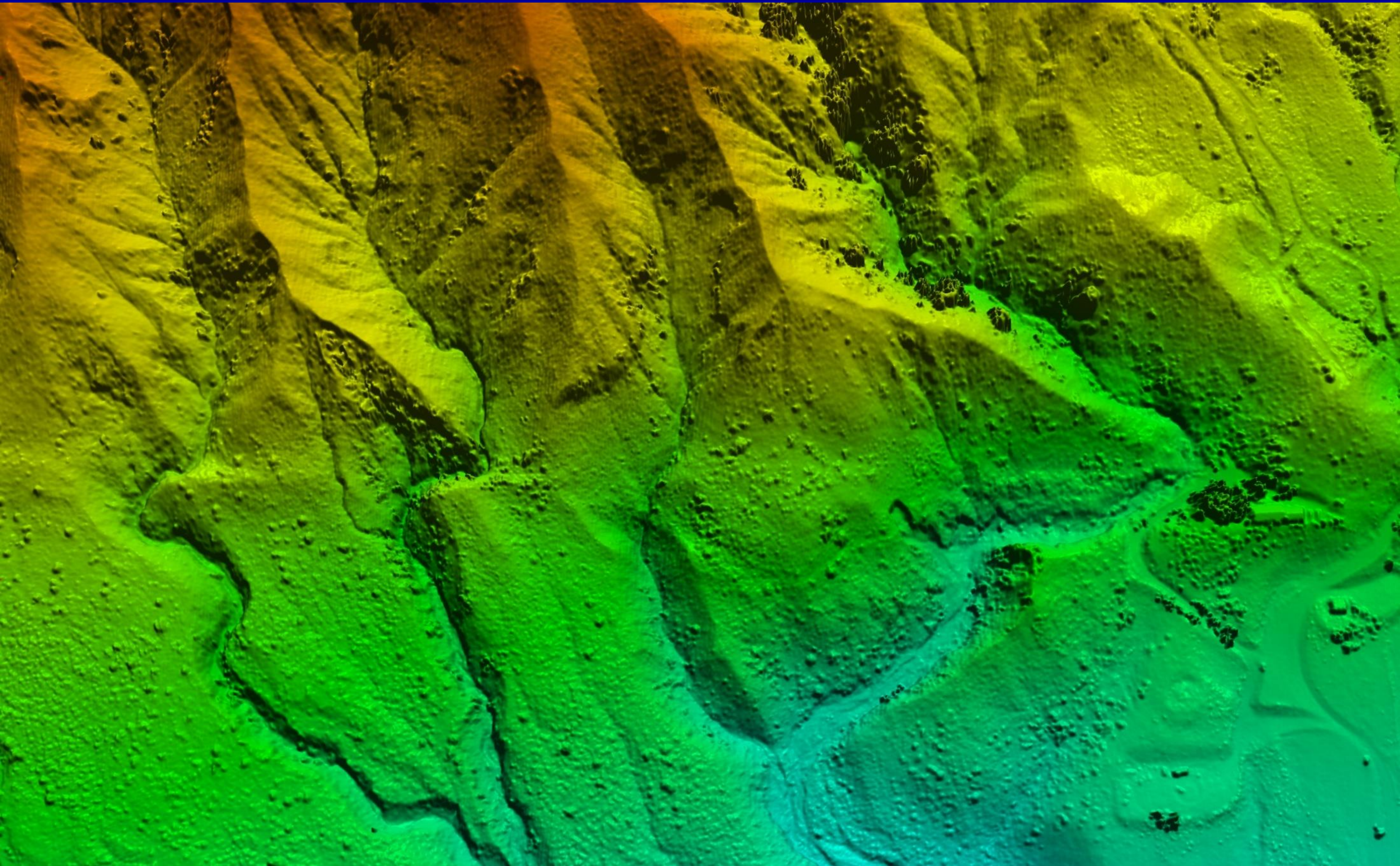
Deflections

- Zakřivení údolí může, ale nemusí být v souladu se smyslem pohybu
- Výsledek načepování (náplavový kužel) – voda teče nejjednodušší cestou)

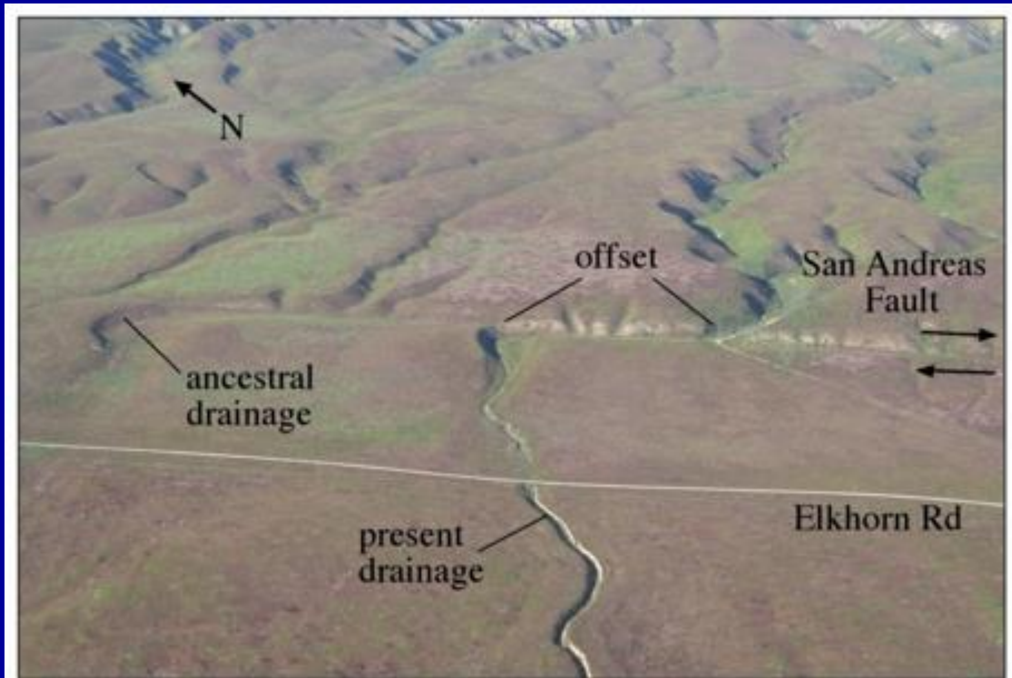
Všechny offsety jsou deflekcí, ale ne všechny deflekce jsou zároveň offsety!

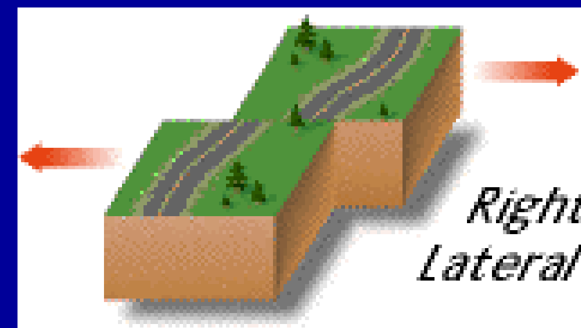
Offset channels

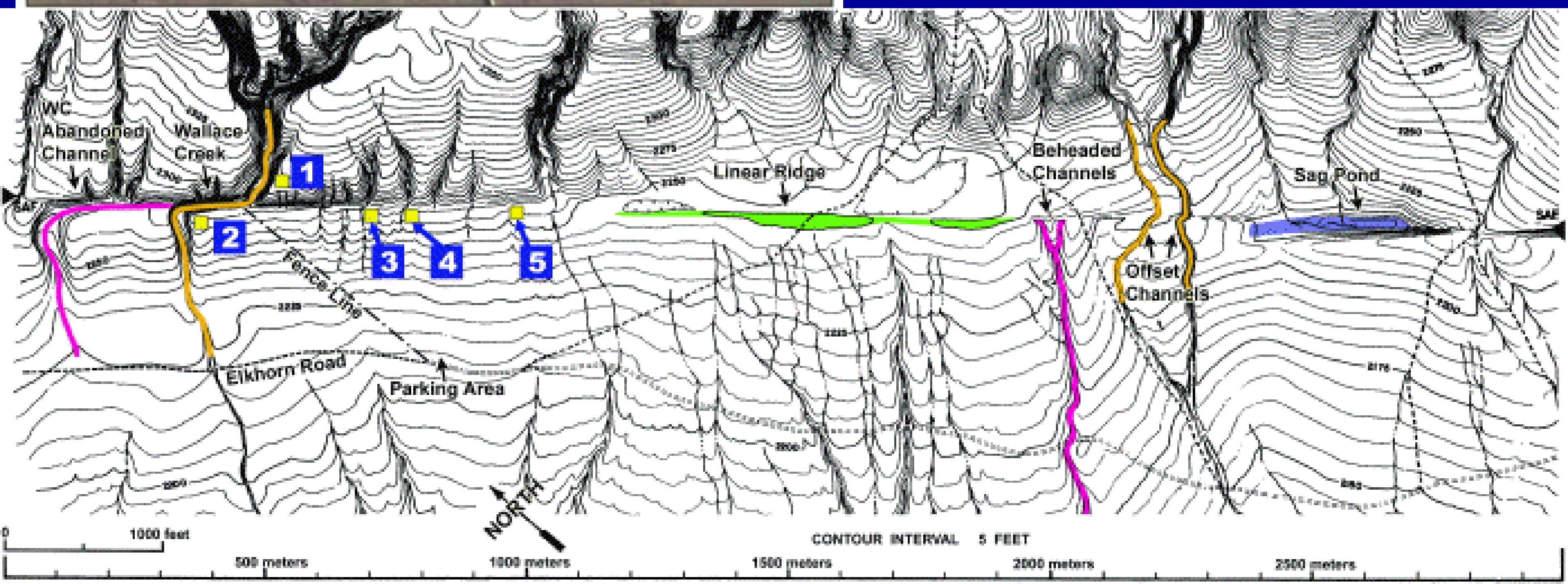
Pitman Canyon ~ 46 m offsets



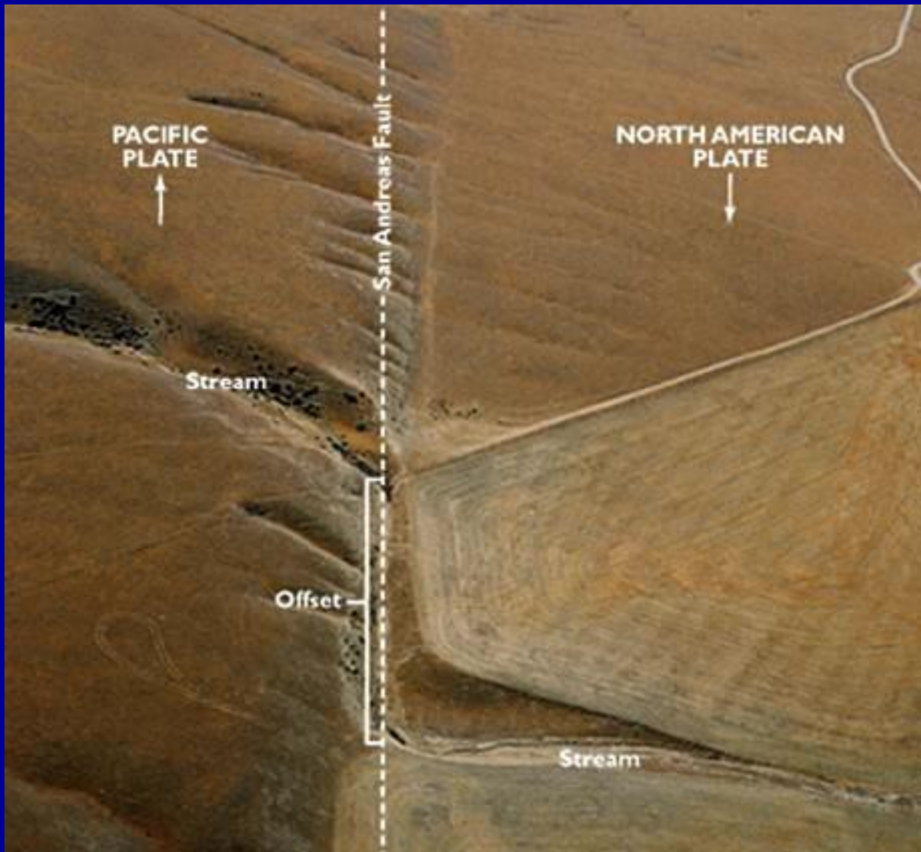
San Andreas Fault,
Carrizo plain, CA



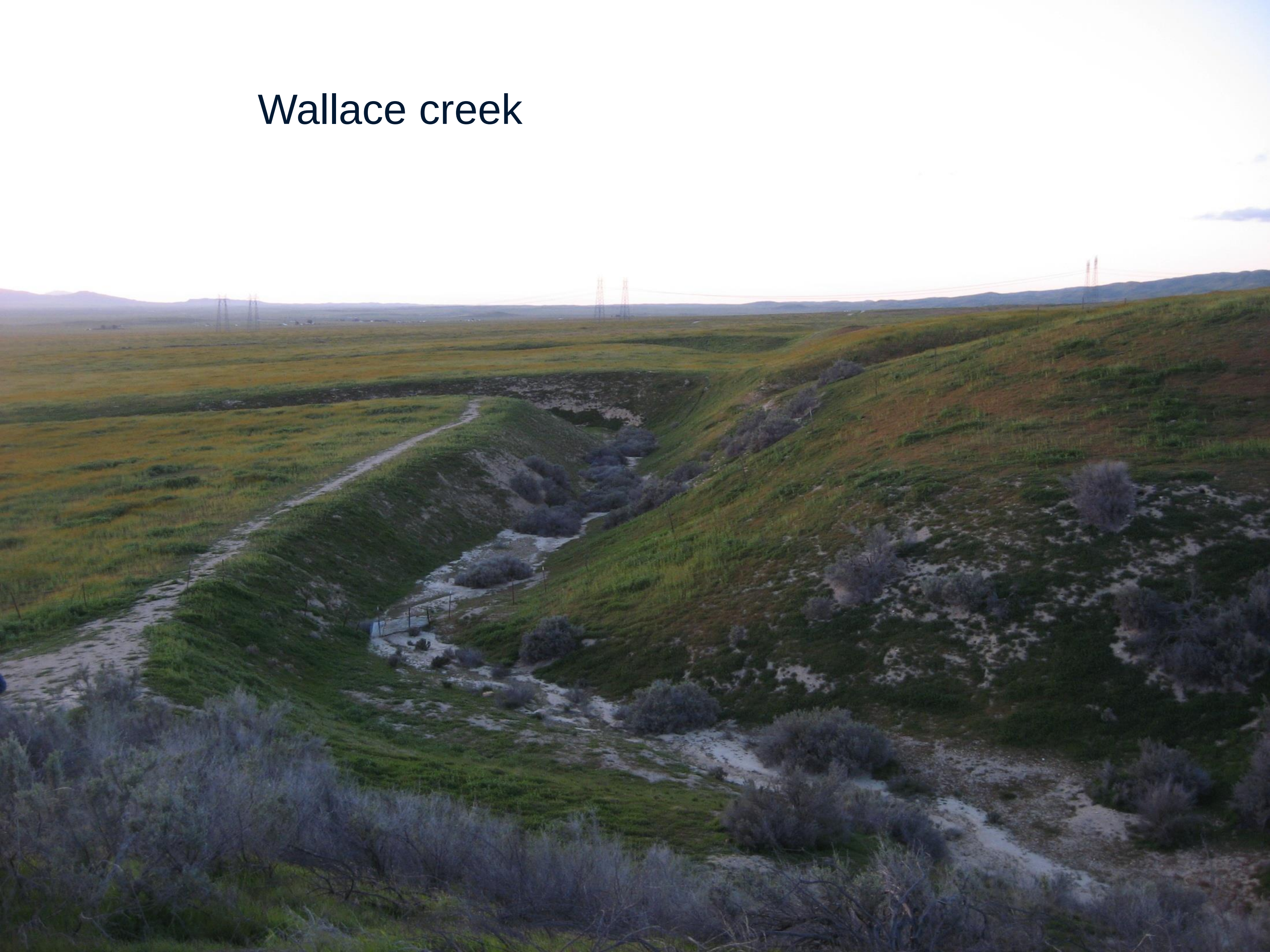




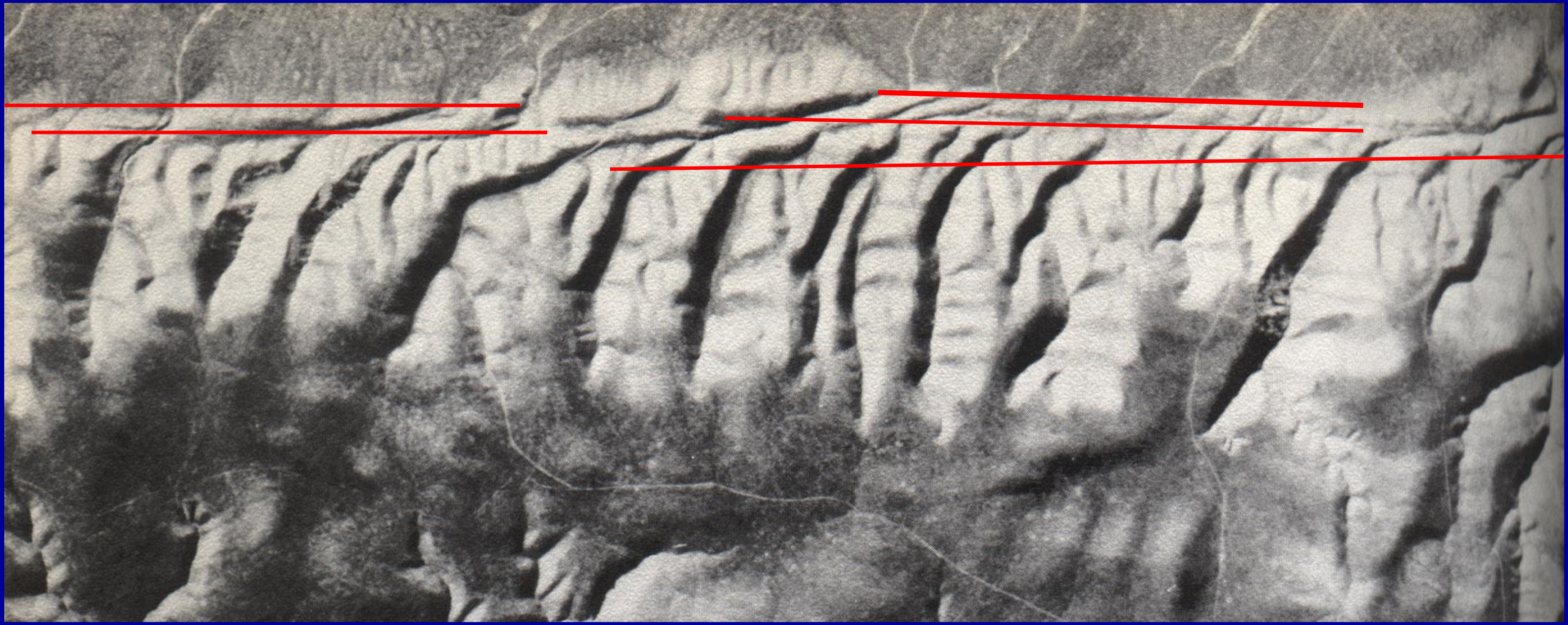
Wallace creek



Wallace creek

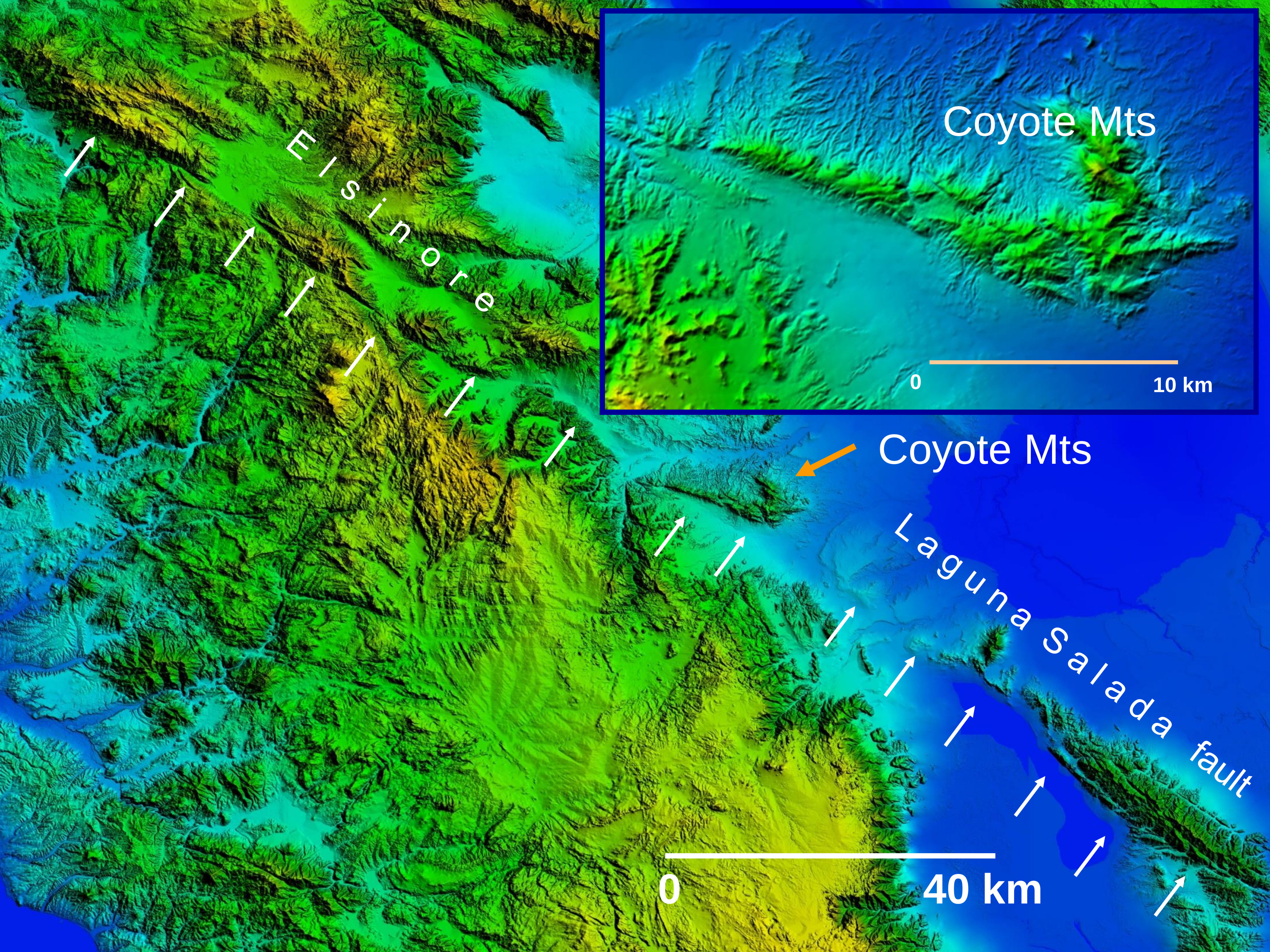


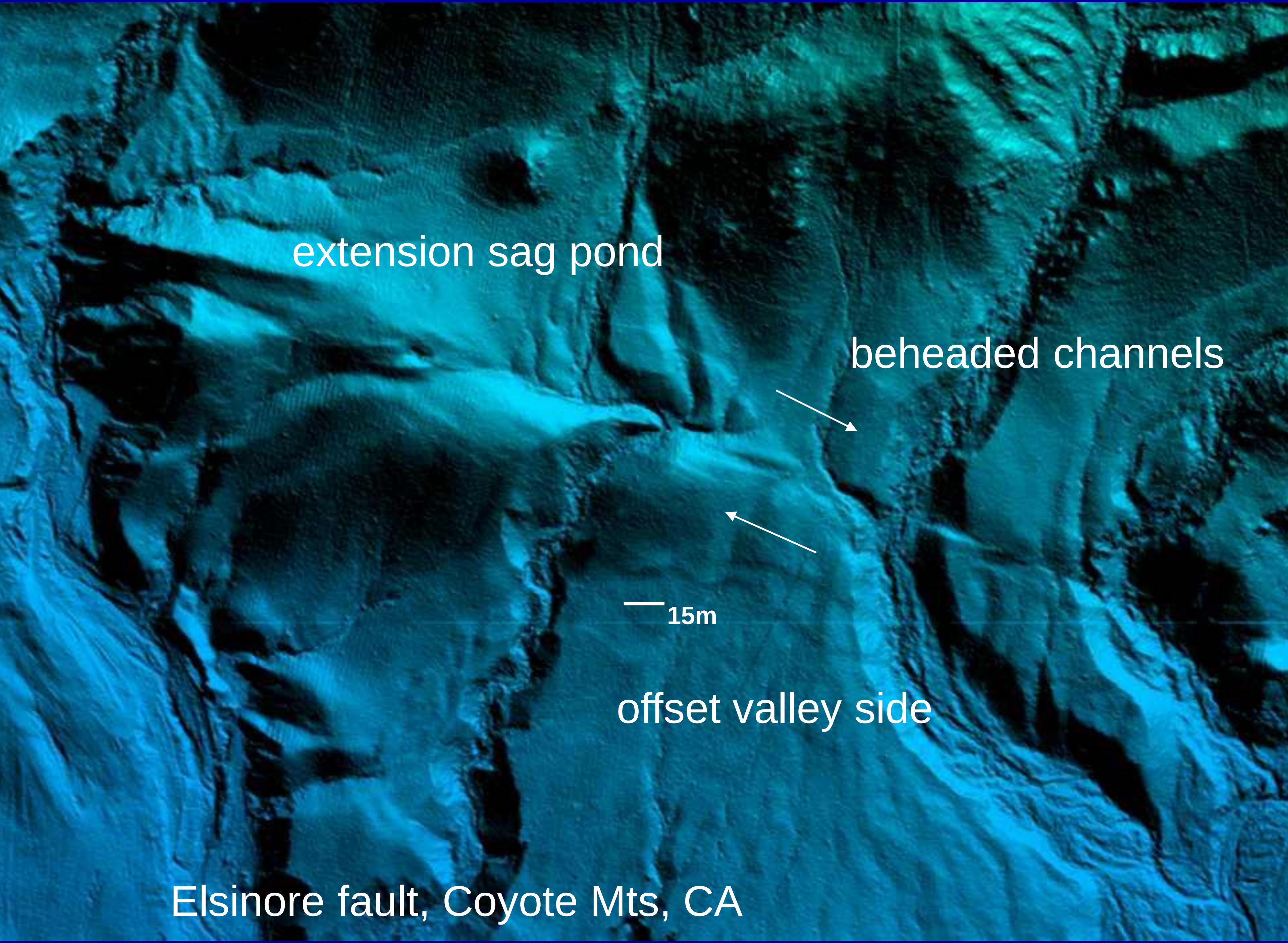
Offset/Deflected channels



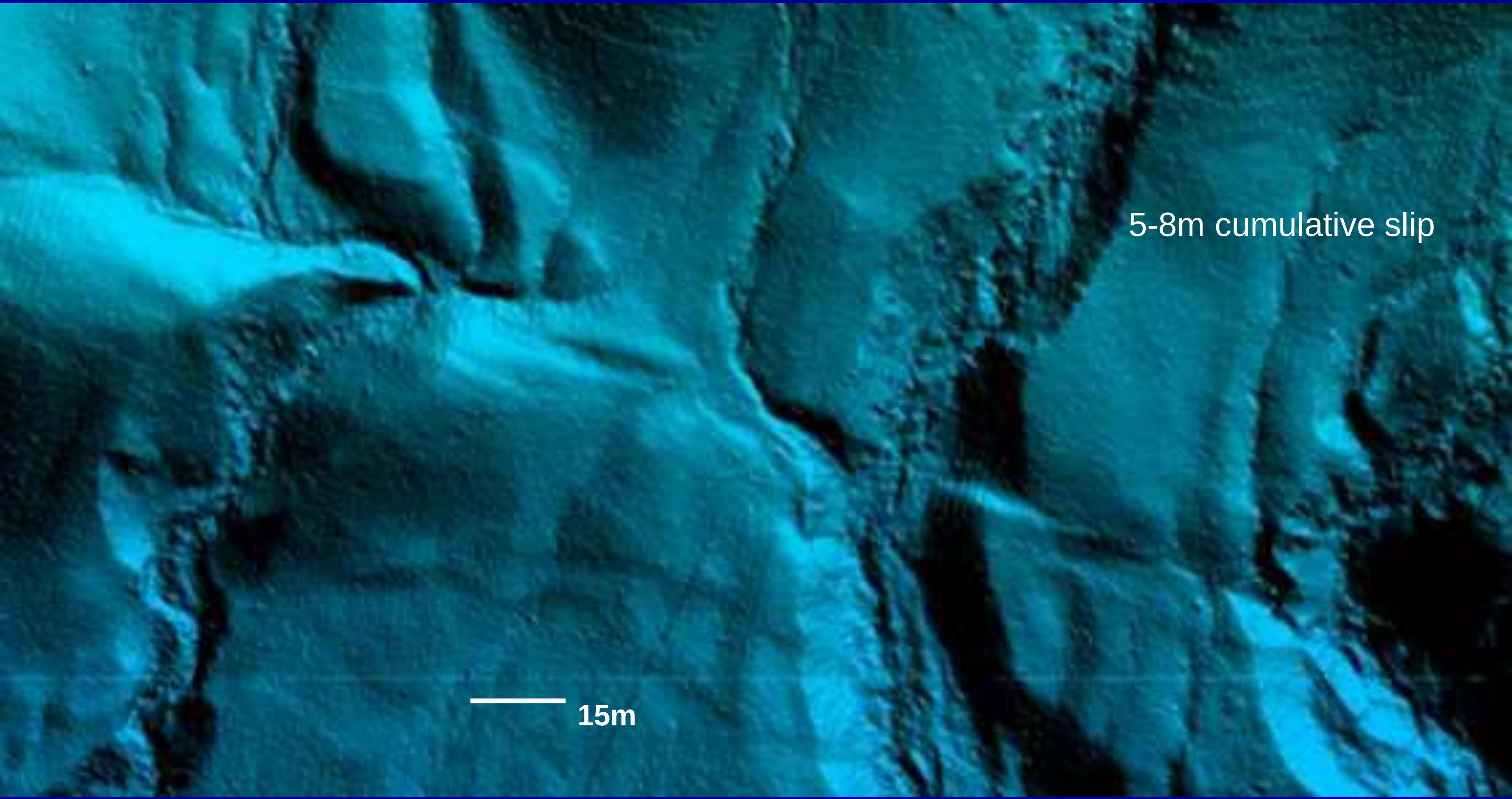
Carizzo plain

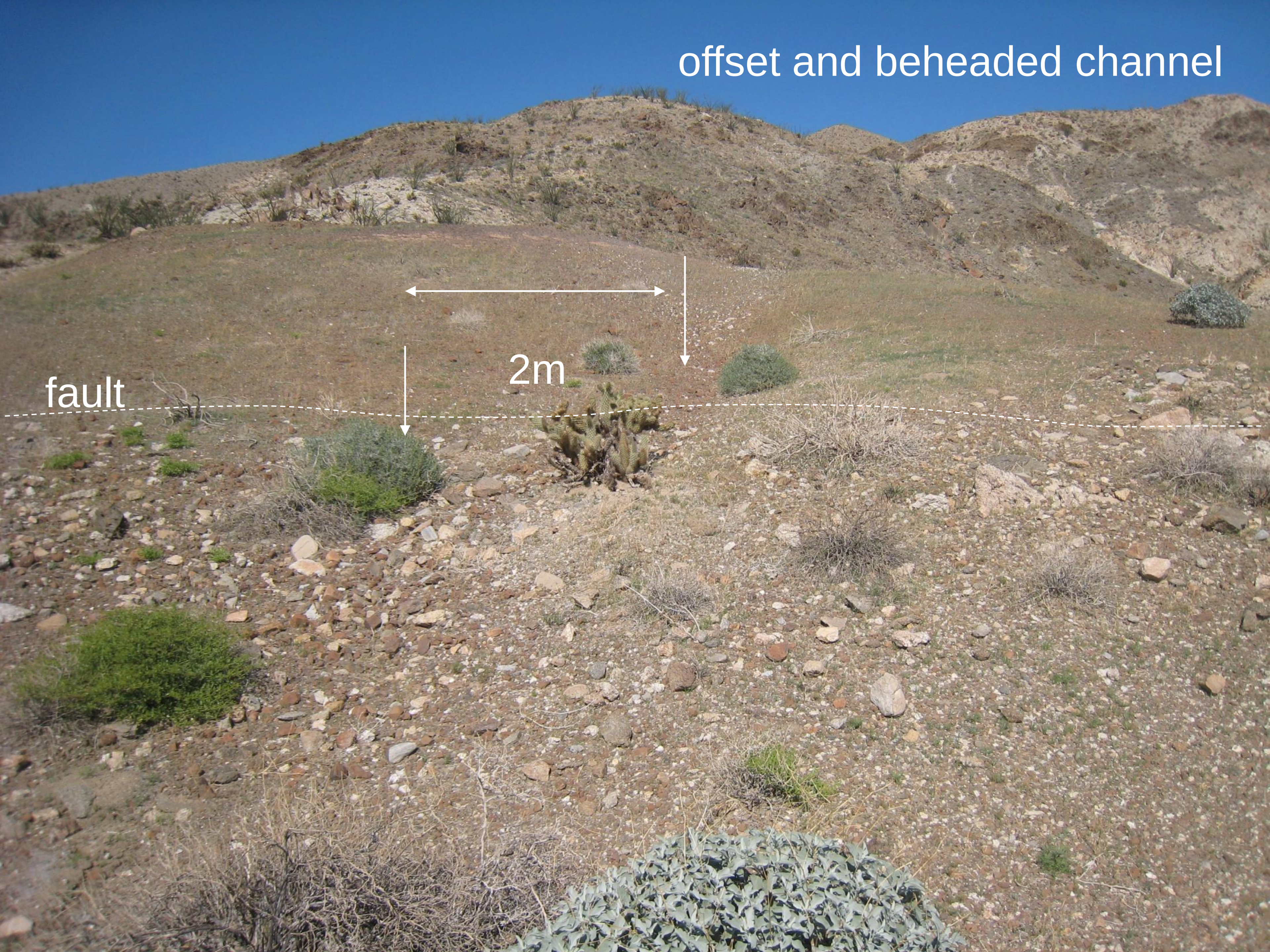

Nevada
California
Hayward Fault
San Francisco
Calaveras Fault
San Andreas Fault
Garlock Fault
Los Angeles
San Jacinto Fault
Elsinore
Coyote Creek Fault
Imperial Fault
Superstition Hills fault
Gulf of California


Coyote Mts
0
10 km
Elsinore
Coyote Mts
Laguna Salada fault
0
40 km

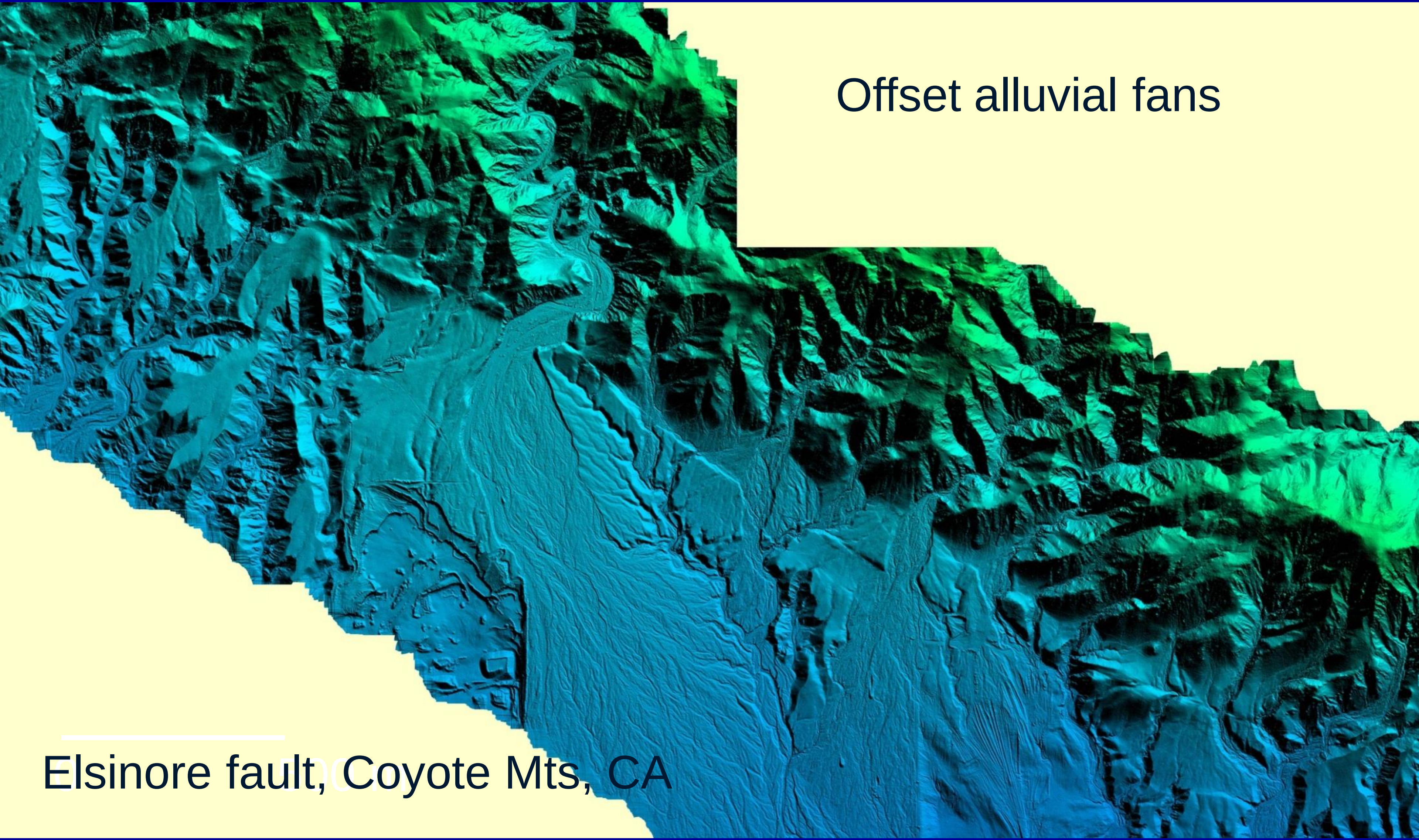

extension sag pond
beheaded channels
15m
offset valley side
Elsinore fault, Coyote Mts, CA

beheaded channels



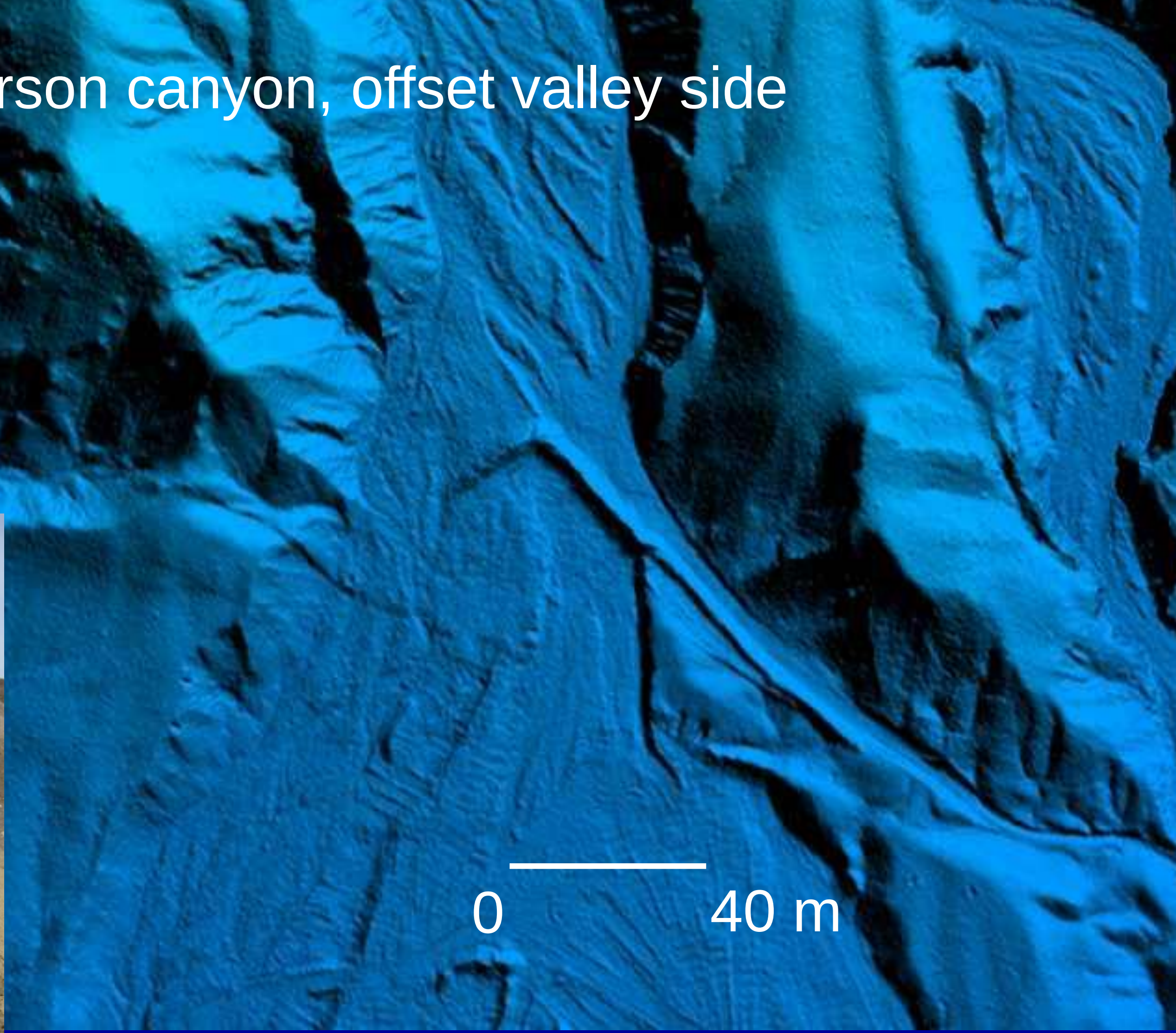

offset and beheaded channel
2m
fault

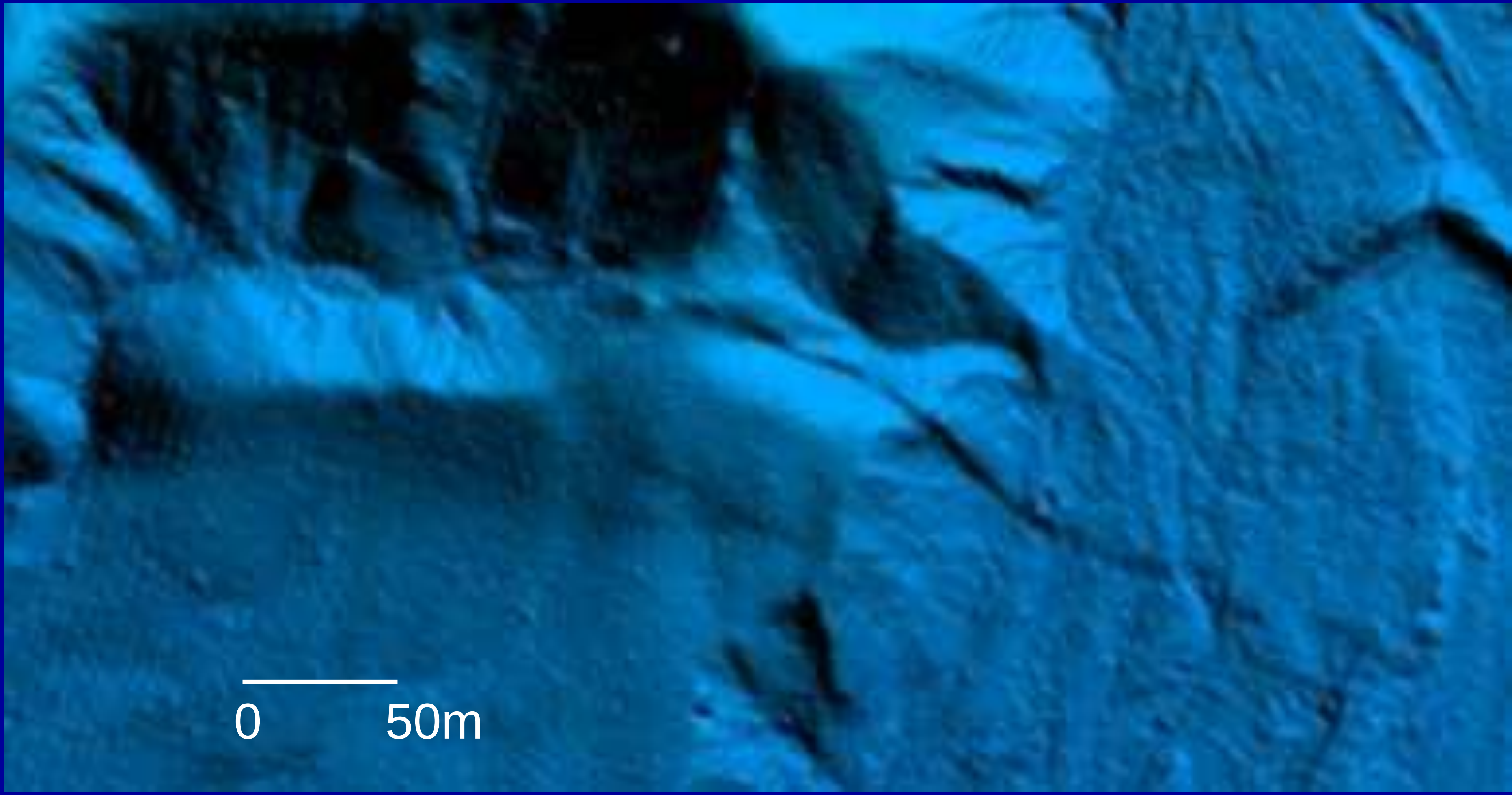
Offset alluvial fans



Elsinore fault, Coyote Mts, CA

Alverson canyon, offset valley side

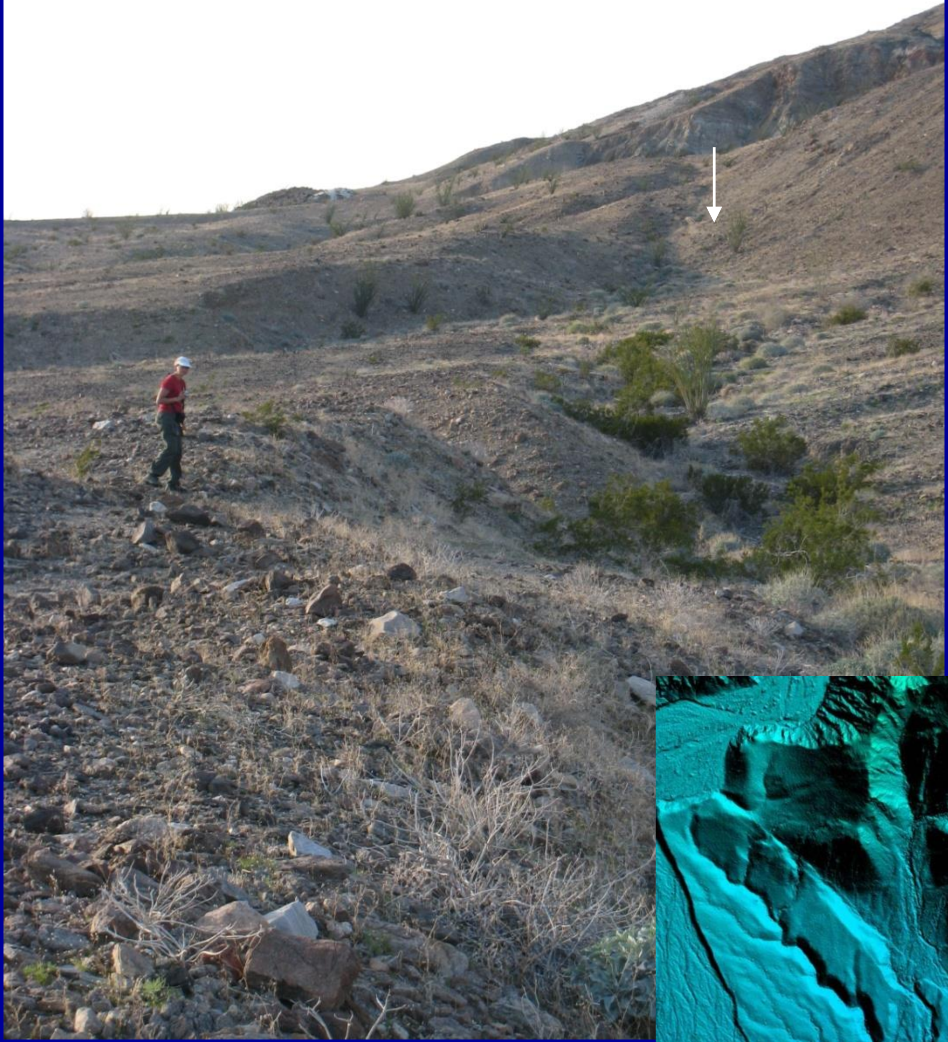


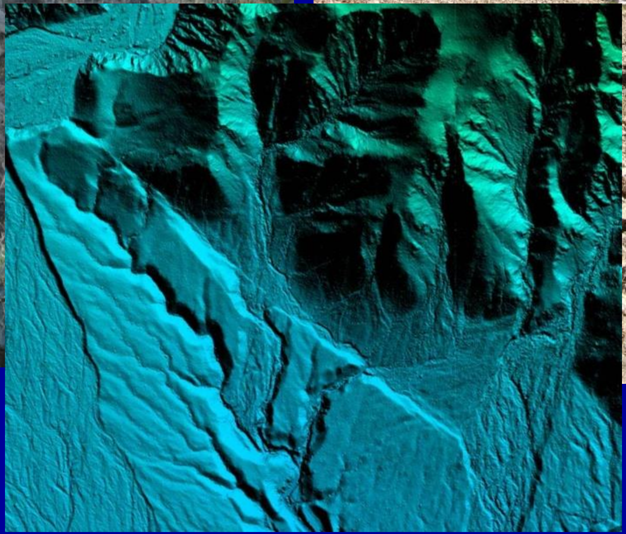

0
50m


offset channels and bars

offset channel bars

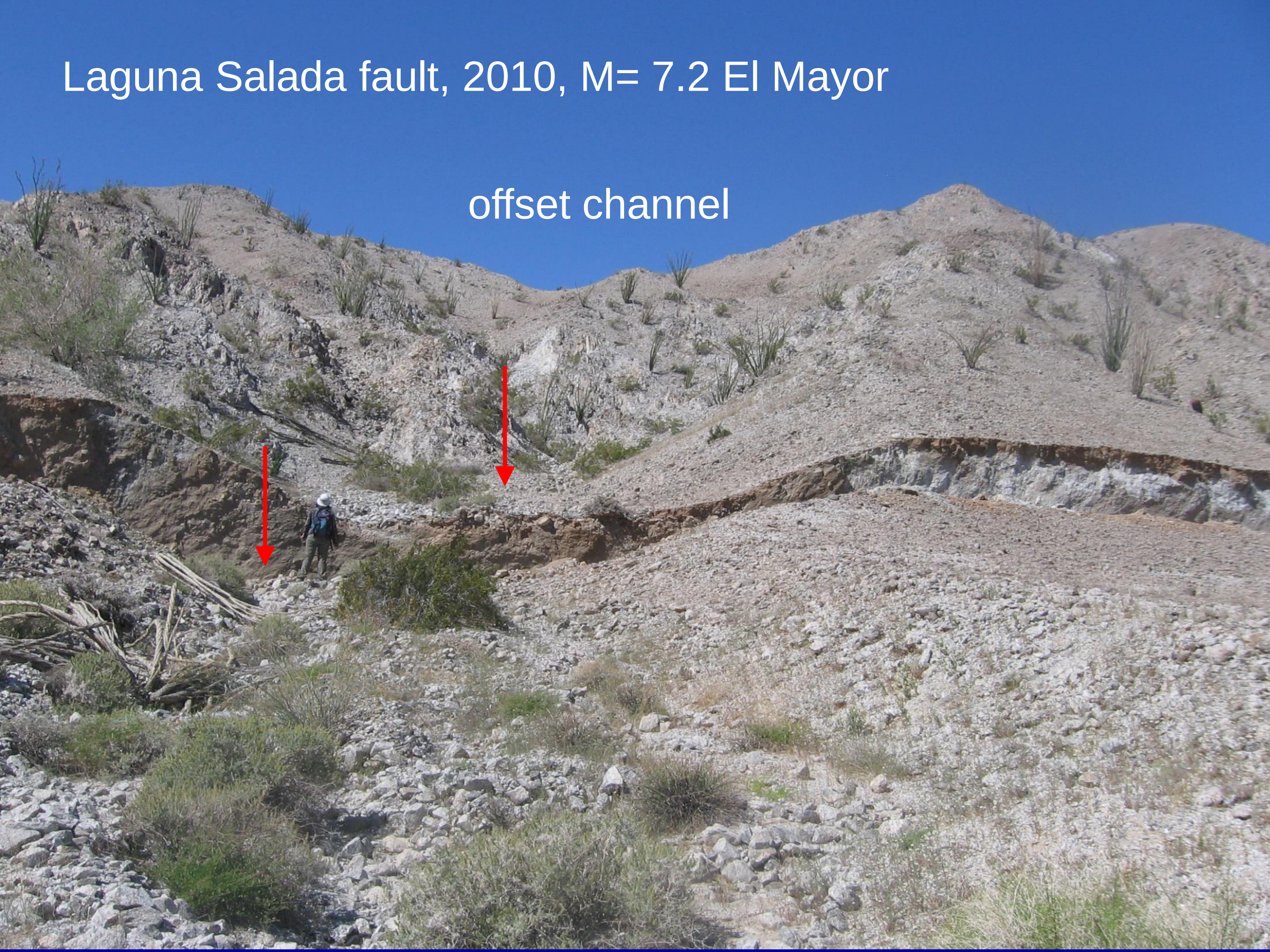
offset alluvial fan





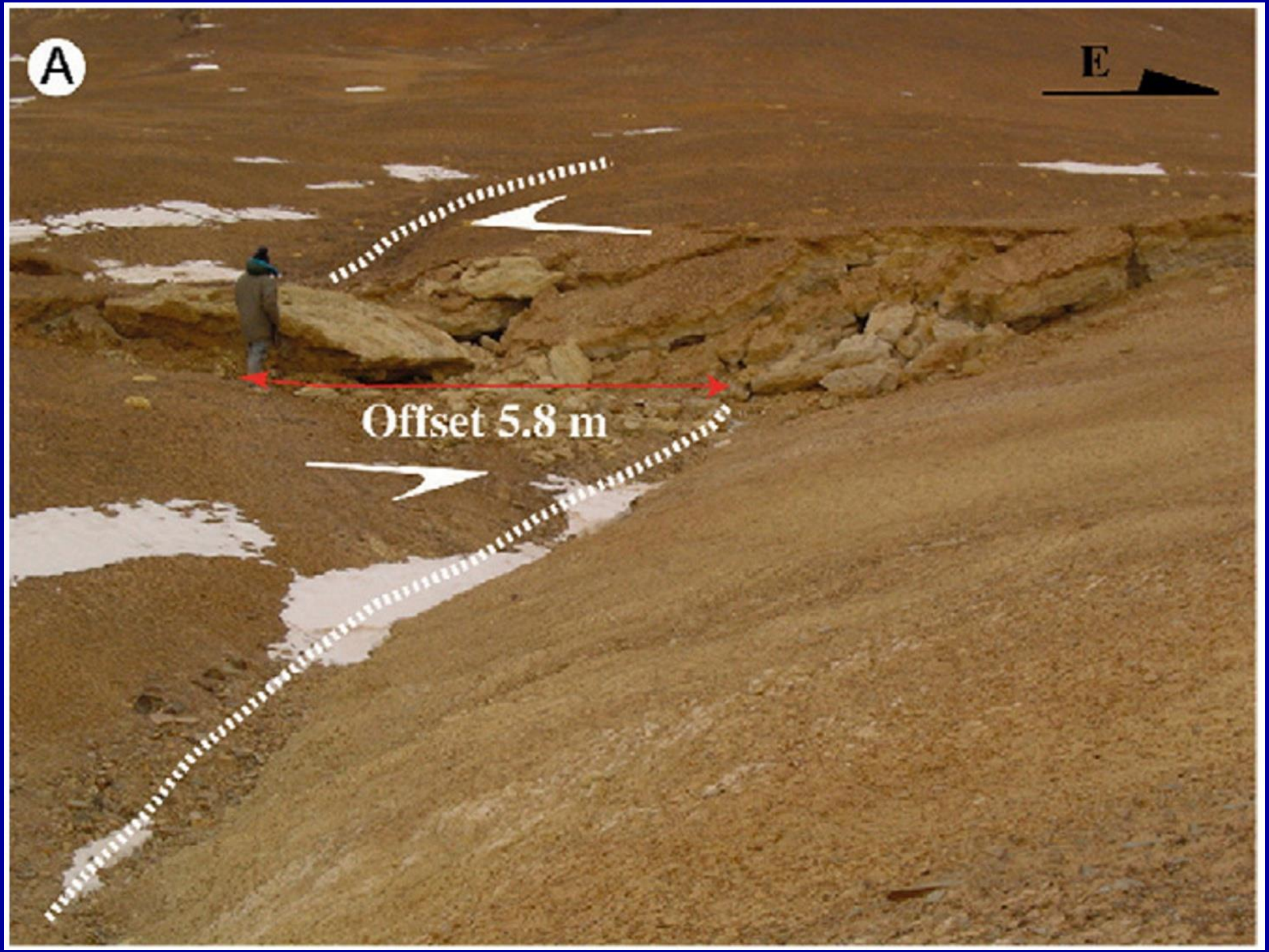
Different lithology – tells us about the amount of offset

Laguna Salada fault, 2010, M= 7.2 El Mayor




offset channel


offset valley side



Kunlun fault, Tibet, 2001 M = 7.8

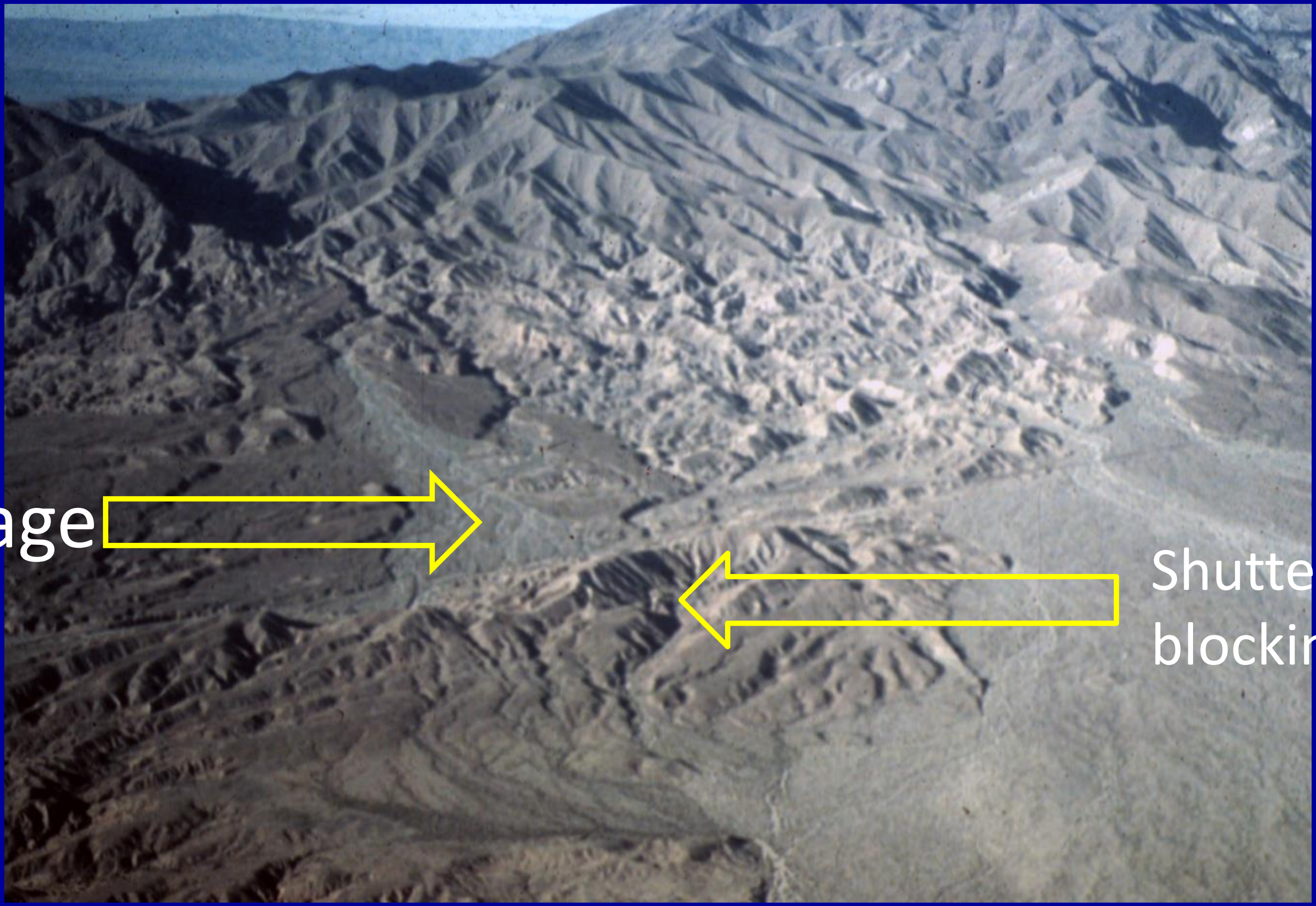
San Jacinto Fault, Southern California

Long-term slip


sag
piercing/matching points
Offset channel margin
sag
Denali fault. Photo: Lloyd Cluff, 1973

Shutter Ridge

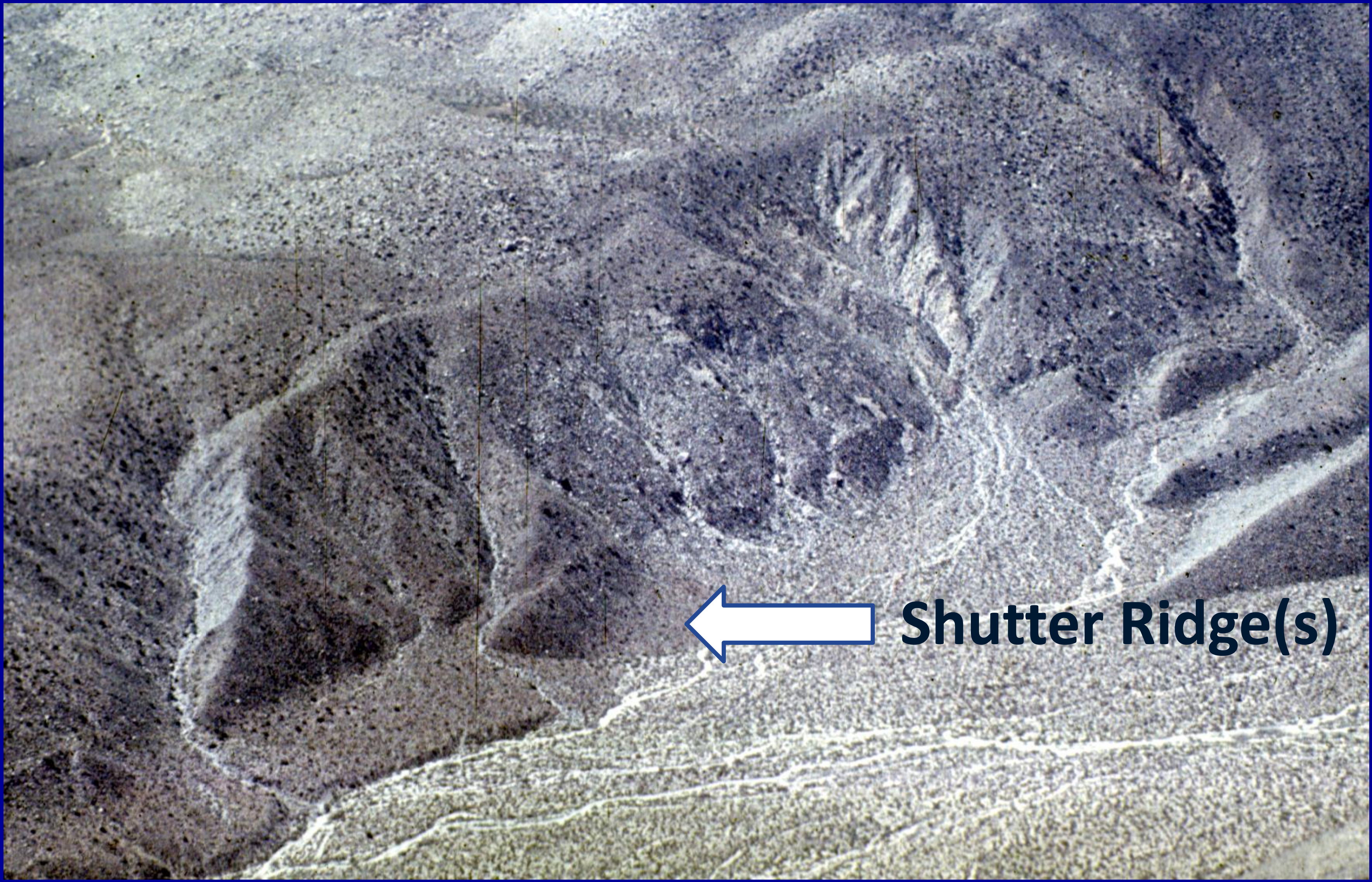
- Hřbet, který se pohyboval horizontálně podél zlomu a zablokoval odtok, údolí



Clark strand of the San Jacinto

Hector Mine Rupture, 1999

San Jacinto Fault, Southern California



Lineární údolí

Lineární údolí – a) pohyby na zlomy, b) jen eroze na zlomu

Transtenze/Transprese

- Obojí ve všech měřítkách – lokální až regionální

- Řízeno zakřivením na SS zlomu (lokální), nebo celkově konvergence/divergence podél SS zlomu (regionální)

Transtenze

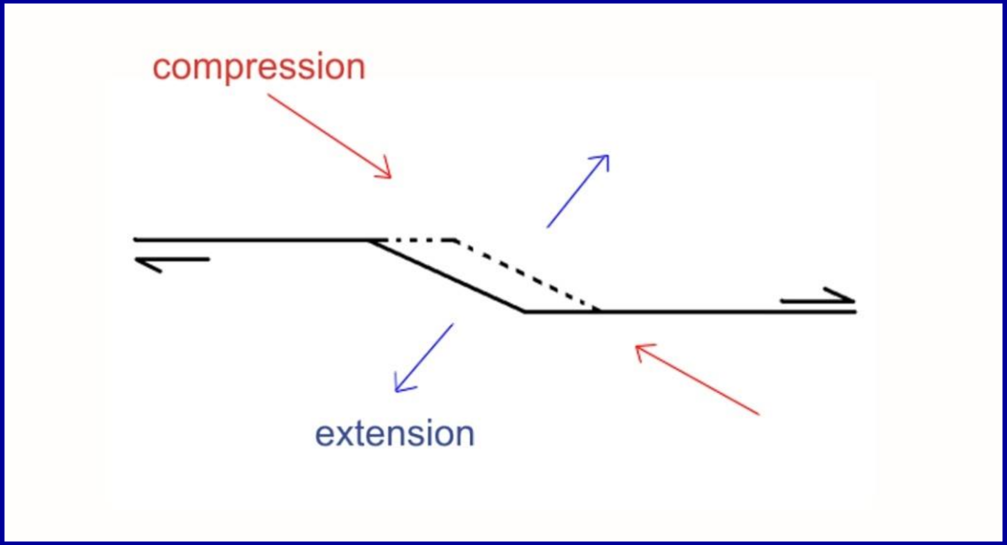
- Současně strike-slip a extenze

Transprese

- Současně strike-slip a komprese

Transtenze

- Komponenta divergence podél SS fault (strike-slip)
- Right step na Dextral (pravostranný) SS fault
- Left step na Sinistral (levostranný) SS fault



Otvírání zapříčiní vznik deprese “sag,” (prohnutí) nebo pull-apart pánve

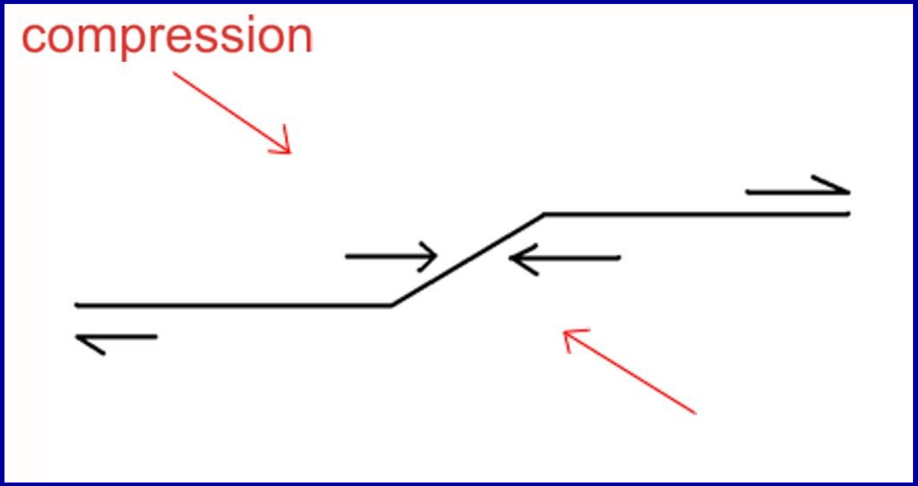
Sag Ponds

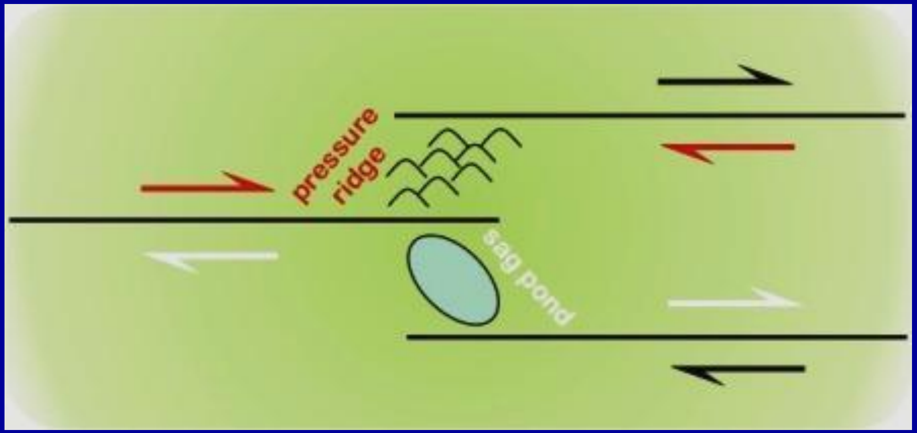
San Andreas

Topographic depression produced by extensional bends or stepovers along a strike-slip fault. It may or may not contain water year-round. Synonymous with pull-apart basin.

Transprese

- Komponenta konvergence podél SS fault
- Left step in Dextral SS fault
- Right step in Sinistral SS Fault



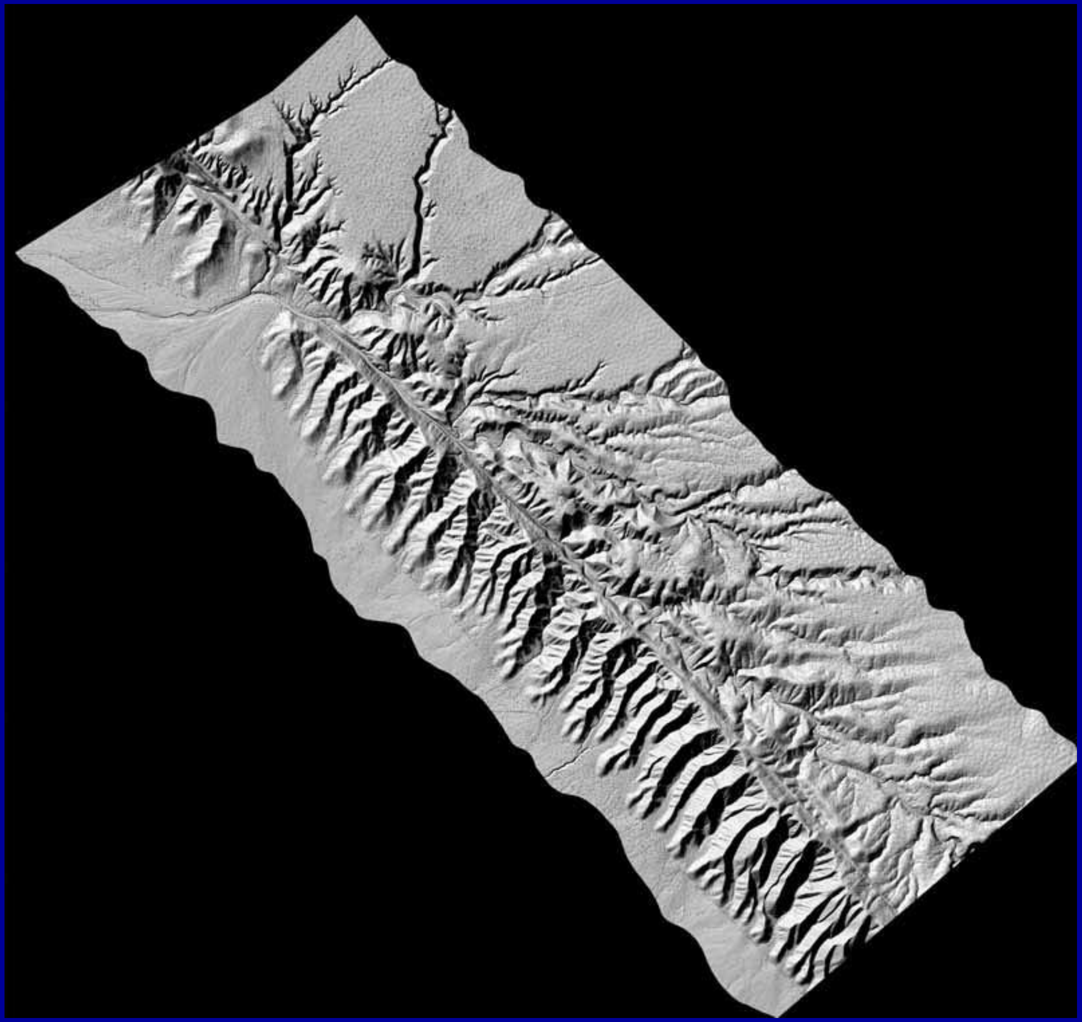


Left step causes a space problem, and a “pressure ridge” is formed

Pressure ridge /kompresní hřbítek

A topographic ridge produced by compressional bends or stepovers along a **strike-slip fault**

Small pressure ridge along SAF in Cholame Valley



Dragon’s Back Pressure Ridge System
podél San Andreas

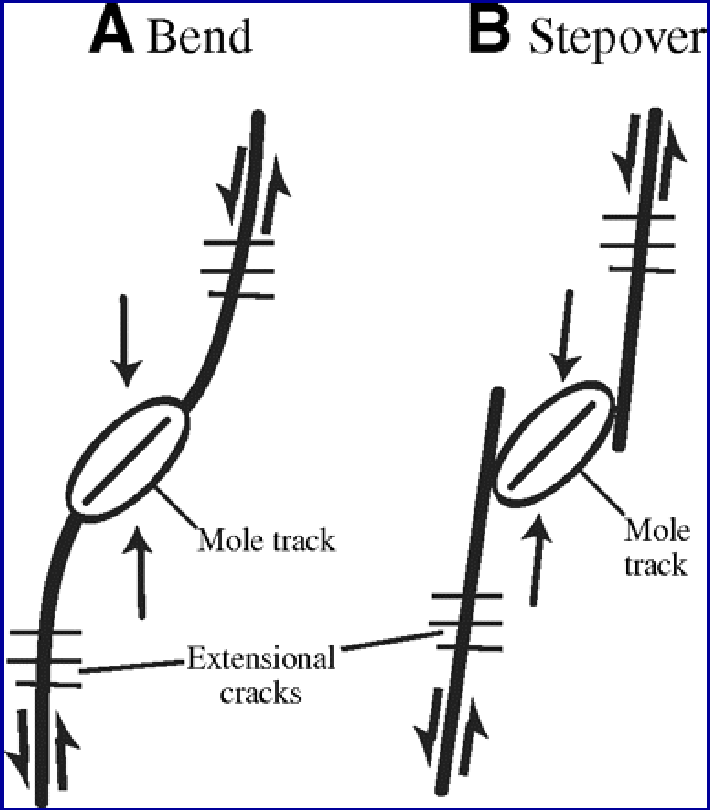
Pressure ridge

Thousands Palms – Indio Hills,
San Andreas fault

Denali fault, 1964, M=8,5

„Mole track“ structure

Materiál je vytlačen podél zlomu tlakem

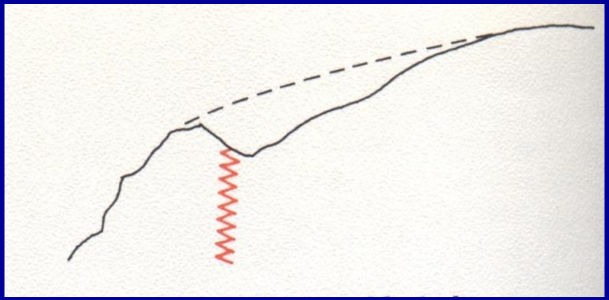


Kunlun fault, Tibet, 2001 M = 7.8

SAF, San Francisco 1906, M = 7.9

Denali fault, Alaska

Side-Hill Benches/Valleys

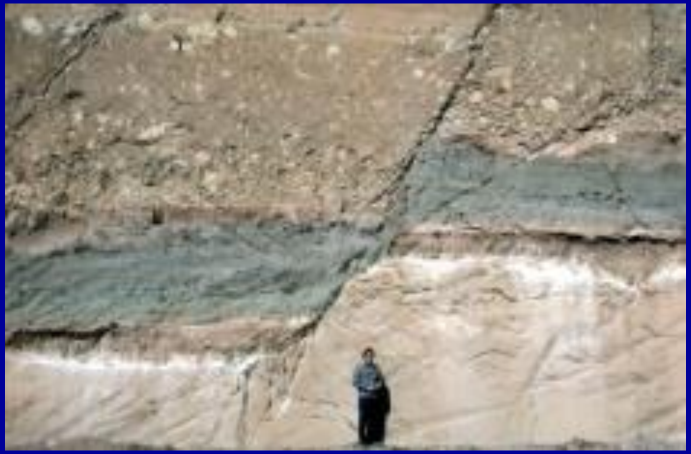


Paralelní zlomy, Kresna Gorge, Bulharsko

Slope inflection along San Andreas Fault

Flat step on the slope

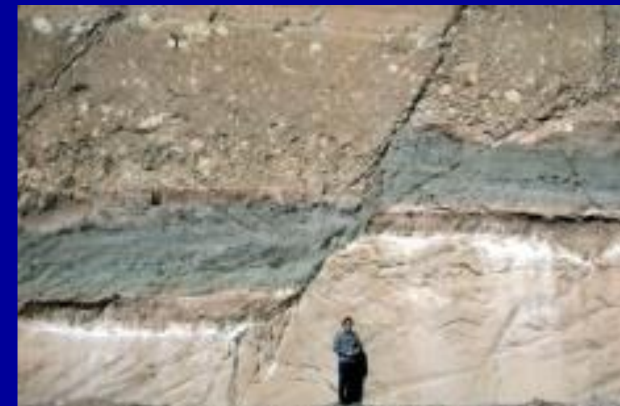
Geomorphology of Extensional Faulting: normal fault

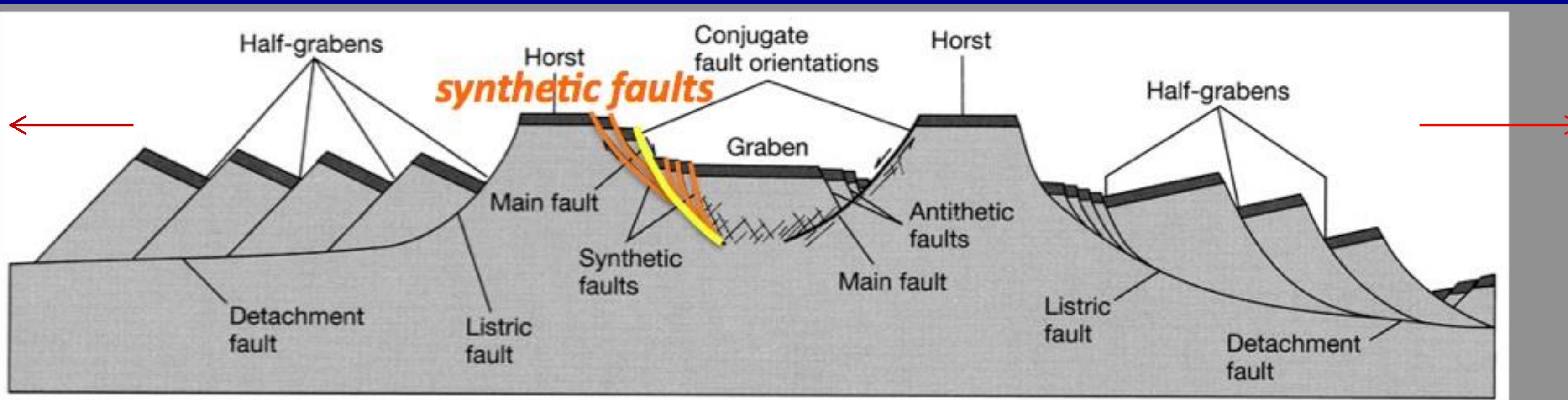


Displacement accommodated in normal faults

- Single, Parallel synthetic, Antithetic

- Primary normal fault (60-70°)
  - Crustal penetrating fault
  - Often has km of displacement
  - Separates linear mountain range from adjacent basin
    - Up-faulted block (horst/hrástě)
    - Down-faulted block (graben/příkopy)

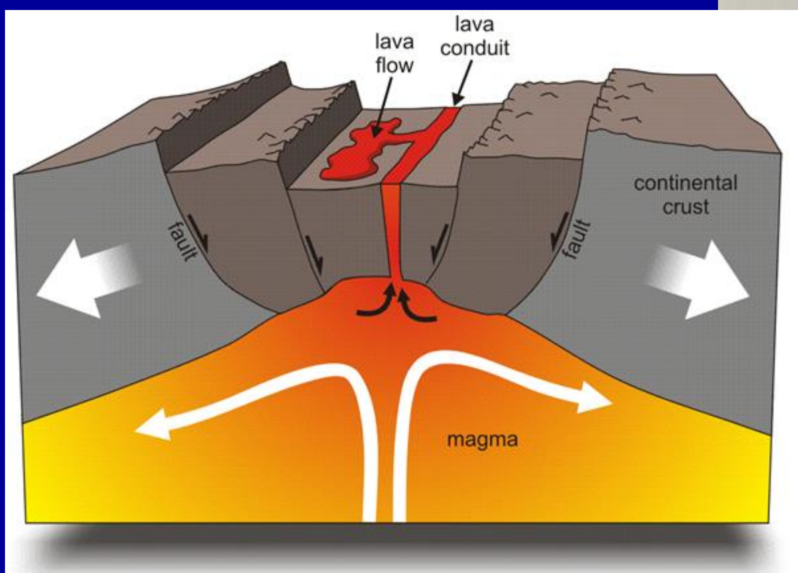


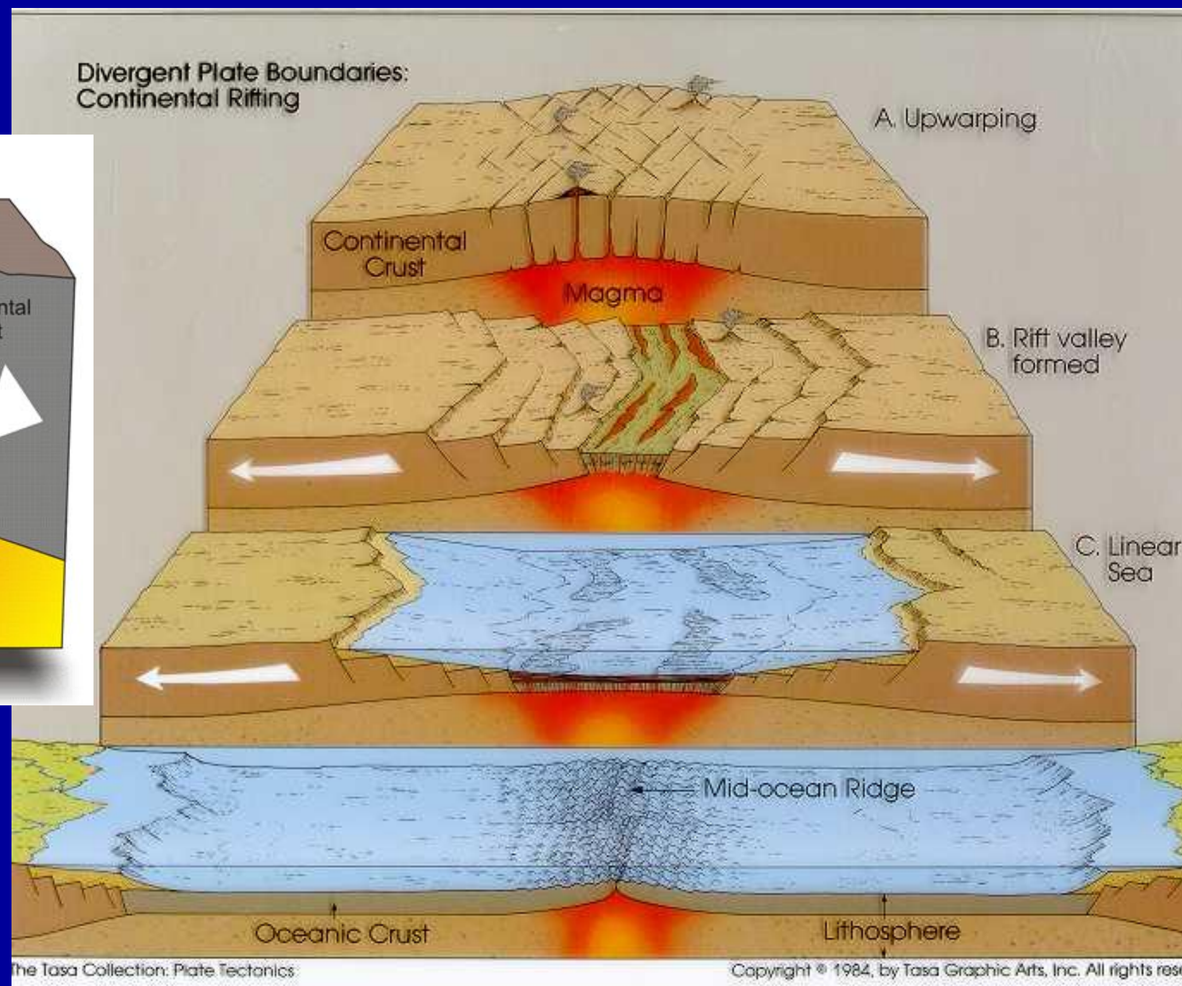


- Subsidiary faults dipping in the same direction as the major fault are <u>synthetic</u>. Those dipping opposite to the major fault are <u>antithetic</u>.

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

Rifts valleys

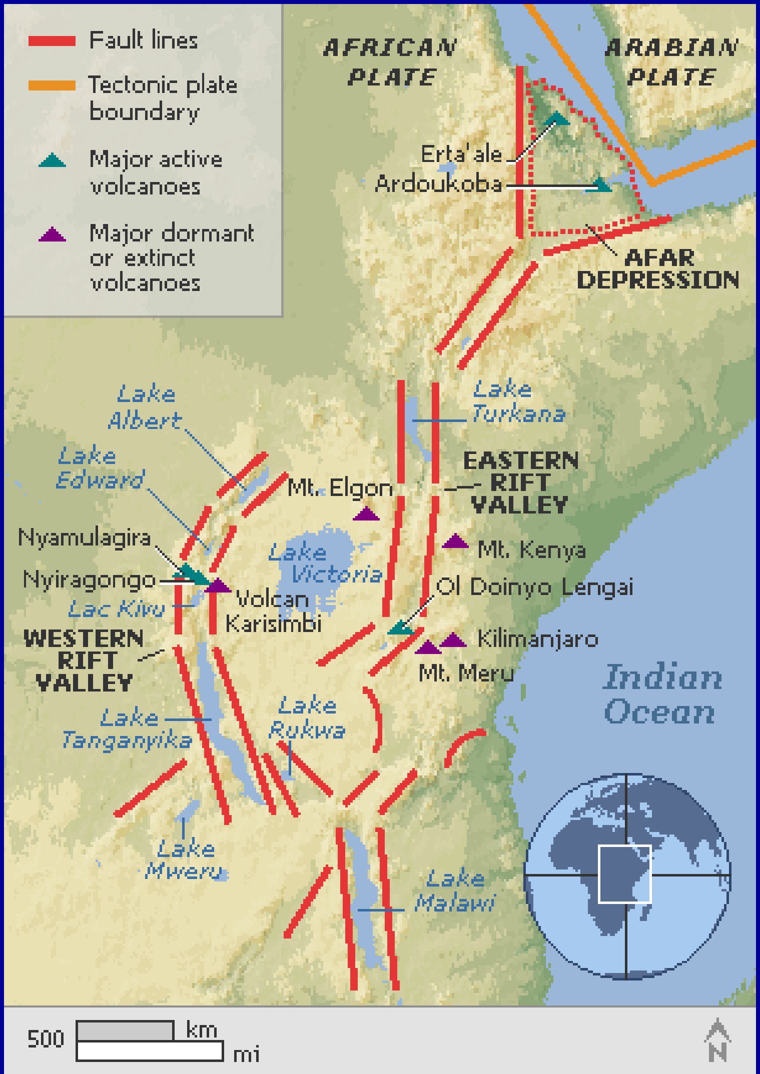


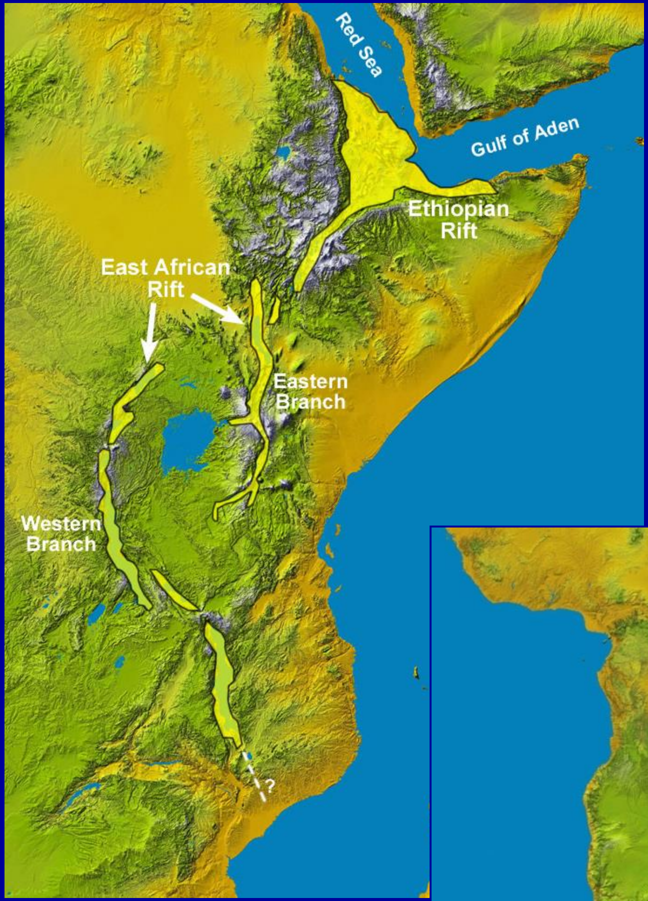


rift – elevated heatflow, vertical compression, horizontal extension

East African Rift Valley

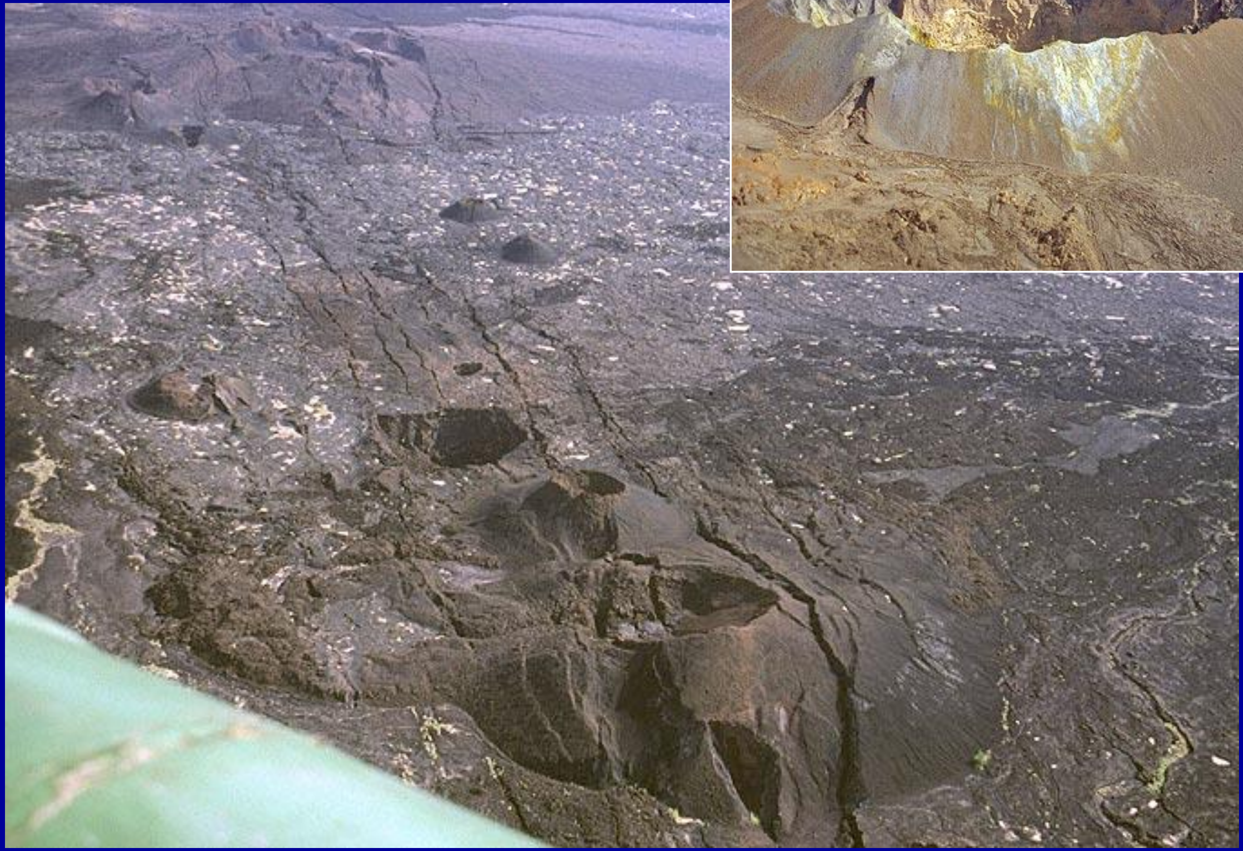
active divergence, rift – numerous of normal faults





East African rift in 20 mil years

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



Normal faults disecting the volcanos, Afar

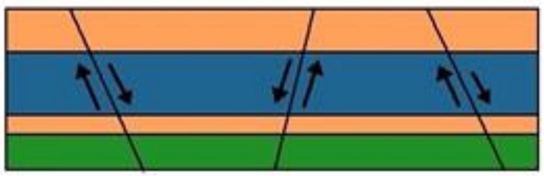
Massive fissure splits open in the Ethiopian Desert

Rift activity 2009

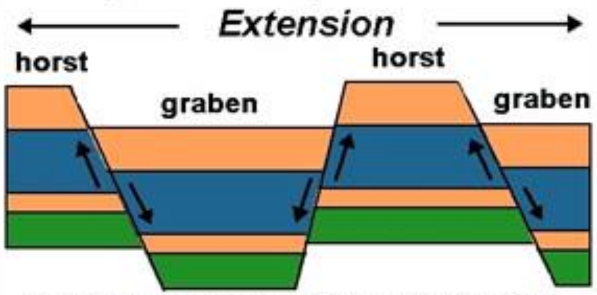
Escarpments

Textbook horst and graben formation

1. Layered rock units

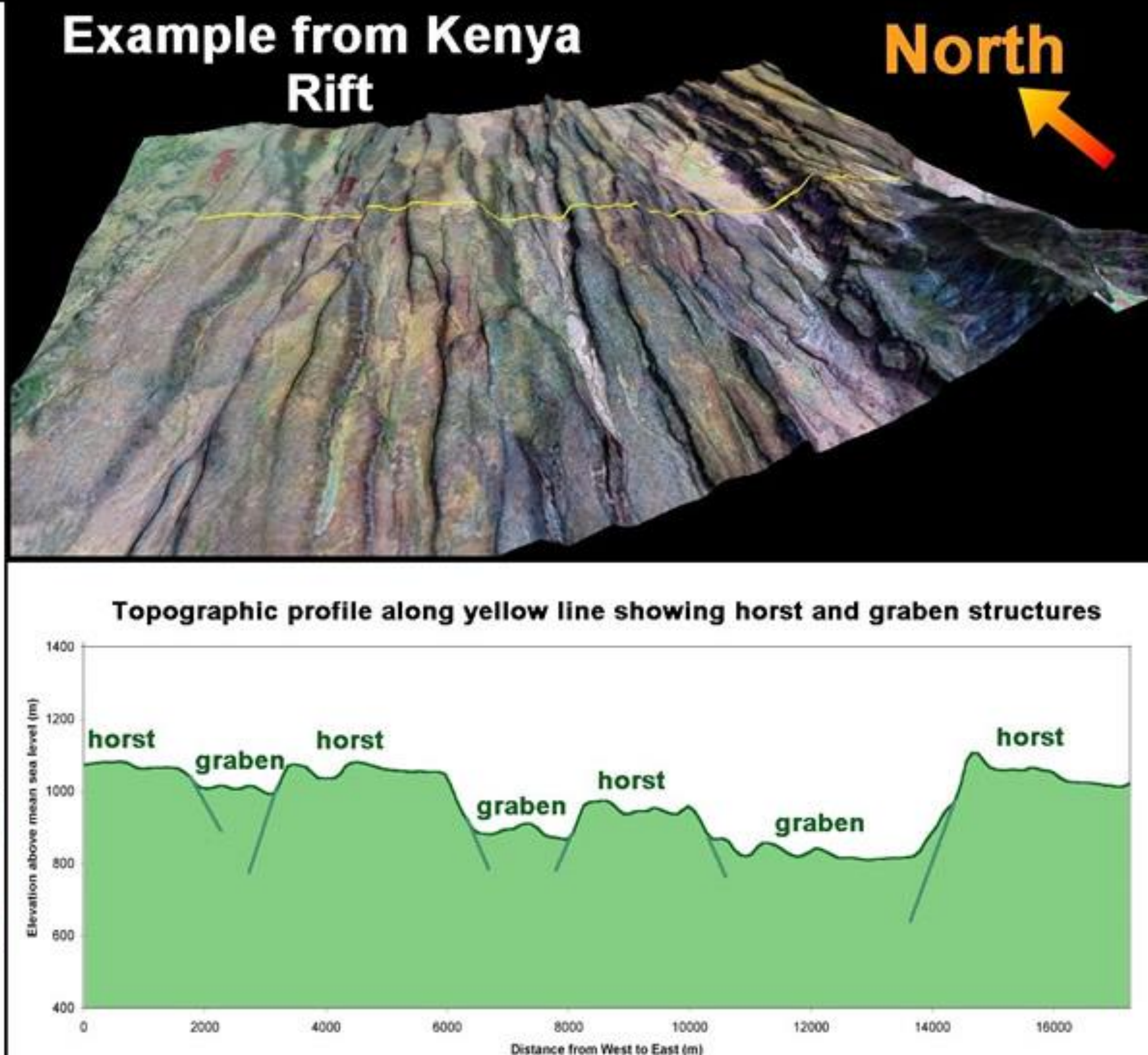


2. Layers are cut by normal faults



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

Example from Kenya Rift



Iceland – Rift Valley

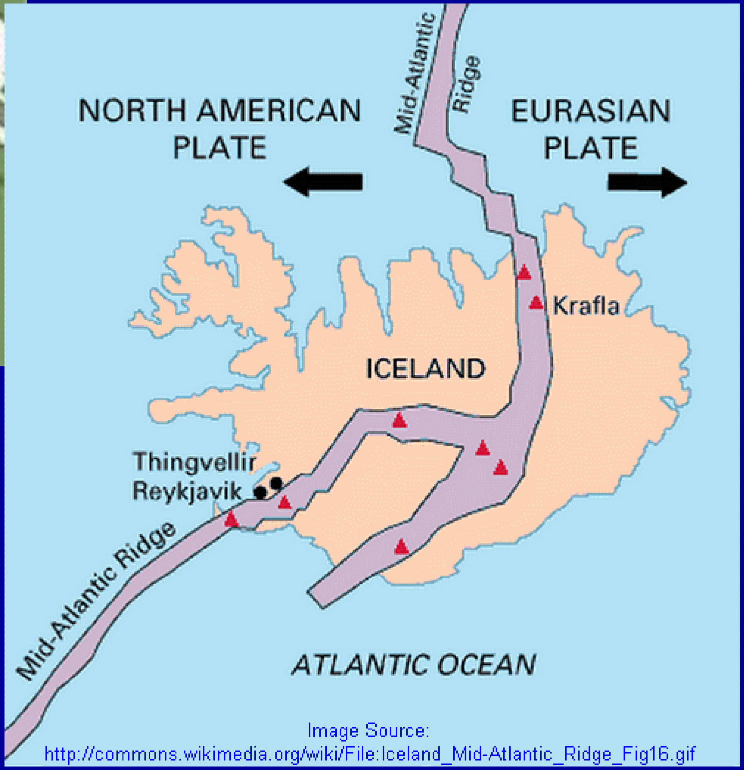
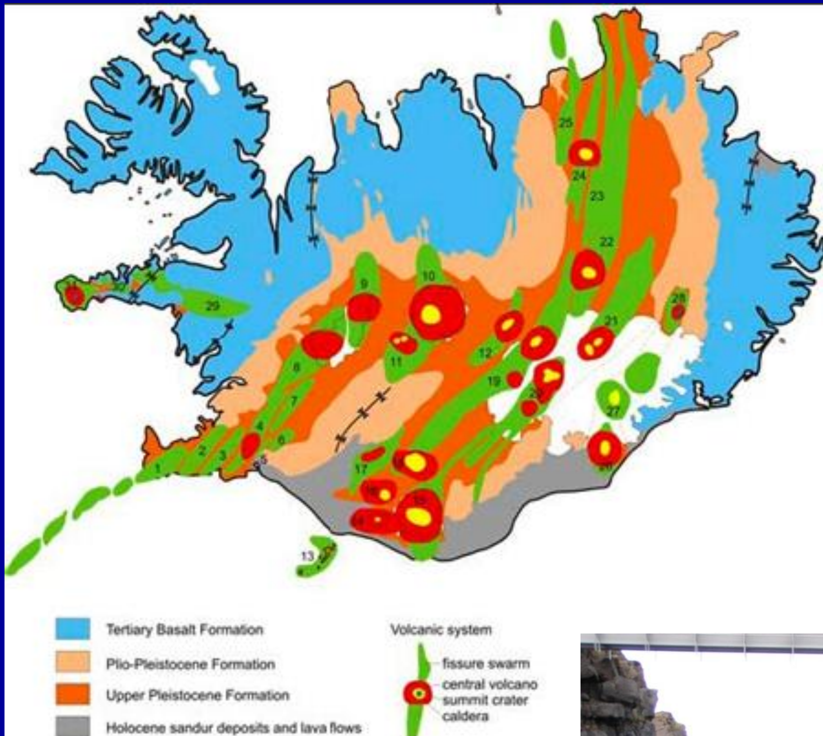


Image Source:
http://commons.wikimedia.org/wiki/File:Iceland_Mid-Atlantic_Ridge_Fig16.gif

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.

Iceland



Geological map of Iceland -
volcanic systems and volcanic zones

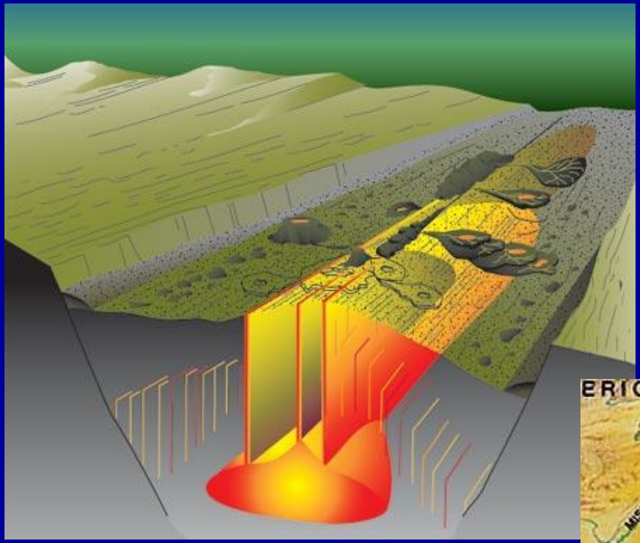
Each volcano

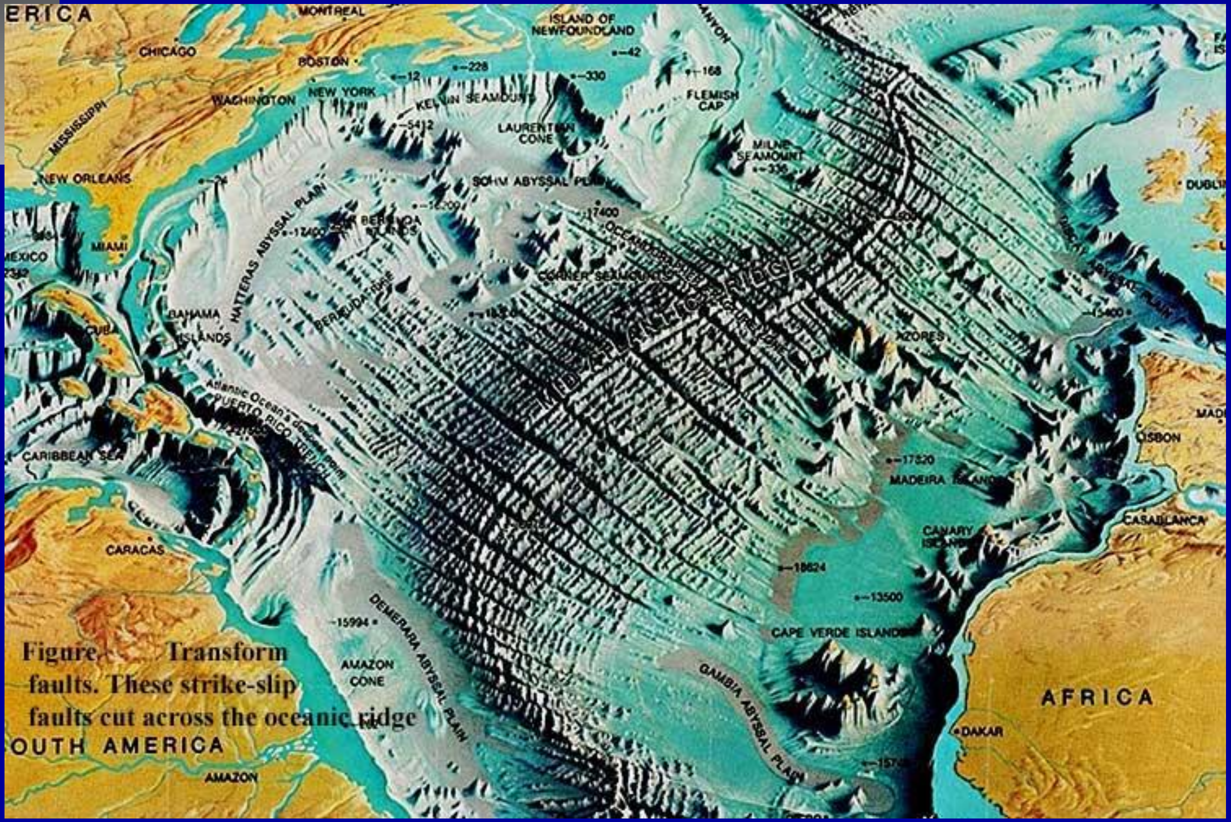
lifetime 0.5-1.5 Ma

30 active volcanic systems

Rift valley, Thingvellir national park, Iceland

Ocean ridge – basaltic oceanic crust



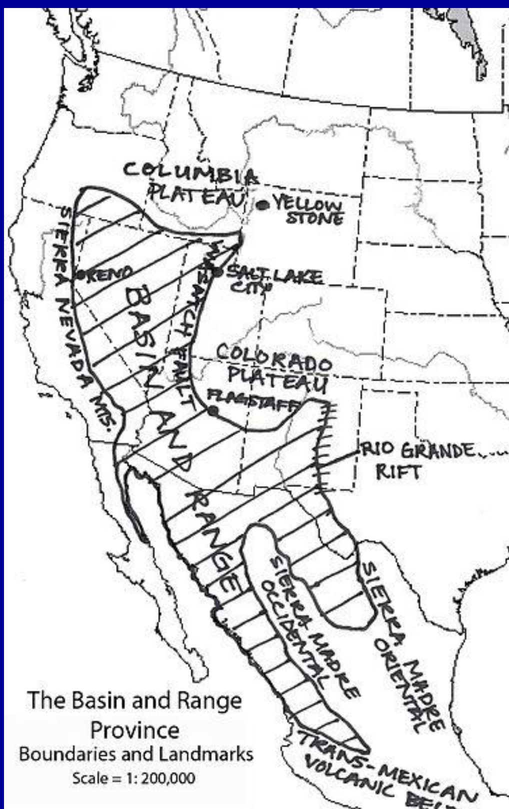


Mid-Atlantic oceanic ridge

Basin and Range topography

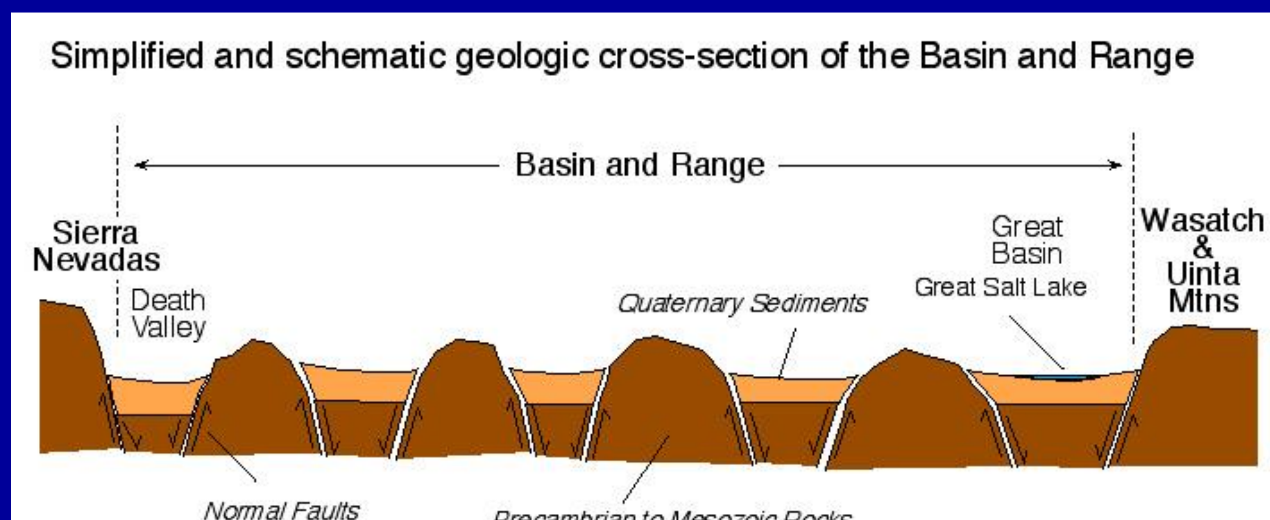
broad extensional faulting

Basin and Range Province



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

elevated heat flow, geothermal energy



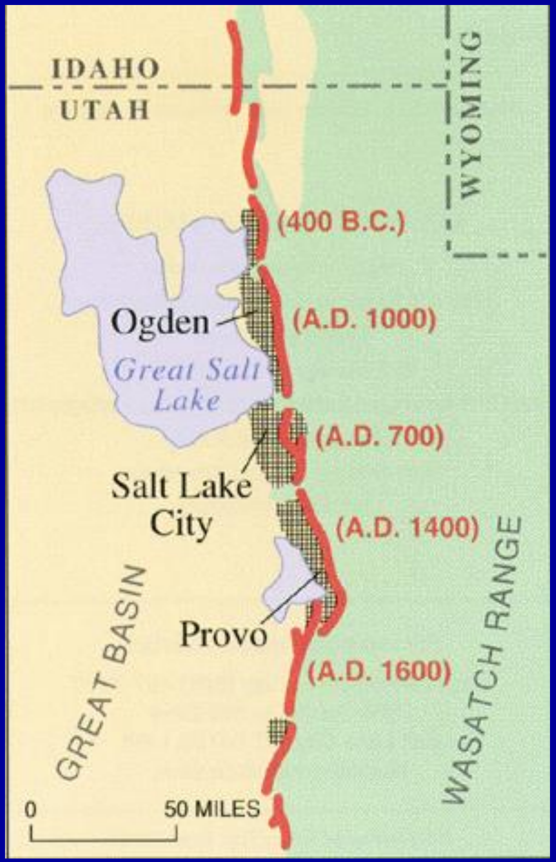
From Sierra Nevada to Wasatch Mts – 800 km

„Local scale„ normal faults

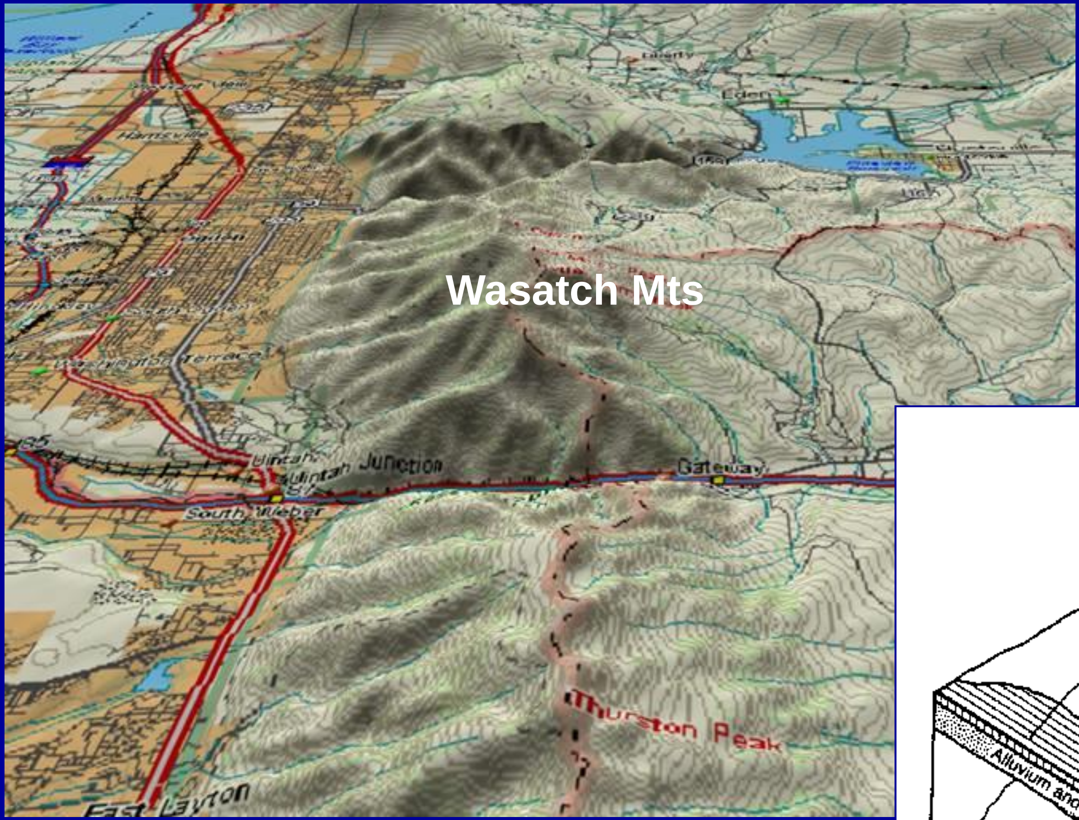
Normal faults - tends to be short 10-50 km

The **Wasatch fault** - eastern boundary of Basin and Range geologic province frontal fault - up to 400 km long,

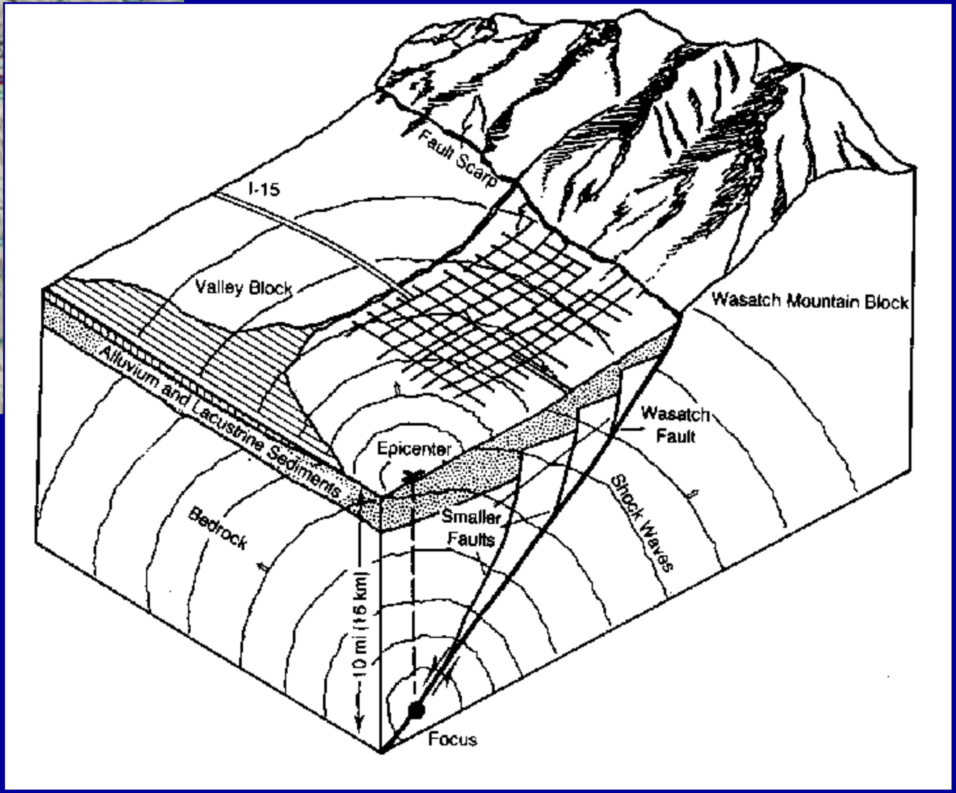
- separate faults or segments 30 – 60 km long, independently produce earthquakes as powerful as local magnitude 7.5



Linear mountain fronts

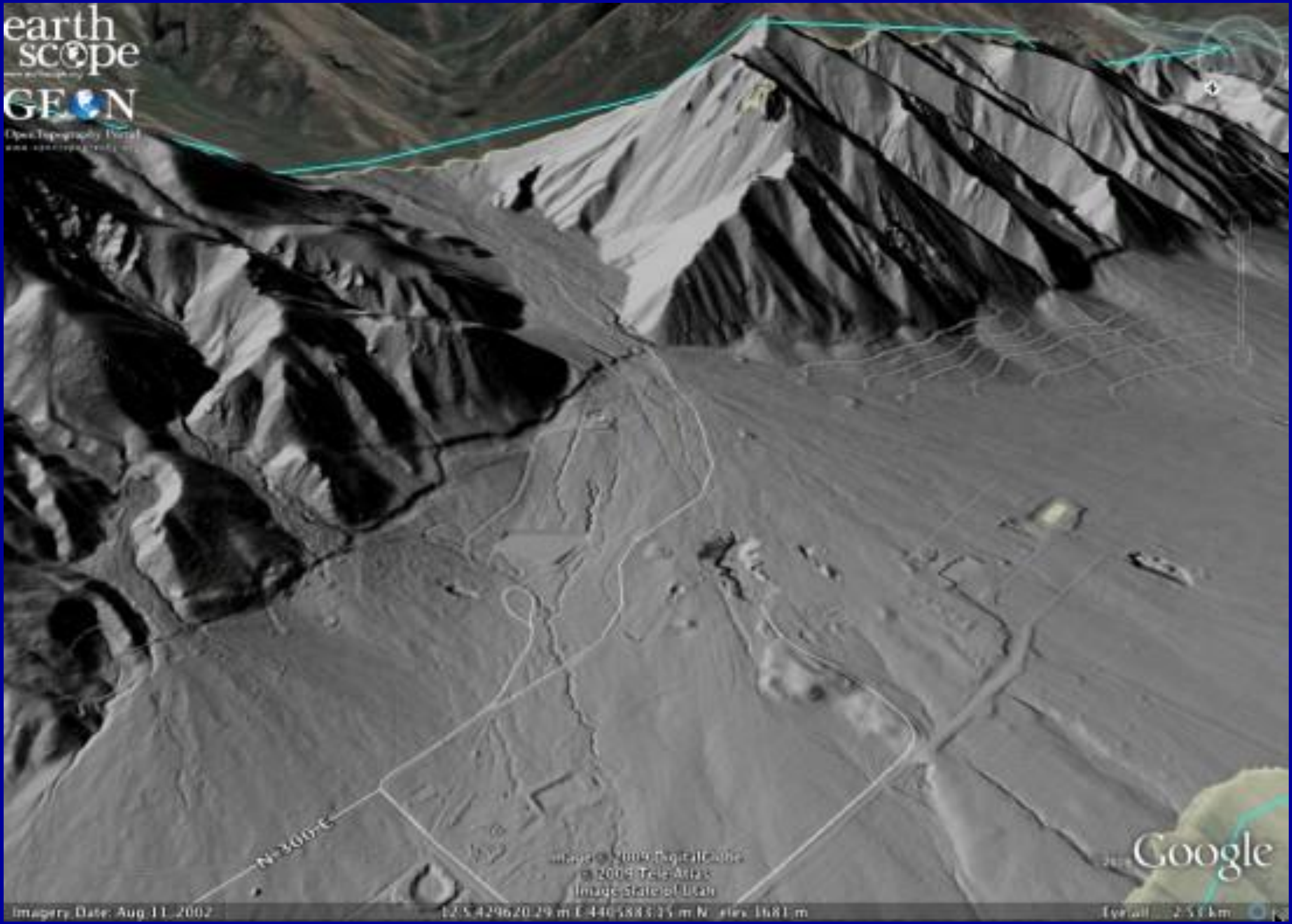


Linear mountaint front
- repeated earthquakes



Wasatch Mountains -
uplifted and tilted to the east

The average rate of uplift
- approx. 1 mm per year.

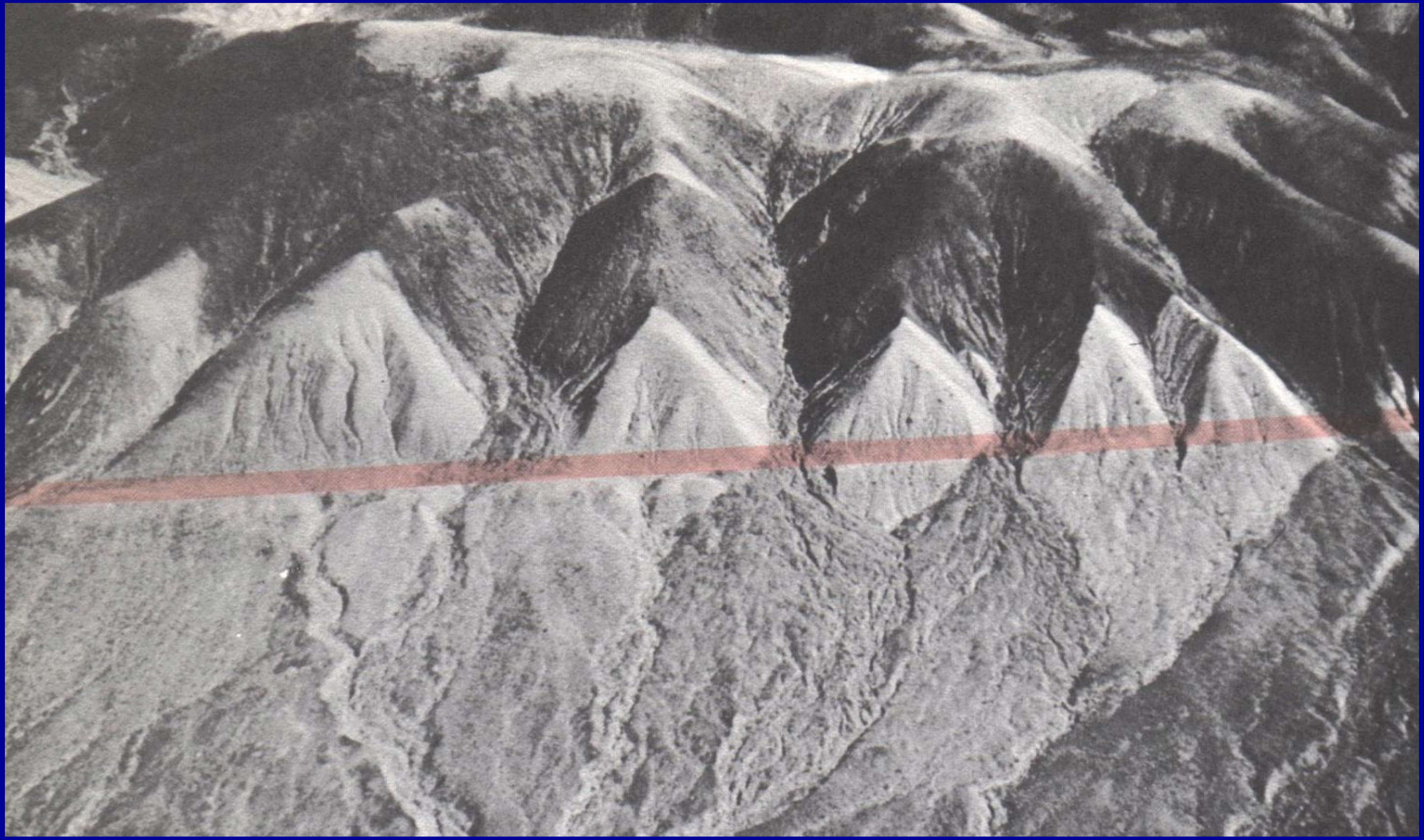


Scarp on the southern part of the Nephi strand of the Wasatch fault:

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



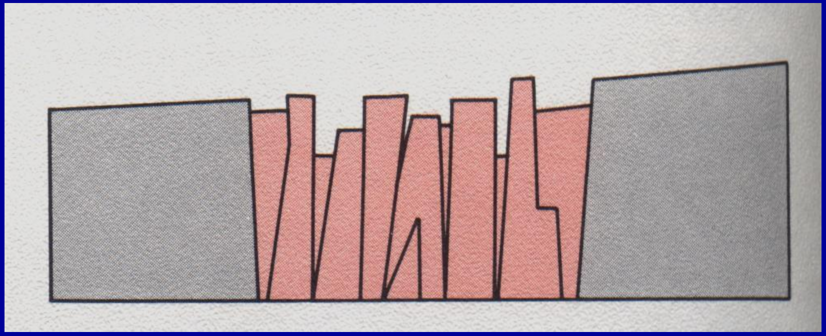
Bloom (1978)

Triangular facets aligned on the fault scarp of Maple Mountain, 15 km south of Provo, Utah. View east. (Photo: H. J. Bissell.)

Subsided blocks

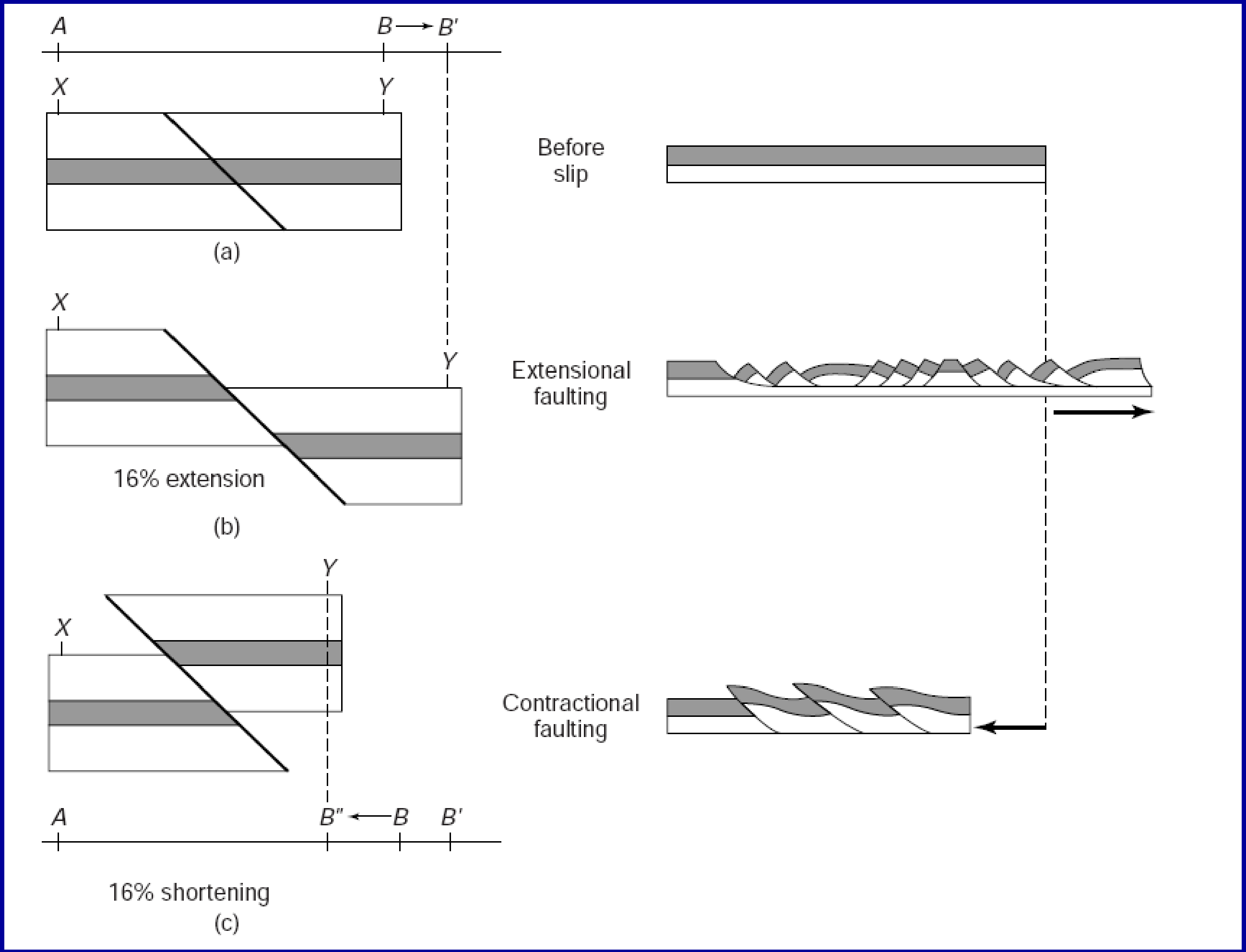
Narrow block subsided between two ridges uplifted by strands of San Andreas Fault

sags and ridges –
by uneven blocks uplift



Crustal shortening + thickening

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

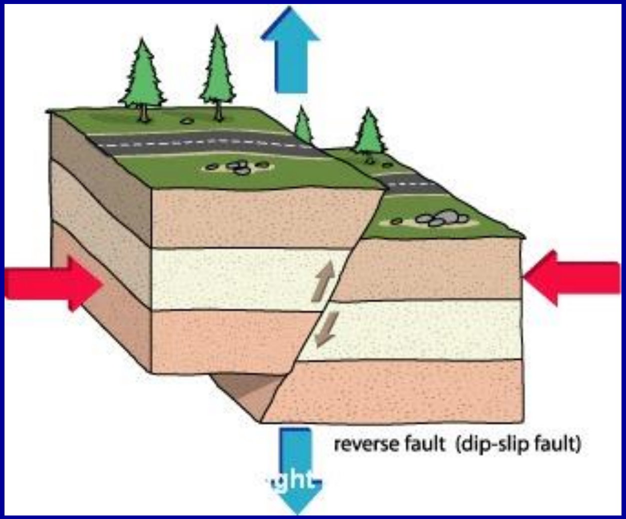


Reverse Faulting, Folding and Uplifting

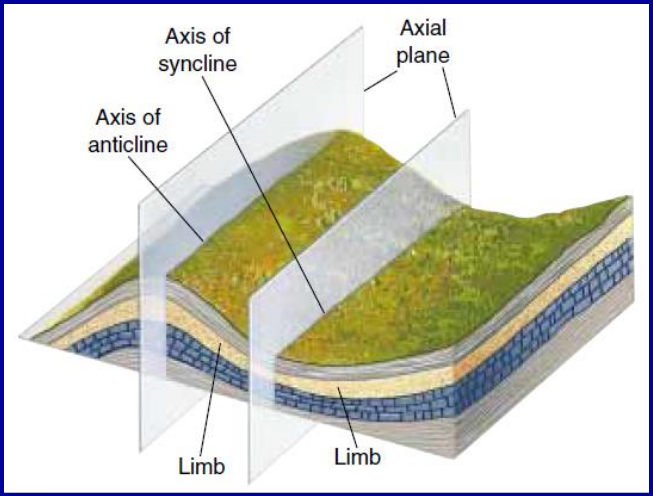
Crustal Shortening

- Implications :

  - Reverse/Thrust Fault

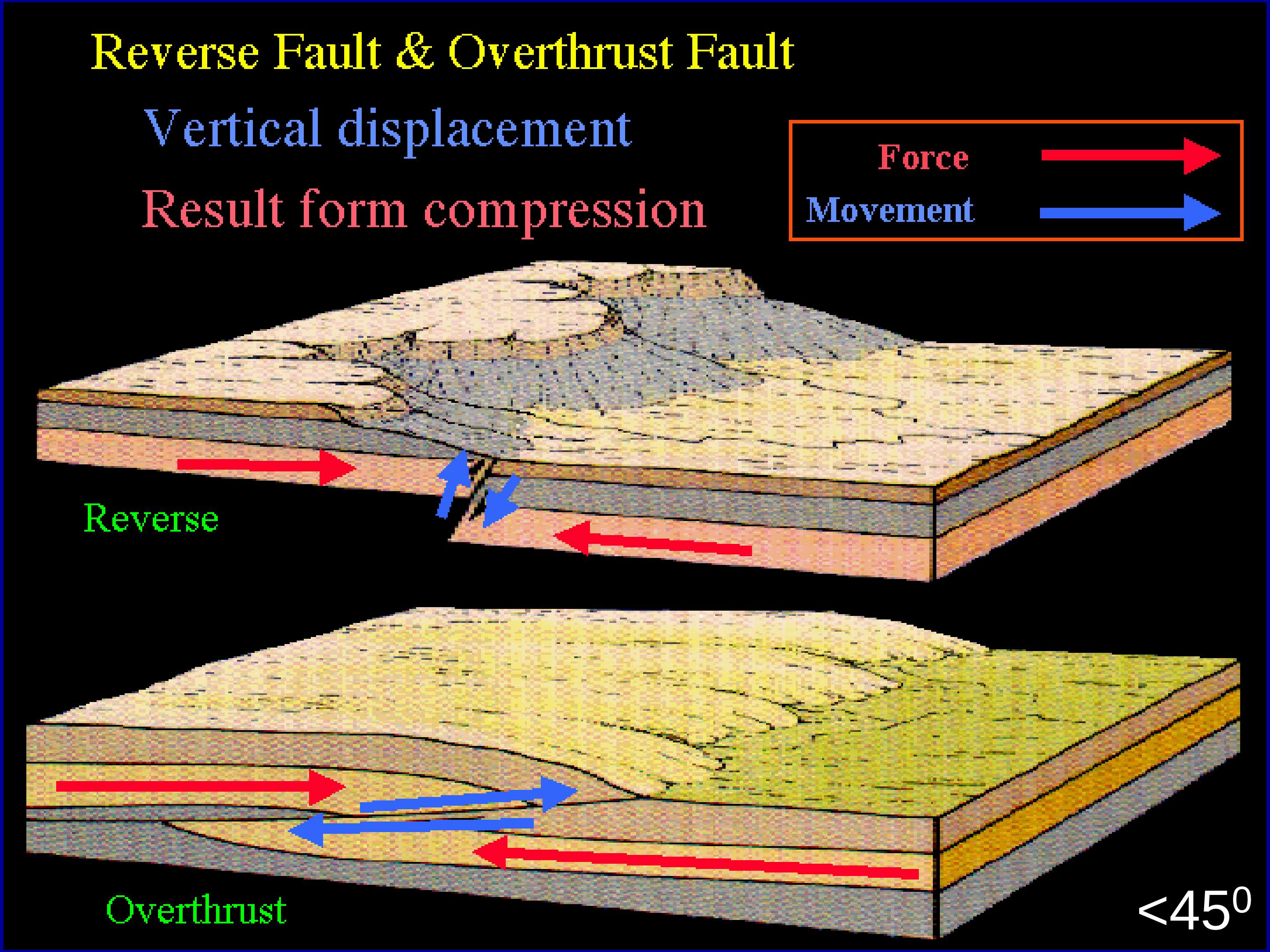


  - Fold



  - Uplift

Reverse – Thrust/overthrust Fault



Reverse Fault : > 45^0

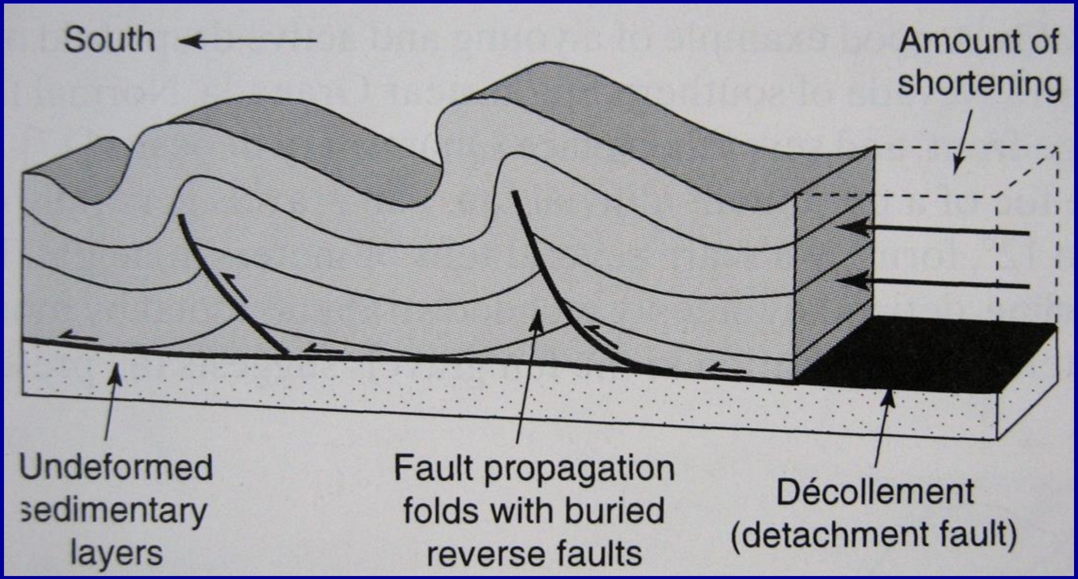
Menší slip – větší reliéf, ale menší oblast postižena

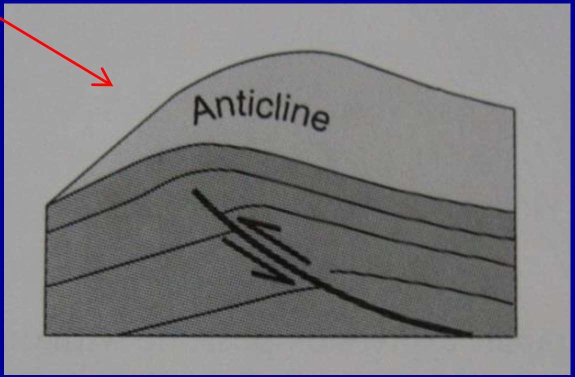
Thrust faults associated with subduction produce a variety of landforms –

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





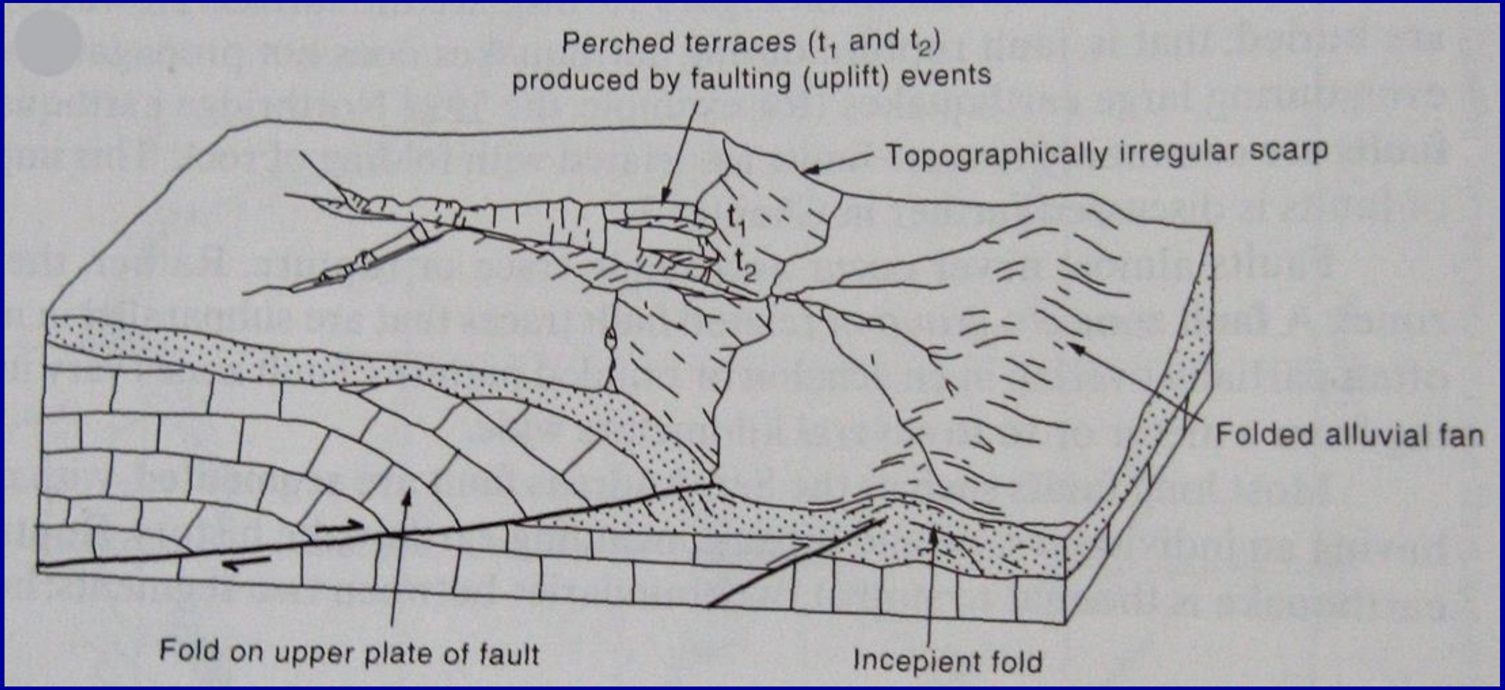
Asymmetric **fault-propagation fold** developed over a décollement

Reverse faults- closely related to folds

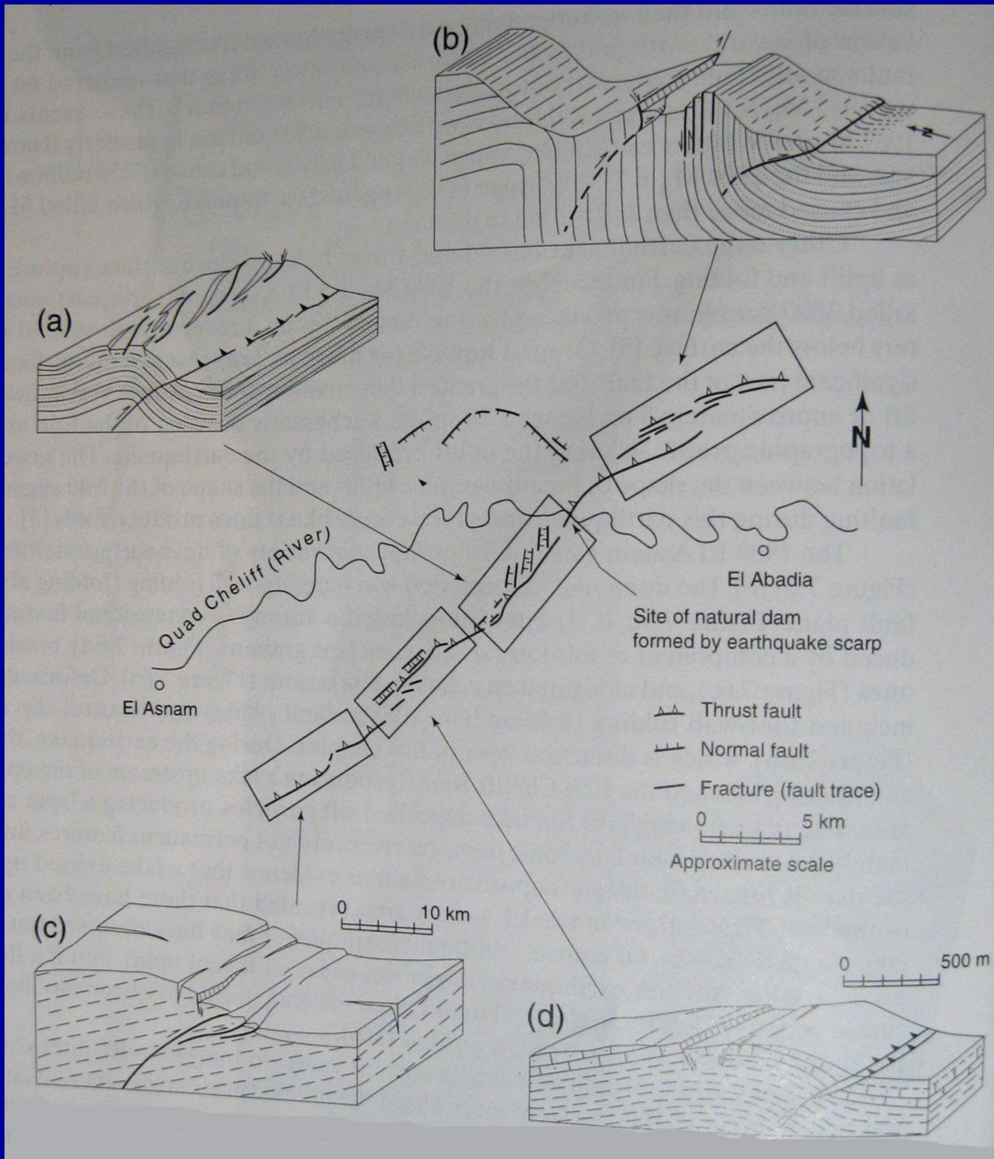
Rate of lateral propagation of faults and fold may be several times **higher than vertical slip rate** of the fault

Landforms associated with reverse faulting

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

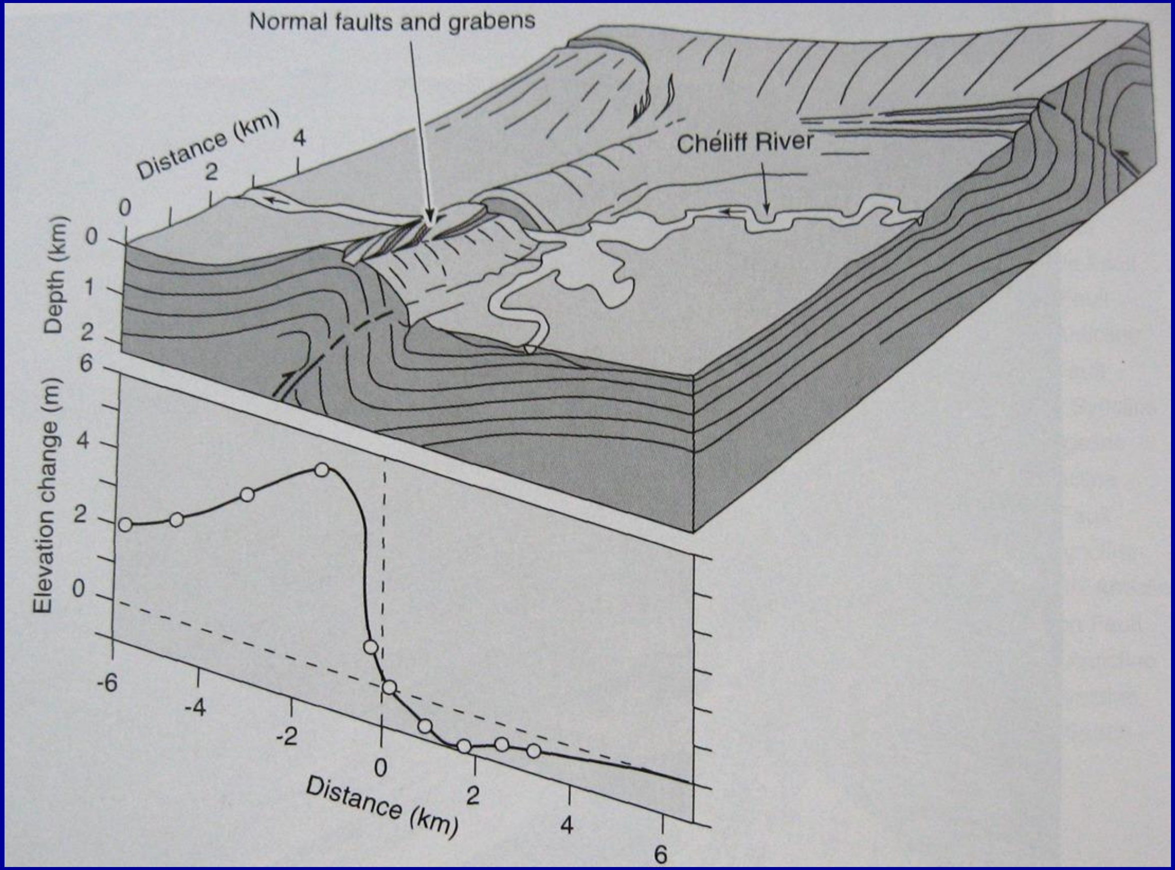


1980 EL Asnam M=7.3, Algeria – fold-and-thrust belt



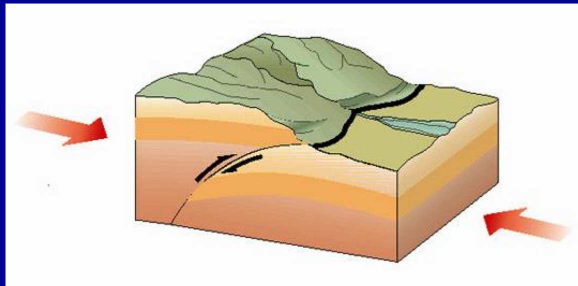
3-6 m slip on reverse fault at the depth,
surface rupture - 2m
mostly anticlinal uplift of 5m
– **seismic folding**

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 repeated earthquakes

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



Fault scarps

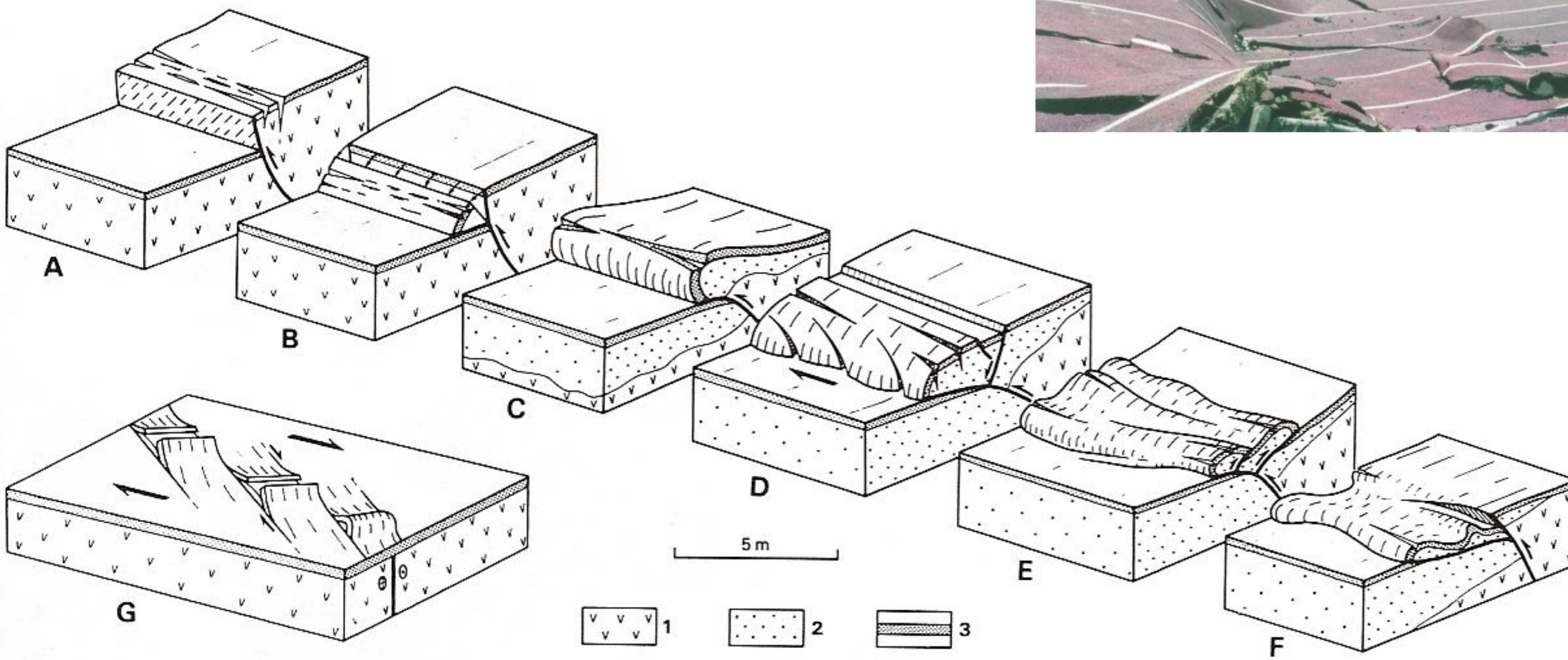
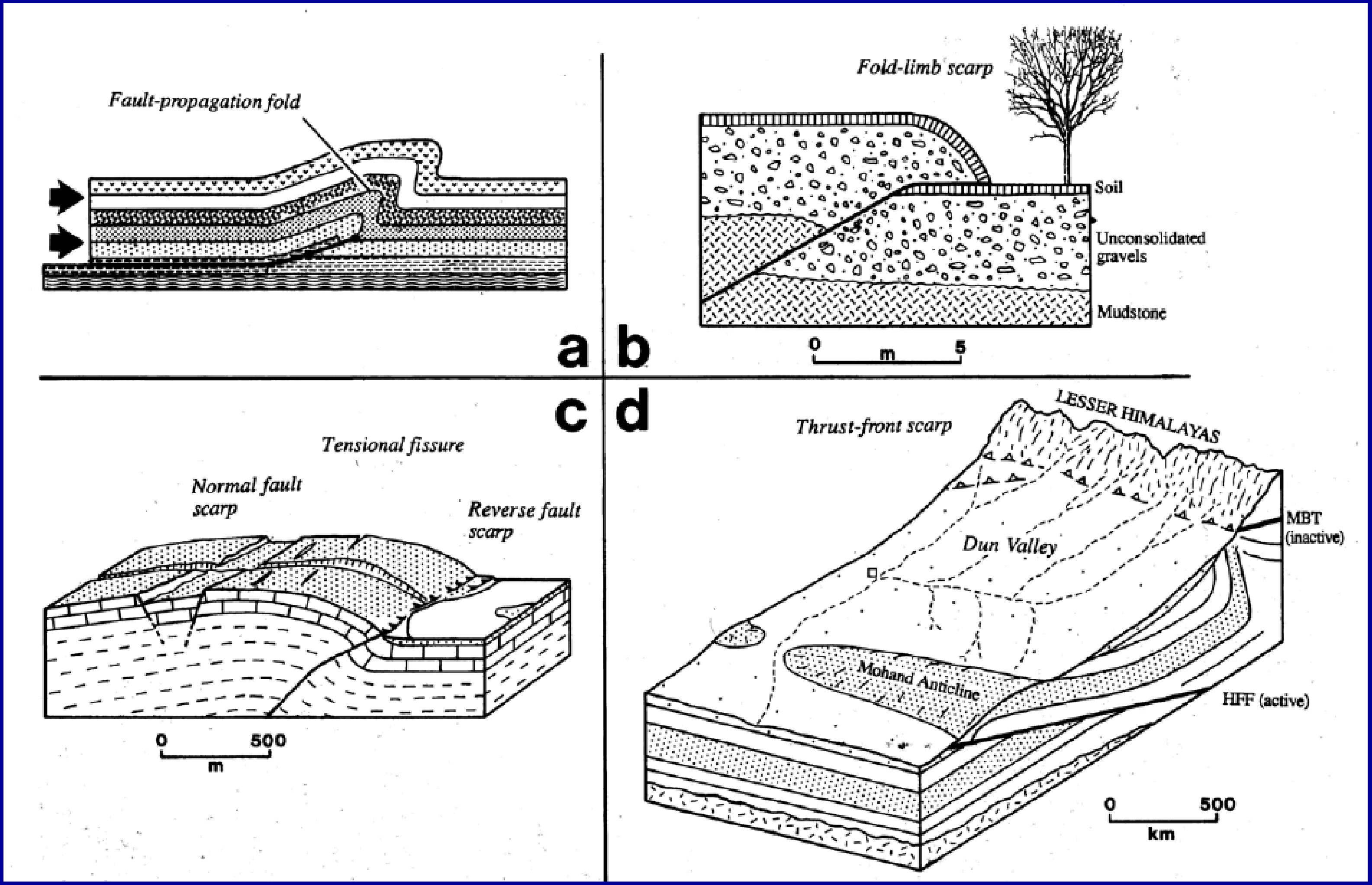


Figure 10–53. Fault-scarp features along the Spitak fault, Armenia. (a) simple thrust scarp; (b) hanging-wall collapse scarp; (c) simple pressure ridge; (d) dextral pressure ridge; (e) back-thrust pressure ridge; (f) low-angle pressure ridge: (g) en échelon pressure ridges. 1, bedrock; 2, soft Quaternary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



Fault-propagation fold
Fold-limb scarp
Soil
Unconsolidated gravels
Mudstone
0 m 5
a
b
c
d
Tensional fissure
Normal fault scarp
Reverse fault scarp
0 500
m
Thrust-front scarp
LESSER HIMALAYAS
MBT (inactive)
Dun Valley
Mohand Anticline
HFF (active)
0 500
km

Fold

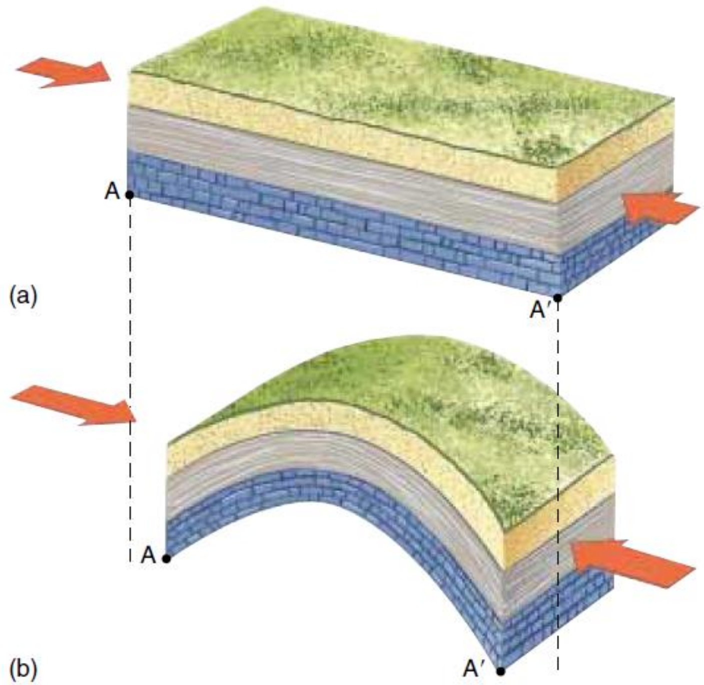
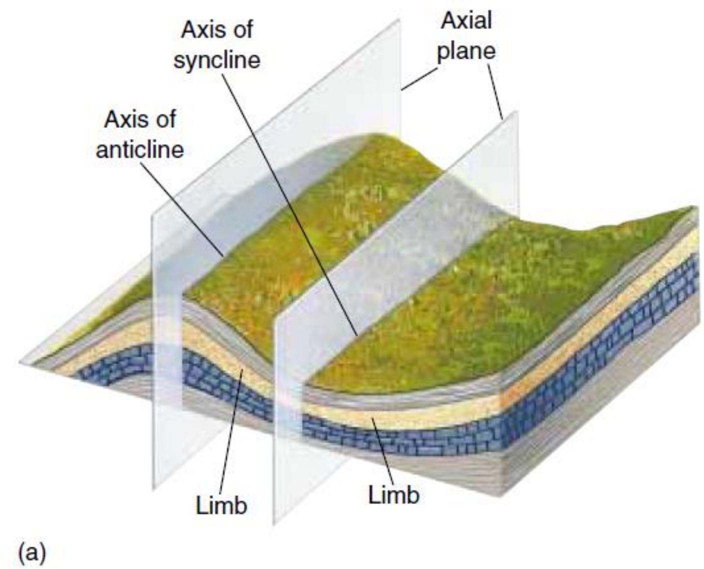
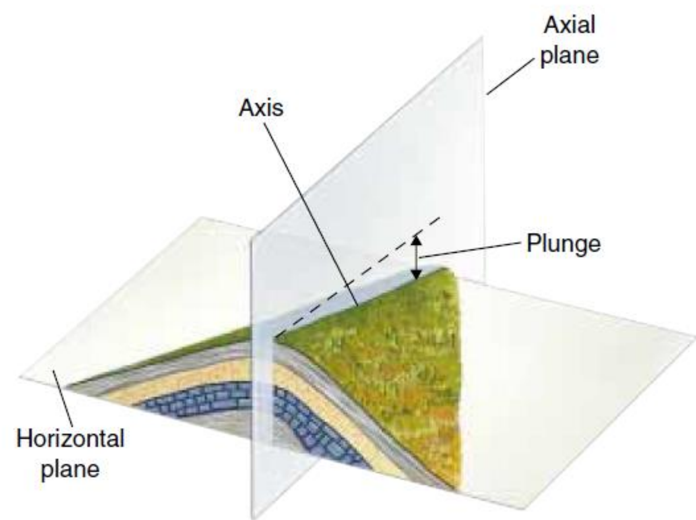
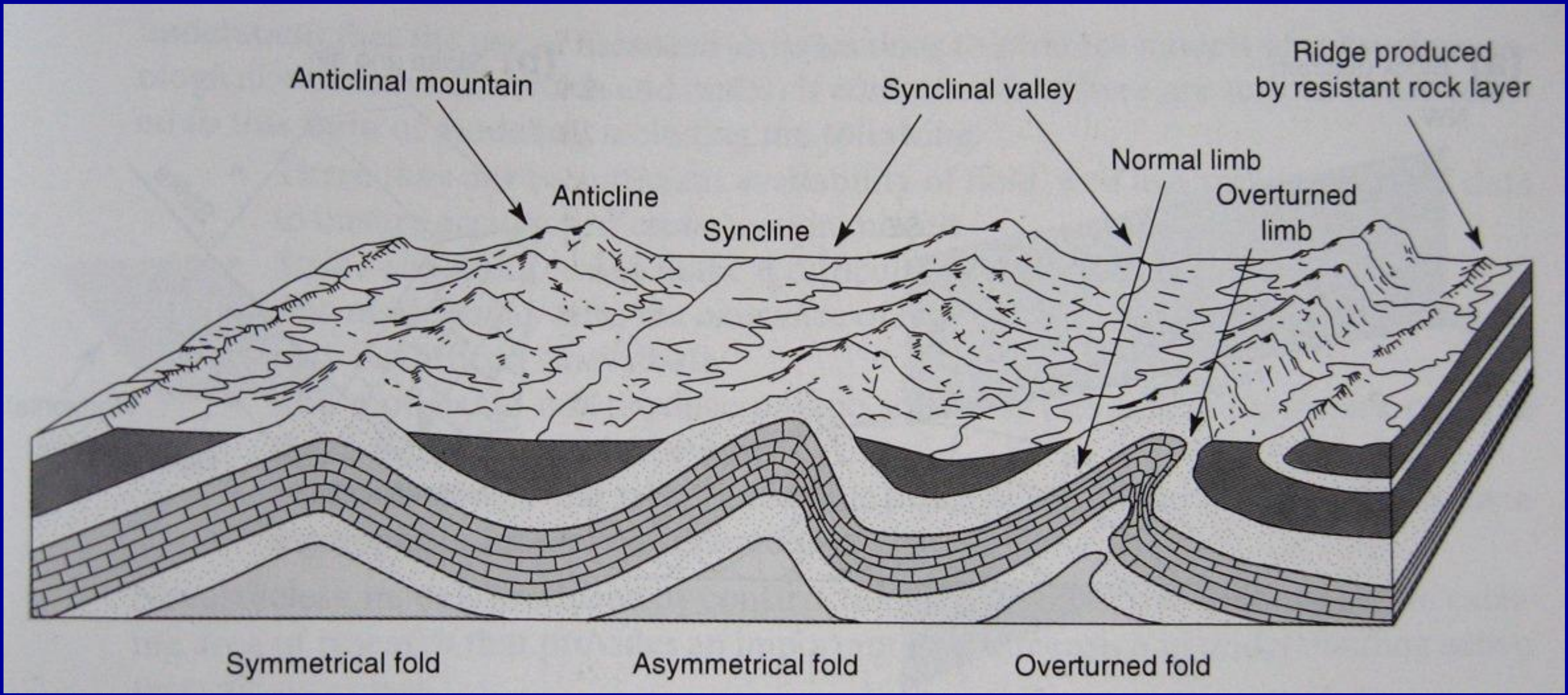


Figure 12–5 (a) Horizontally layered sedimentary rocks. (b) A fold in the same rocks. The forces that folded the rocks are shown by the arrows. Notice that points A and A′ are closer after folding.





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
Normal limb
Anticline
Overturned
limb
Syncline
Symmetrical fold
Asymmetrical fold
Overturned fold

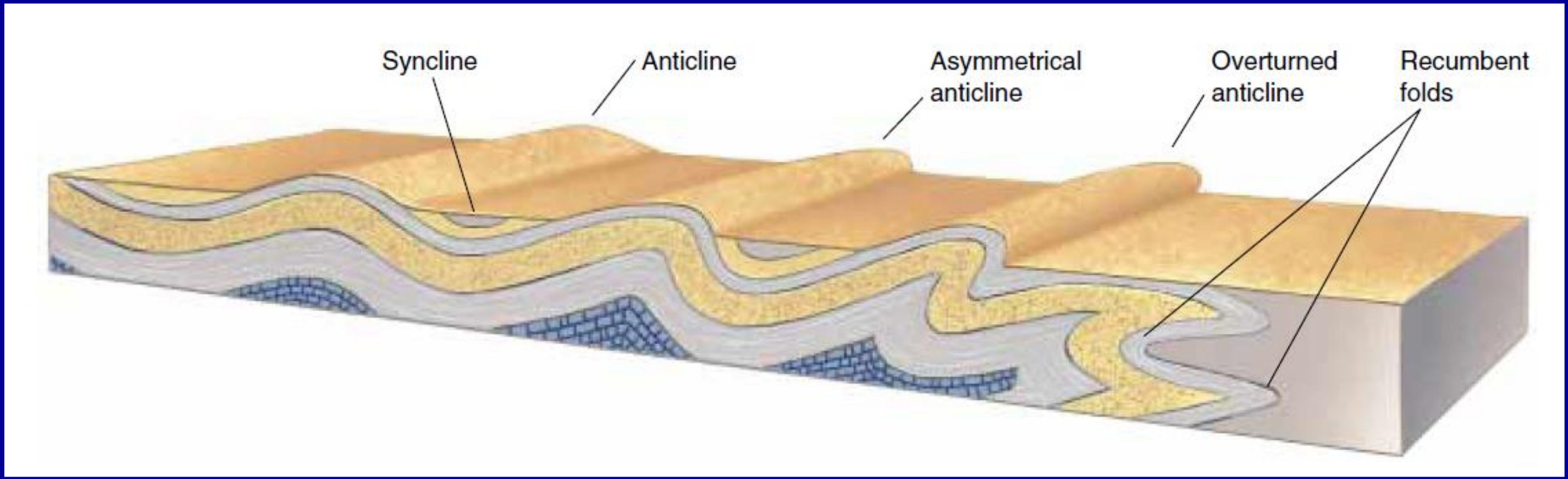

Syncline
Anticline
Asymmetrical
anticline
Overturned
anticline
Recumbent
folds

FIGURE 10.7 An asymmetric, plunging fold (the Sheep Mountain Anticline in Wyoming, USA). Thompson and Turk, 1998