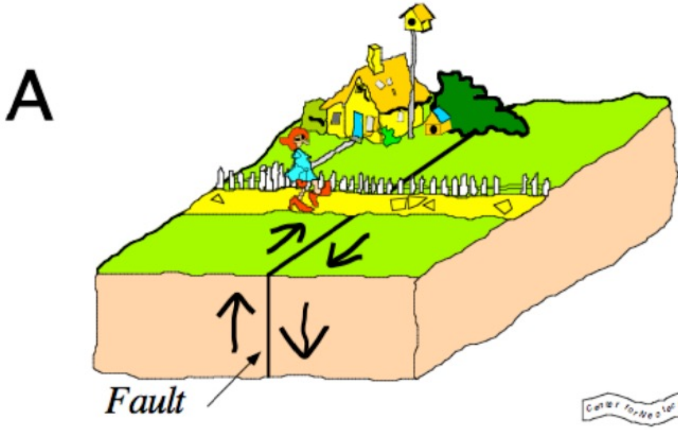
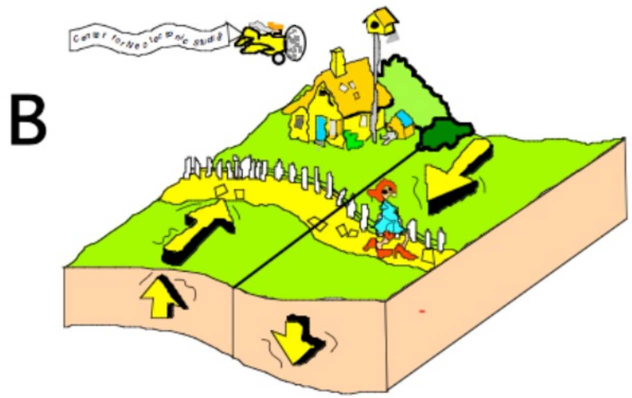
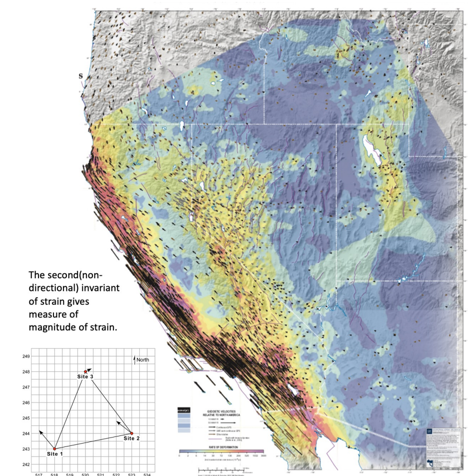
Seismicity and Earthquakes of Nevada and western U.S.

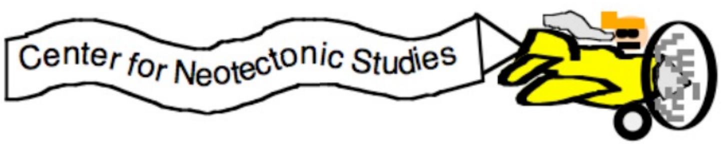
These are the contemporary release of accumulated strain registered by Geodesy.

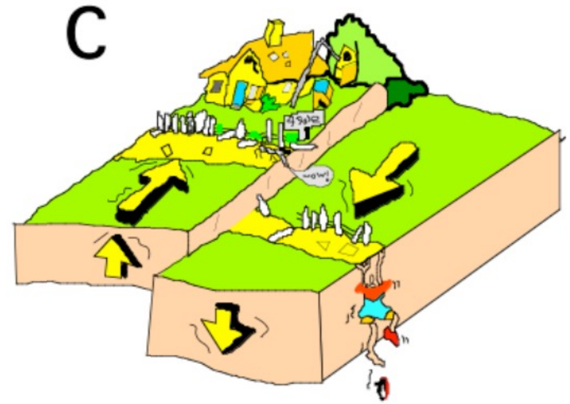


With stress – comes strain – and the ultimate and repeated failure of crustal rocks on faults – which in turn produce sound and leave both a geological and geomorphological signature....

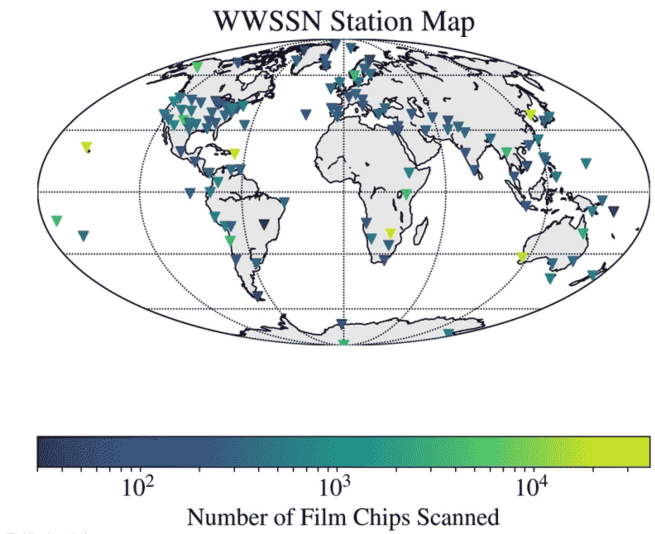






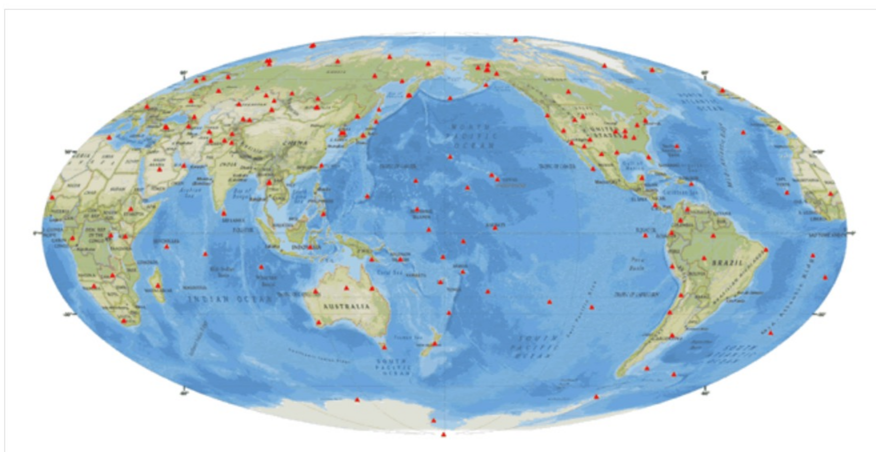


The sudden displacement produces vibrations- sound – which led to development of instruments and arrays to measure those sound to allow determination of the size and location of the source of the earthquakes.



The first global seismic network was developed in the 1960's – earthquake vibrations were recorded on paper and collected over months to years and sent to central facility to study particular earthquakes – this has morphed through time to real time recording across a network of more than 150 stations around the world...

GSN – Global Seismographic Network



- **Partners:**
  - Incorporated Research Institutions for Seismology (IRIS)
  - National Science Foundation (NSF)
  - University of California San Diego, IDA
  - Comprehensive Test Ban Treaty Organization
  - Federation of Digital Broad-Band Seismograph Networks (FDSN)

With over 150 permanent station recording continuously this network is aimed at monitoring the largest and longest period seismic waves, and thus the largest earthquakes, around the globe.

National Earthquake Information Center (NEIC)

The NEIC collects data through the operation of national and global networks, and through cooperative agreements. To enable the detection and location of all felt earthquakes with the U.S.

the NEIC acts as the National Operations Center of the Advanced National Seismic System (ANSS), a cooperative venture between the NEIC and the operators of the regional seismic networks across the United States.

The NEIC is the national data center and archive for earthquake information.

QuakeFeed – their app – should be on your phone

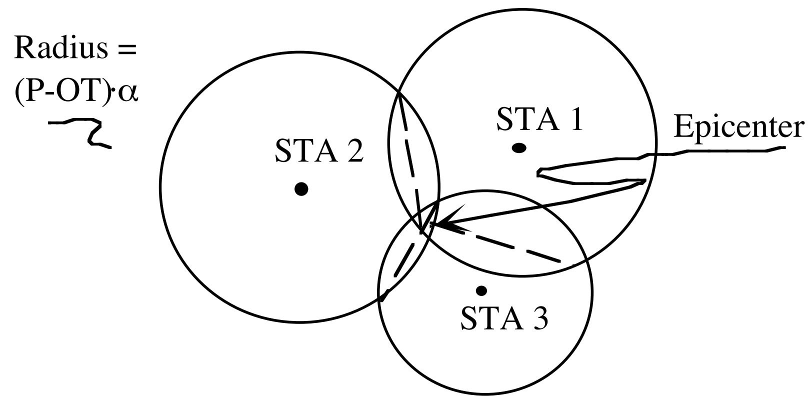
Locating earthquakes employs same principles as locating GPS receivers

Important point is that the accuracy of

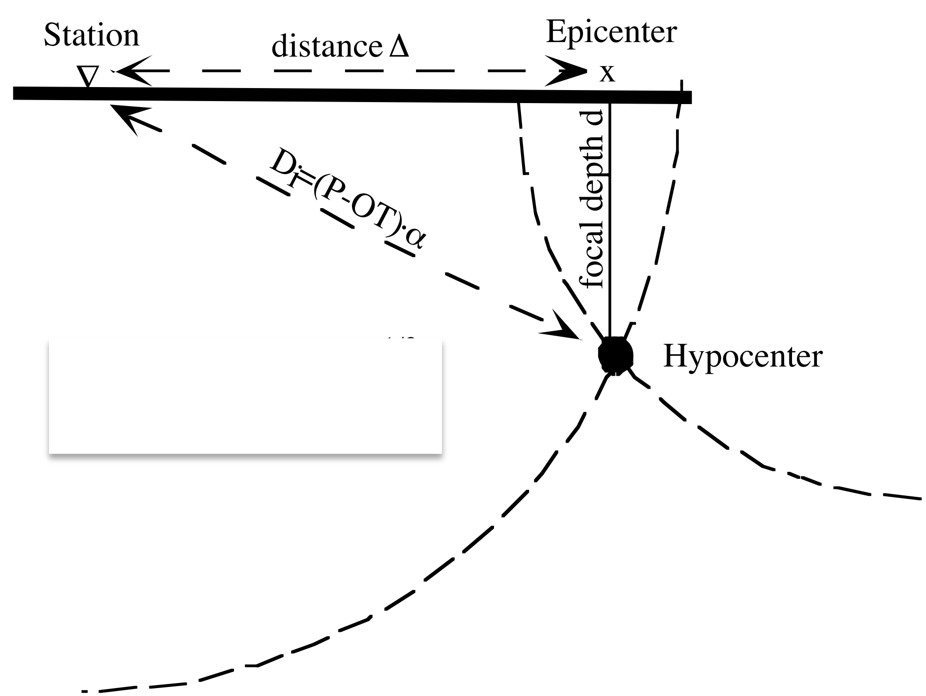
EPICENTER
And
FOCAL DEPTH

Determinations is a function of how dense is the station spacing in the networks.

Map View to illustrate epicenter determination

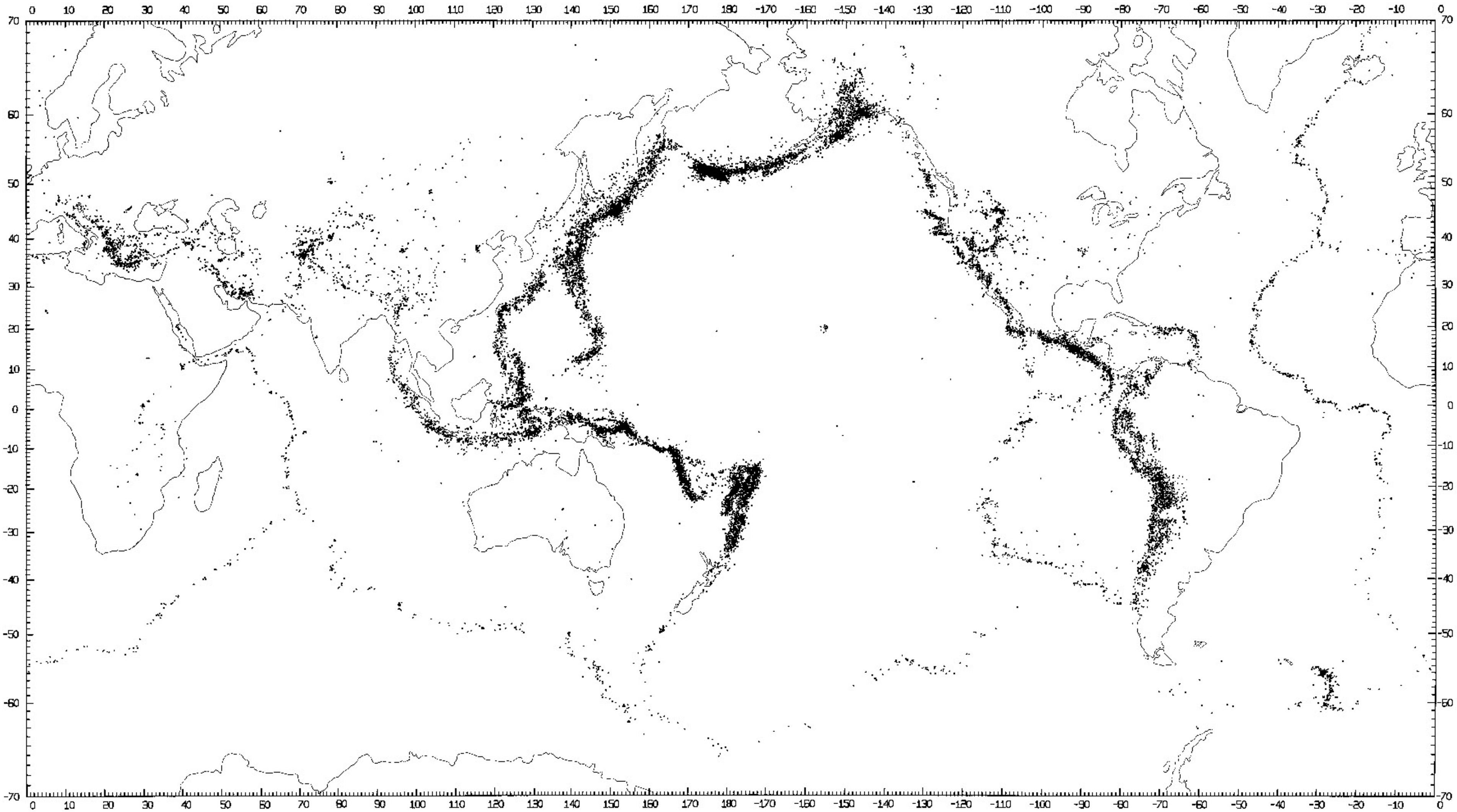


Cross Section to illustrate focal depth determination



Focal depth = sqrt $(D^2-\Delta^2)$

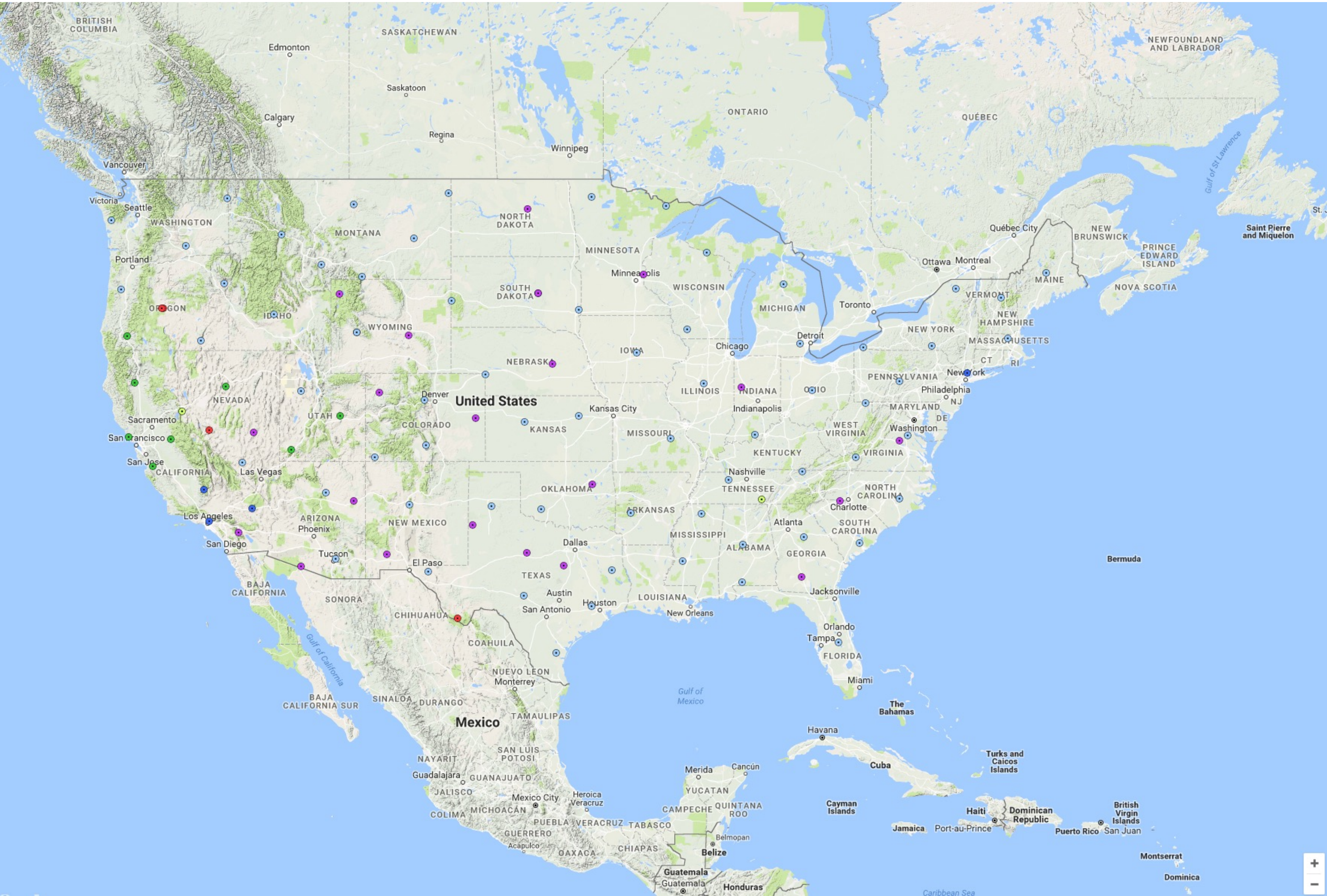
This first plot of the global pattern of seismicity by Barazangi and Dorman dates to the 1960s – implication-> the data provide a picture of tectonic strain release at best ‘complete’ over the last ~50 years....



SEISMICITY OF THE EARTH, 1961-1967, ESSA, CGS EPICENTERS

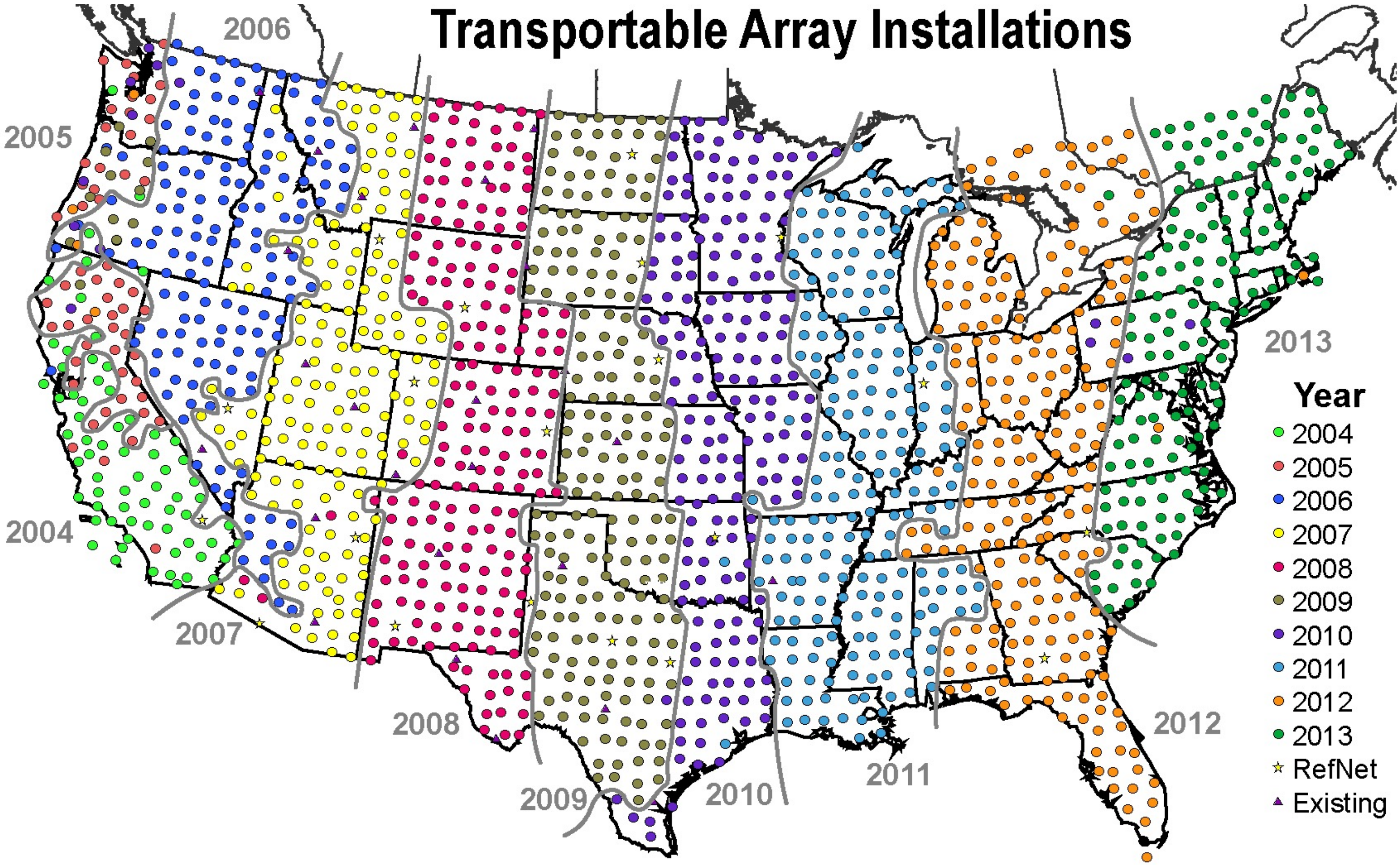
DEPTHS 000-700 KM.

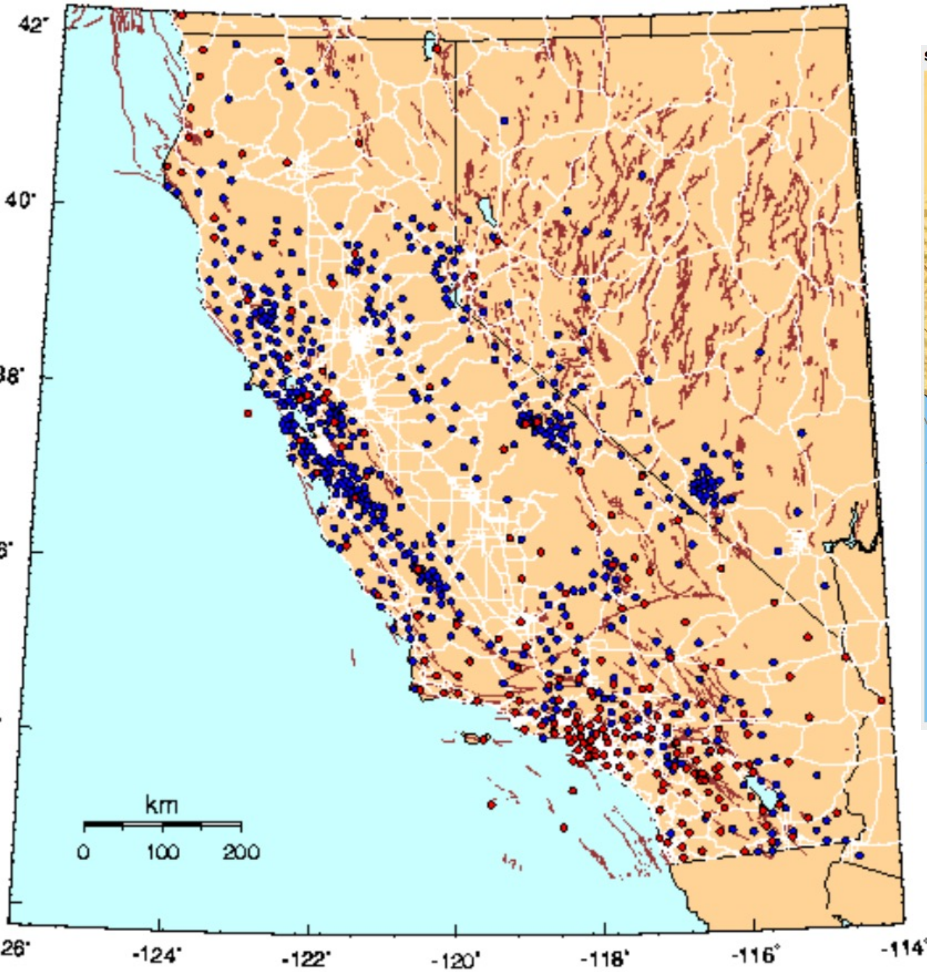
US Array (reference stations) – A continental-scale network (part of ANSS)
One of 3 components of 'EARTHSCOPE' project funded by NSF – This dates to ~2006...



US Array (Transportable stations)

400 high-quality broadband seismographs leap frogges across the conterminous US.

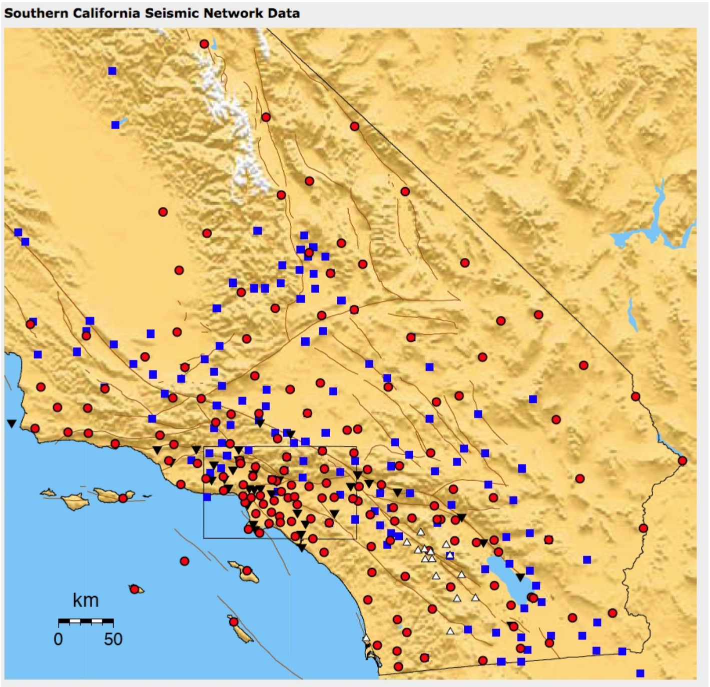




CISN
California Integrated
Seismic Network

California and western Nevada by the numbers (*as of June 2002*):

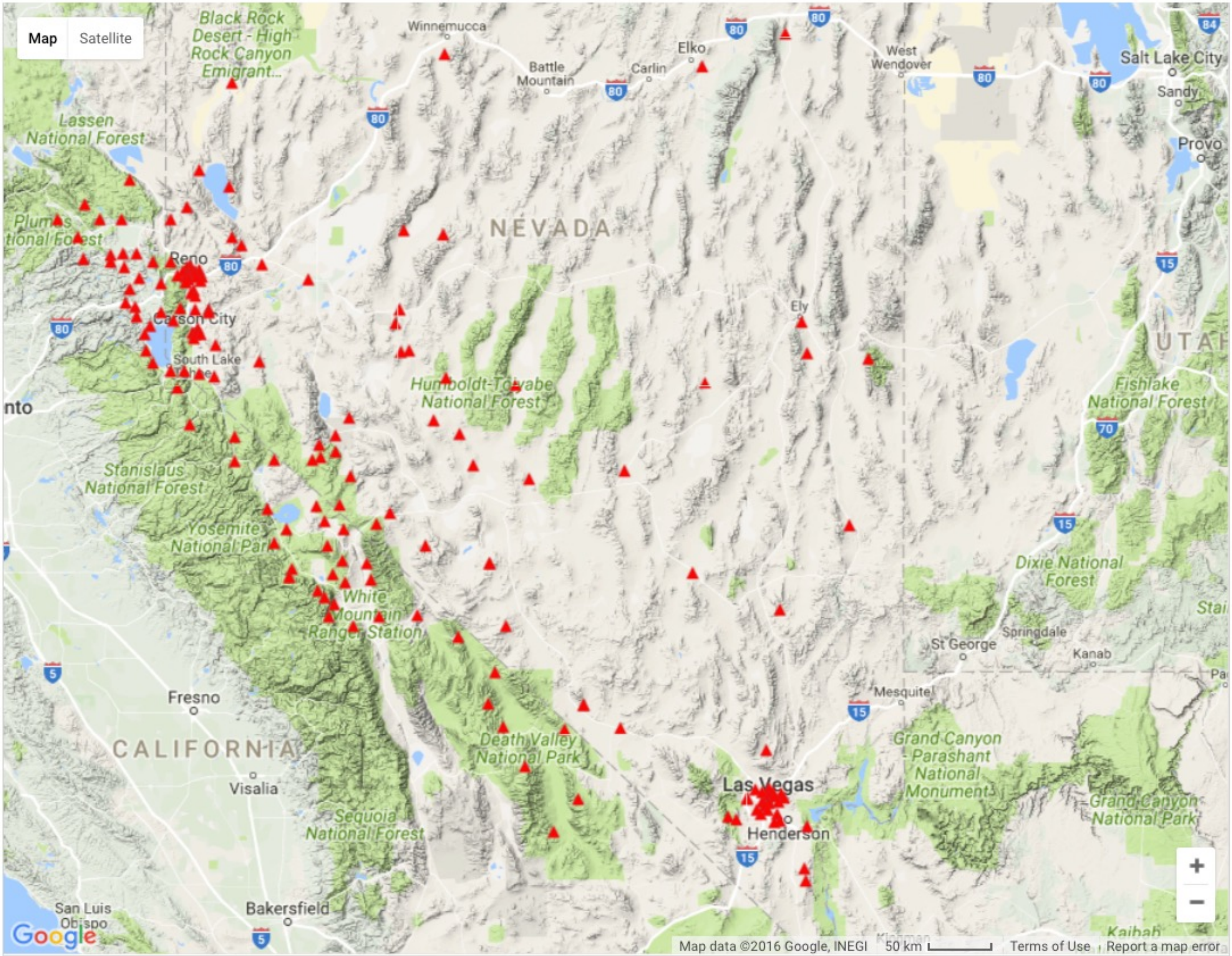
- 614 short-period sensors
- 198 broadband sensors
- 1563 strong-motion sensors (~460 without communications)
- 708 instrumented structures (lifelines, dams, buildings)
- 38 borehole installations

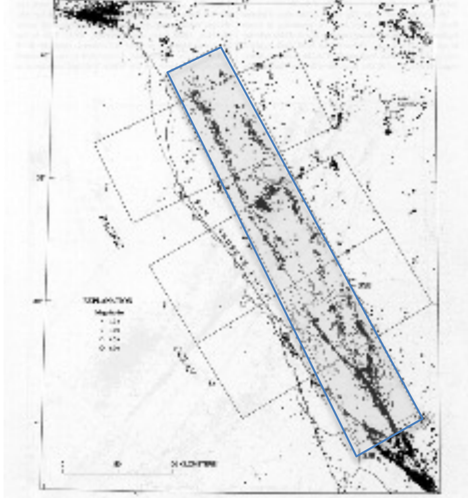


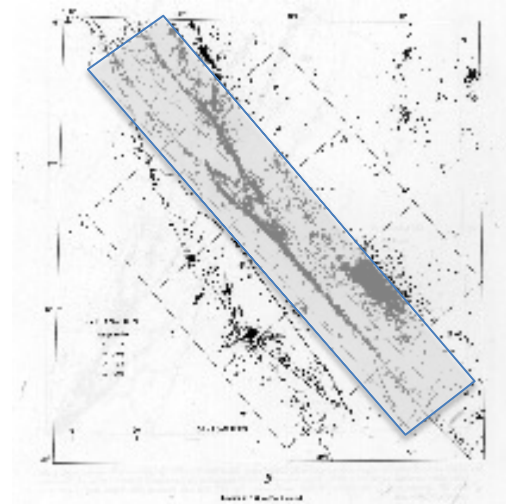
The Southern California Seismic Network (SCSN) records data from more than 370 seismic stations. Each station records seismic waves from both near and distant earthquakes. All the data are transmitted automatically to Caltech/USGS in Pasadena for processing and distribution of information such as epicenters, magnitudes, and ShakeMaps. The SCSN is also part of the California Integrated Seismic Network (CISN) that coordinates earthquake monitoring statewide. The symbols indicate different types of seismic stations.

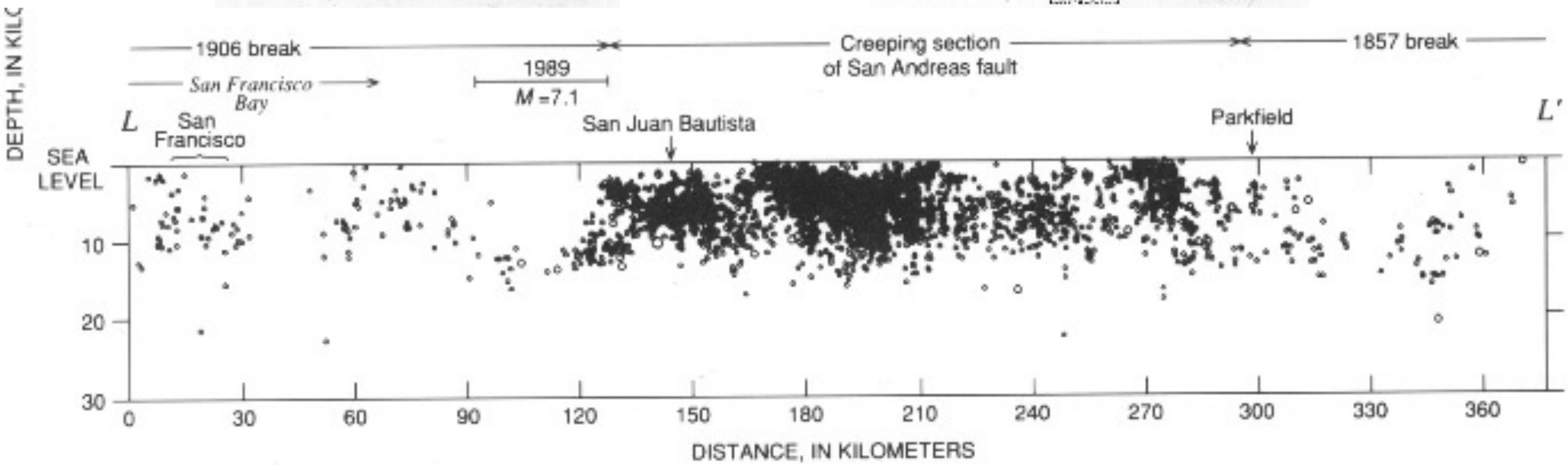
UNR Seismo Lab ‘Nevada Seismic Network’

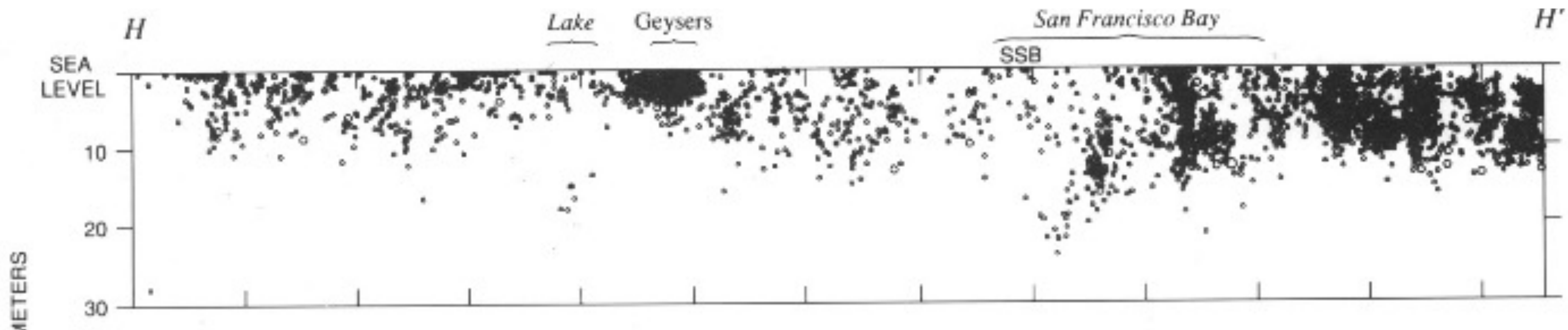
http://www.fdsn.org/networks/

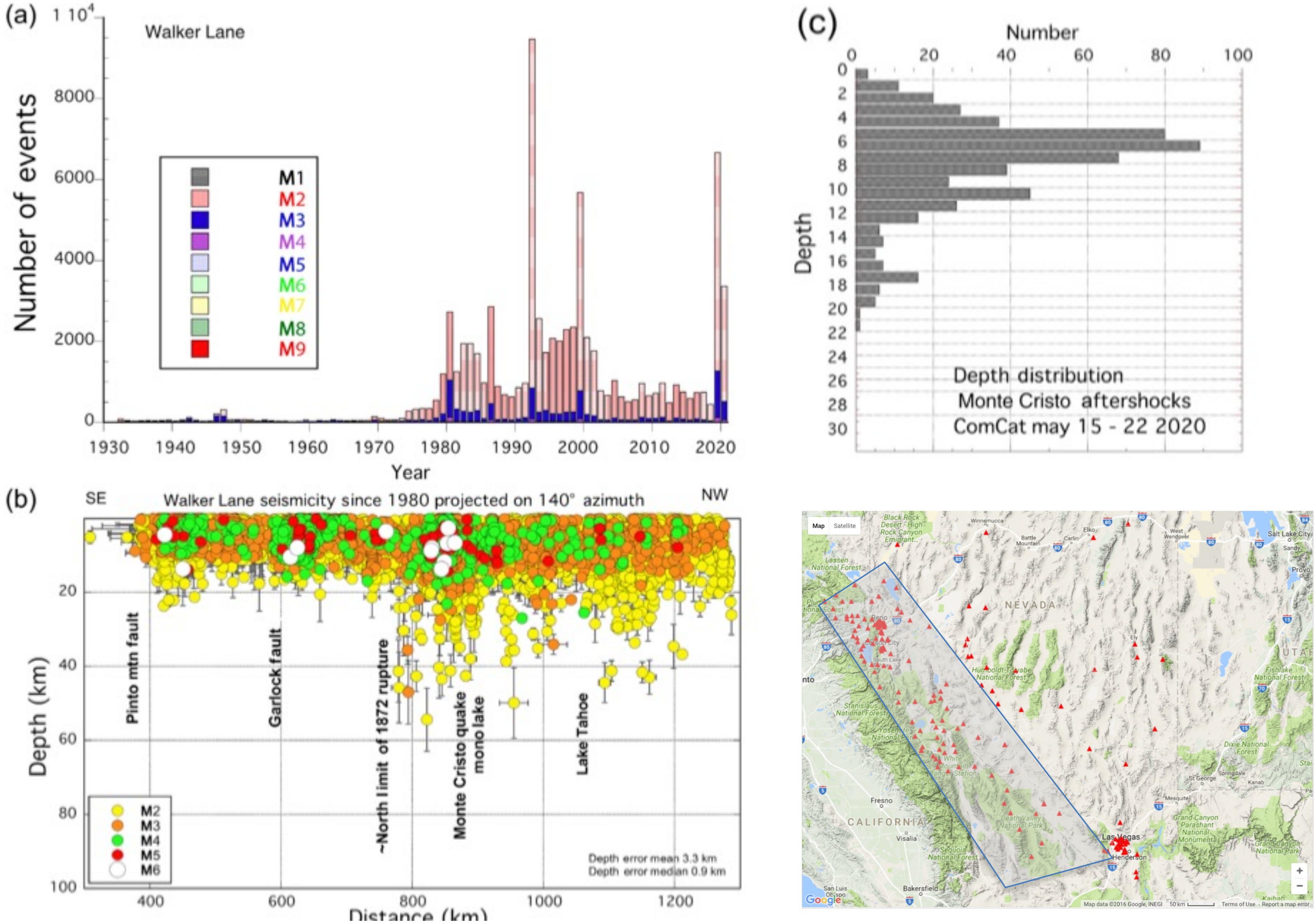


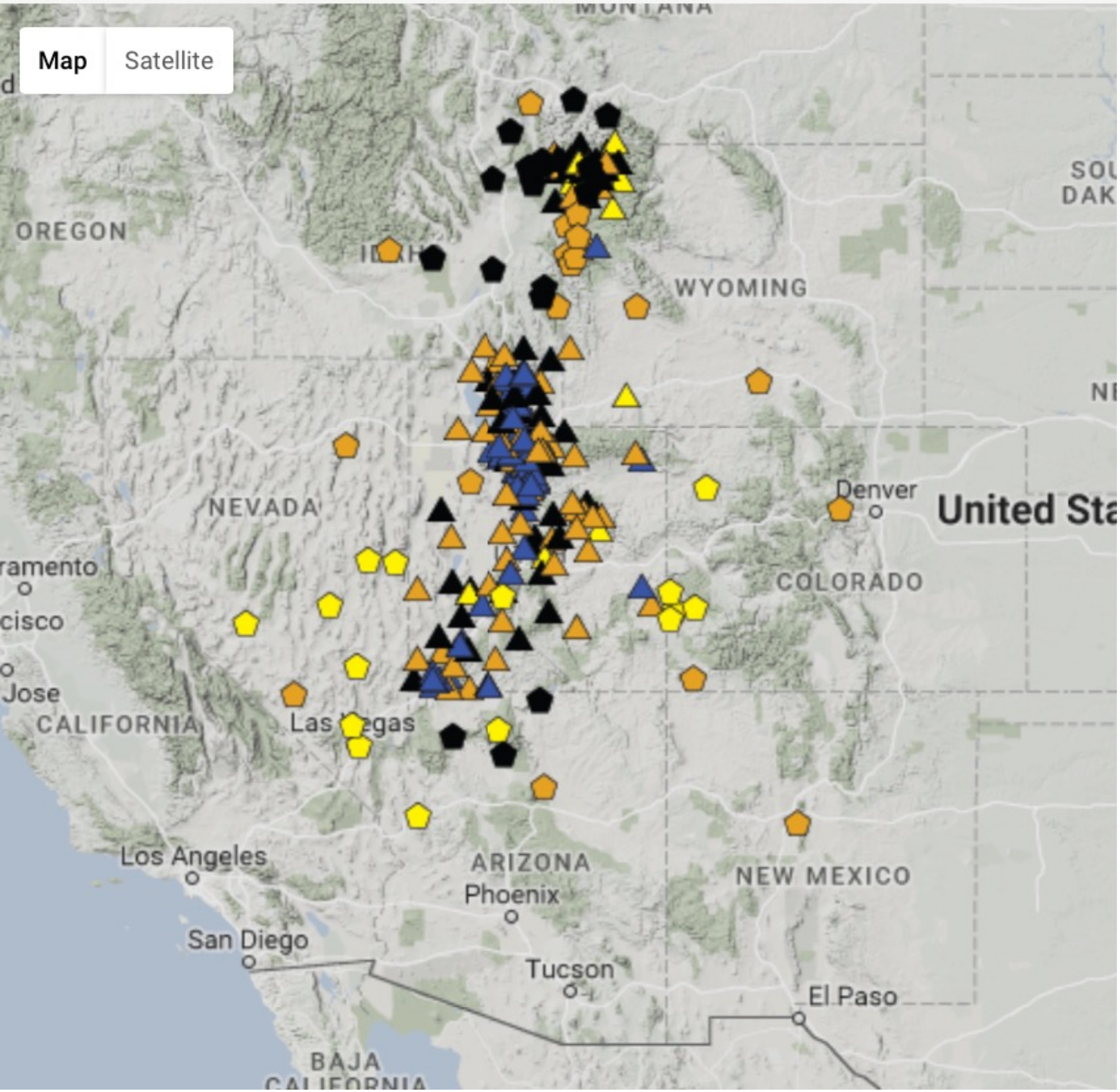





DEPTH, IN KILOMETERS
1906 break
Creeping section
of San Andreas fault
1857 break
San Francisco
Bay
1989
M =7.1
L
L′
San
Francisco
San Juan Bautista
Parkfield
SEA
LEVEL
10
20
30
0
30
60
90
120
150
180
210
240
270
300
330
360
DISTANCE, IN KILOMETERS

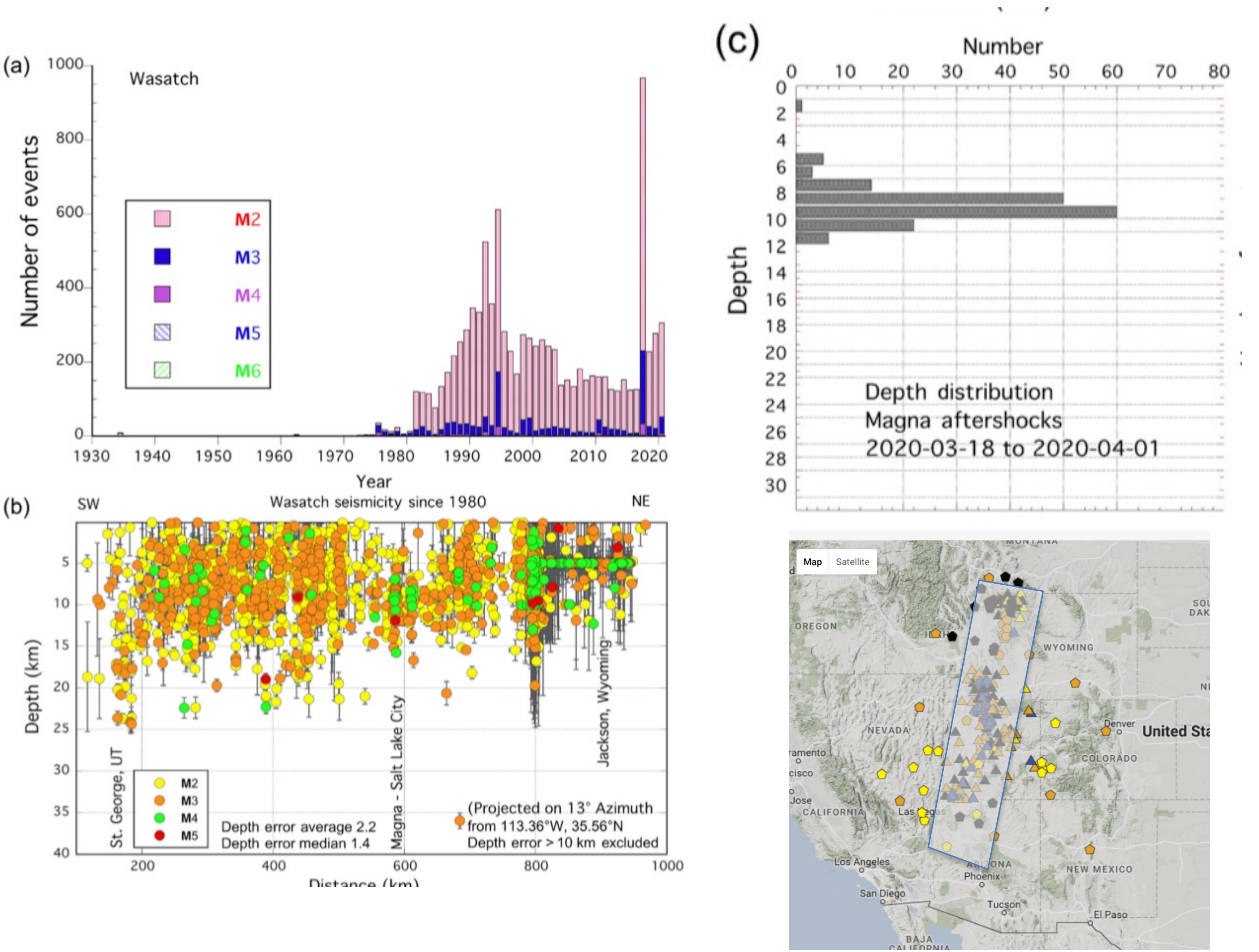

H
H′
Lake
Geysers
San Francisco Bay
SSB
SEA
LEVEL
10
20
30


(a)
Walker Lane
Number of events
1 10^4
8000
6000
4000
2000
0
M1
M2
M3
M4
M5
M6
M7
M8
M9
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
(b)
SE
Walker Lane seismicity since 1980 projected on 140° azimuth
NW
Depth (km)
20
40
60
80
100
Pinto mtn fault
Garlock fault
~North limit of 1872 rupture
Monte Cristo quake
mono lake
Lake Tahoe
M2
M3
M4
M5
M6
Depth error mean 3.3 km
Depth error median 0.9 km
400
600
800
1000
1200
Distance (km)
(c)
Number
0
20
40
60
80
100
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Depth distribution
Monte Cristo aftershocks
ComCat may 15 - 22 2020
NEVADA
CALIFORNIA
UTAH
Reno
Las Vegas
Henderson
Fresno
Visalia
Bakersfield
Map data ©2016 Google, INEGI

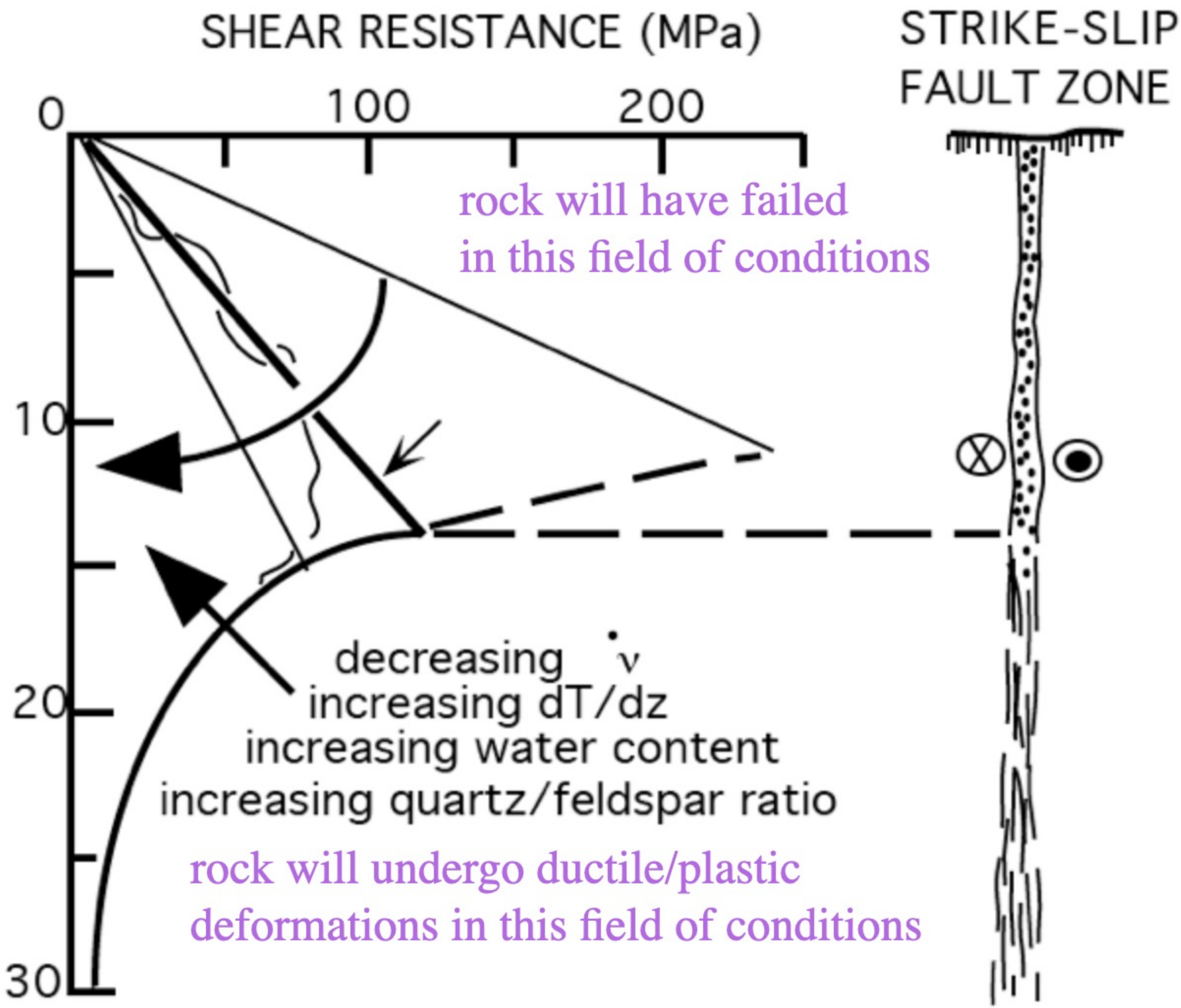


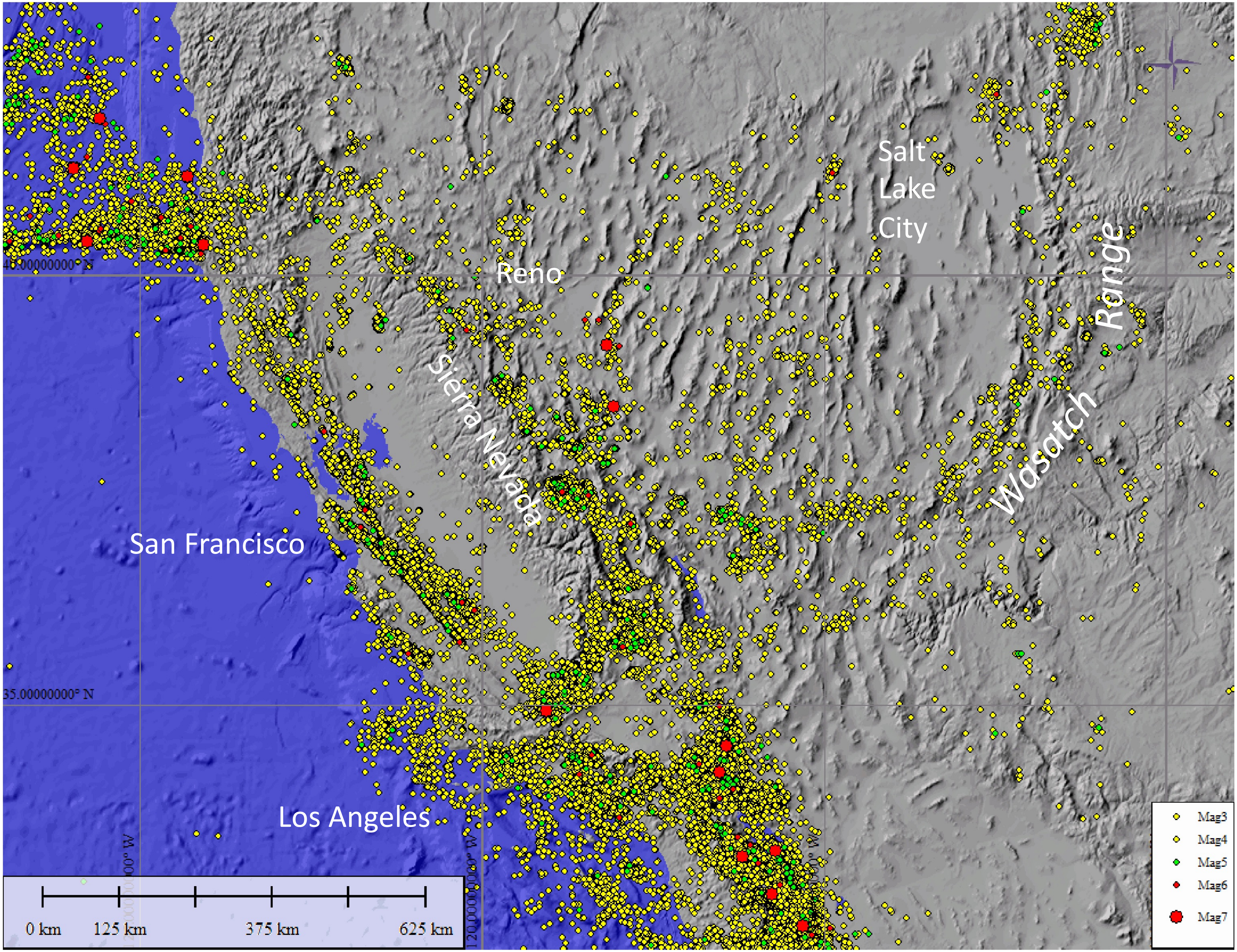
Orange – broadband
Yellow - broadband
Black – short period
Blue – strong ground motion

University of Utah Seismograph Stations.

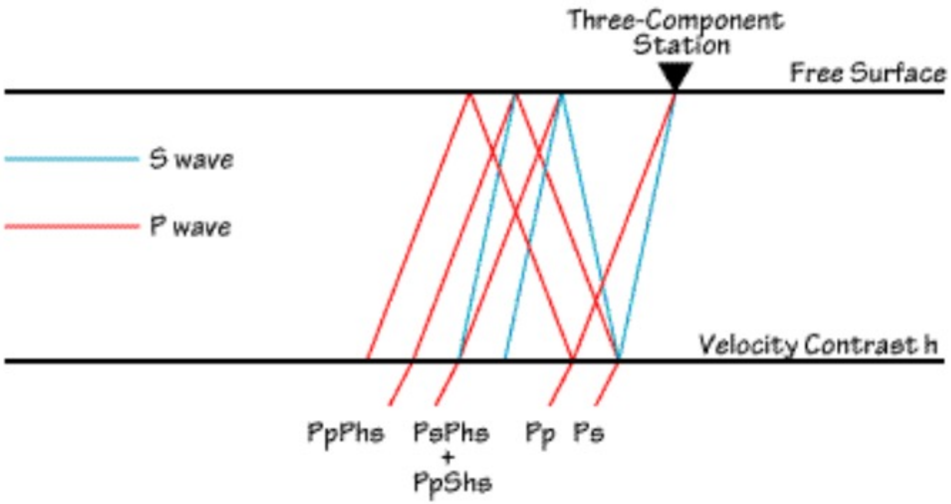


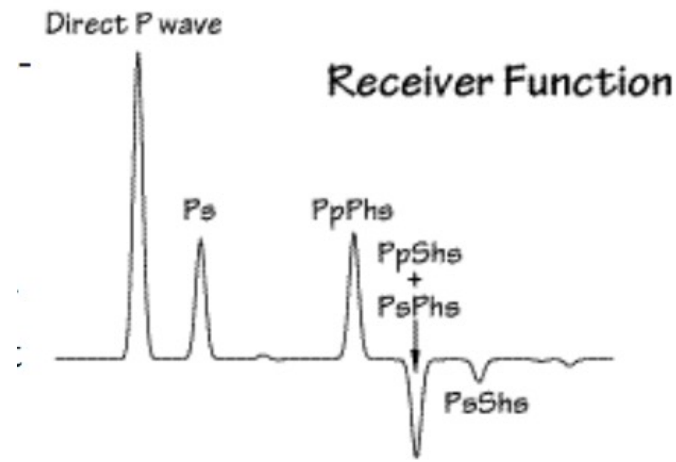
(a)
Wasatch
Number of events
1000
800
600
400
200
0
M2
M3
M4
M5
M6
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year
(b)
SW
Wasatch seismicity since 1980
NE
Depth (km)
5
10
15
20
25
30
35
40
St. George, UT
Magna - Salt Lake City
Jackson, Wyoming
M2
M3
M4
M5
Depth error average 2.2
Depth error median 1.4
(Projected on 13° Azimuth
from 113.36°W, 35.56°N
Depth error > 10 km excluded
200
400
600
800
1000
Distance (km)
(c)
Number
0
10
20
30
40
50
60
70
80
Depth
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Depth distribution
Magna aftershocks
2020-03-18 to 2020-04-01
Map
Satellite
MONTANA
OREGON
WYOMING
NEVADA
COLORADO
CALIFORNIA
Denver
United Sta
Los Angeles
San Diego
Phoenix
Tucson
El Paso
NEW MEXICO
ARIZONA
BAJA

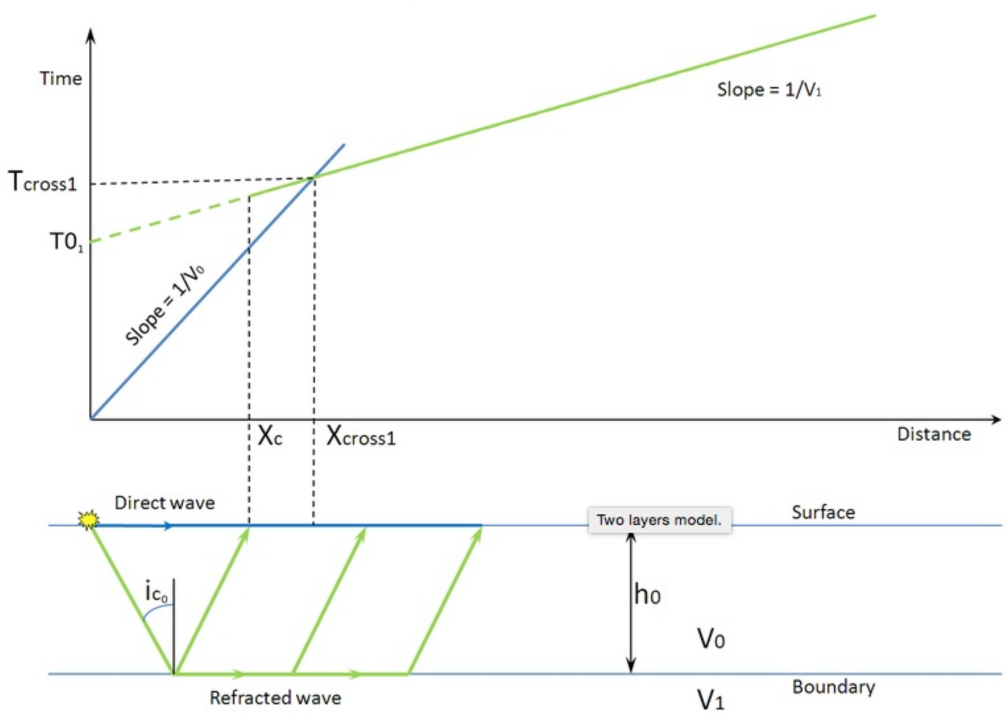

SHEAR RESISTANCE (MPa)
STRIKE-SLIP
FAULT ZONE
0
100
200
10
20
30
rock will have failed
in this field of conditions
decreasing $\dot{v}$
increasing dT/dz
increasing water content
increasing quartz/feldspar ratio
rock will undergo ductile/plastic
deformations in this field of conditions


Salt
Lake
City
Reno
Sierra Nevada
Wasatch Range
San Francisco
Los Angeles
40.00000000° N
35.00000000° N
0 km
125 km
375 km
625 km
Mag3
Mag4
Mag5
Mag6
Mag7

Also arising from Seismological Studies – Information of thickness of CRUST







Both little and large earthquakes provide ability to look at velocity structure of the crust.

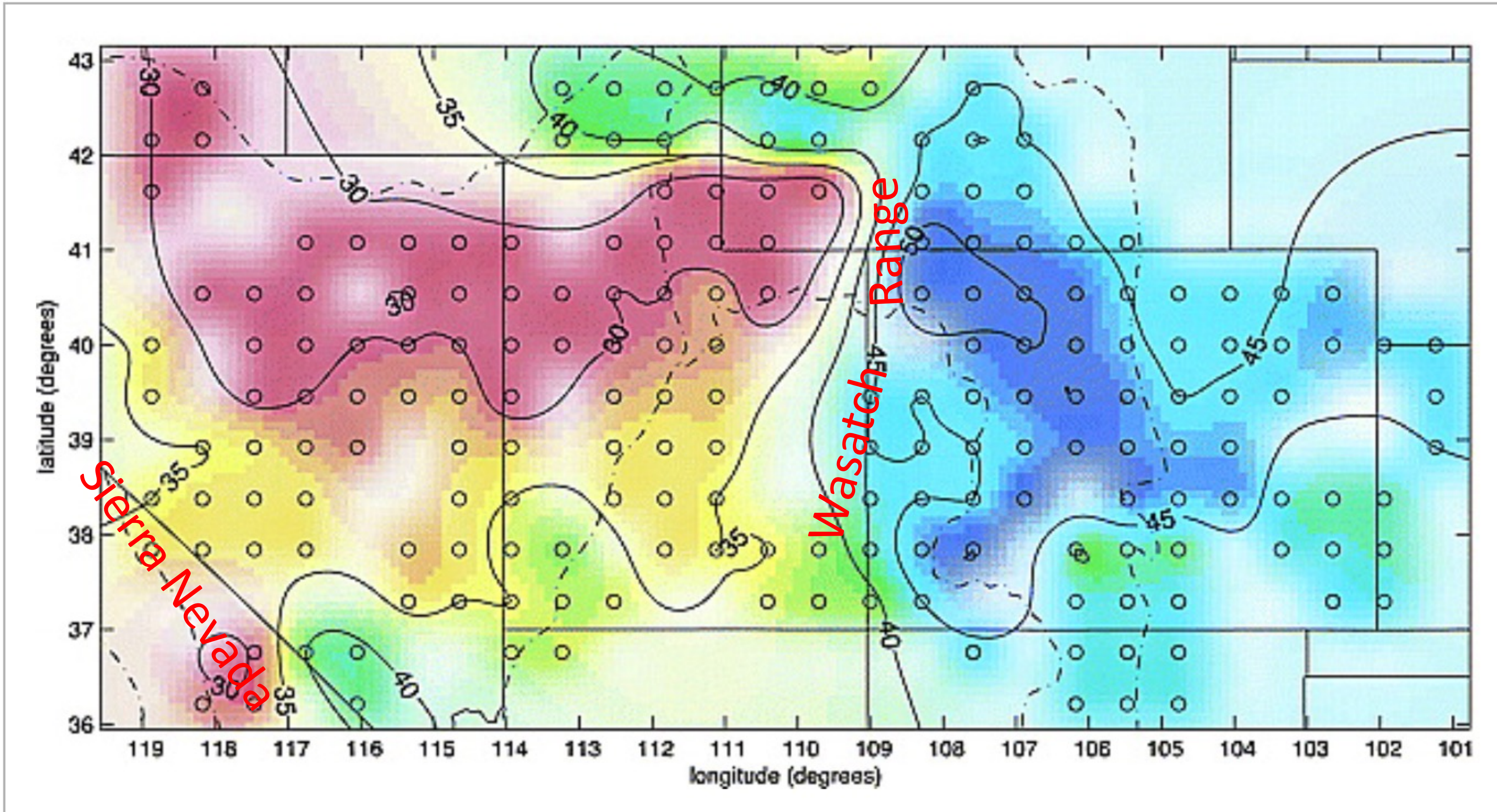
Depth of MOHO – generally considered the boundary between crust and mantle. It is expressed as a rapid velocity increase and associated with a distinct chemical/mineralogic change.

Map of Crustal Thickness (Depth to Moho). Values range from 30 to 50 km. Blue is thicker, Red is thinner.

Images of crustal variations in the intermountain west

By: Gilbert, HJ; Sheehan, AF

JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH Volume: 109 Issue: B3 Article Number: B03306 Published: MAR 20 2004

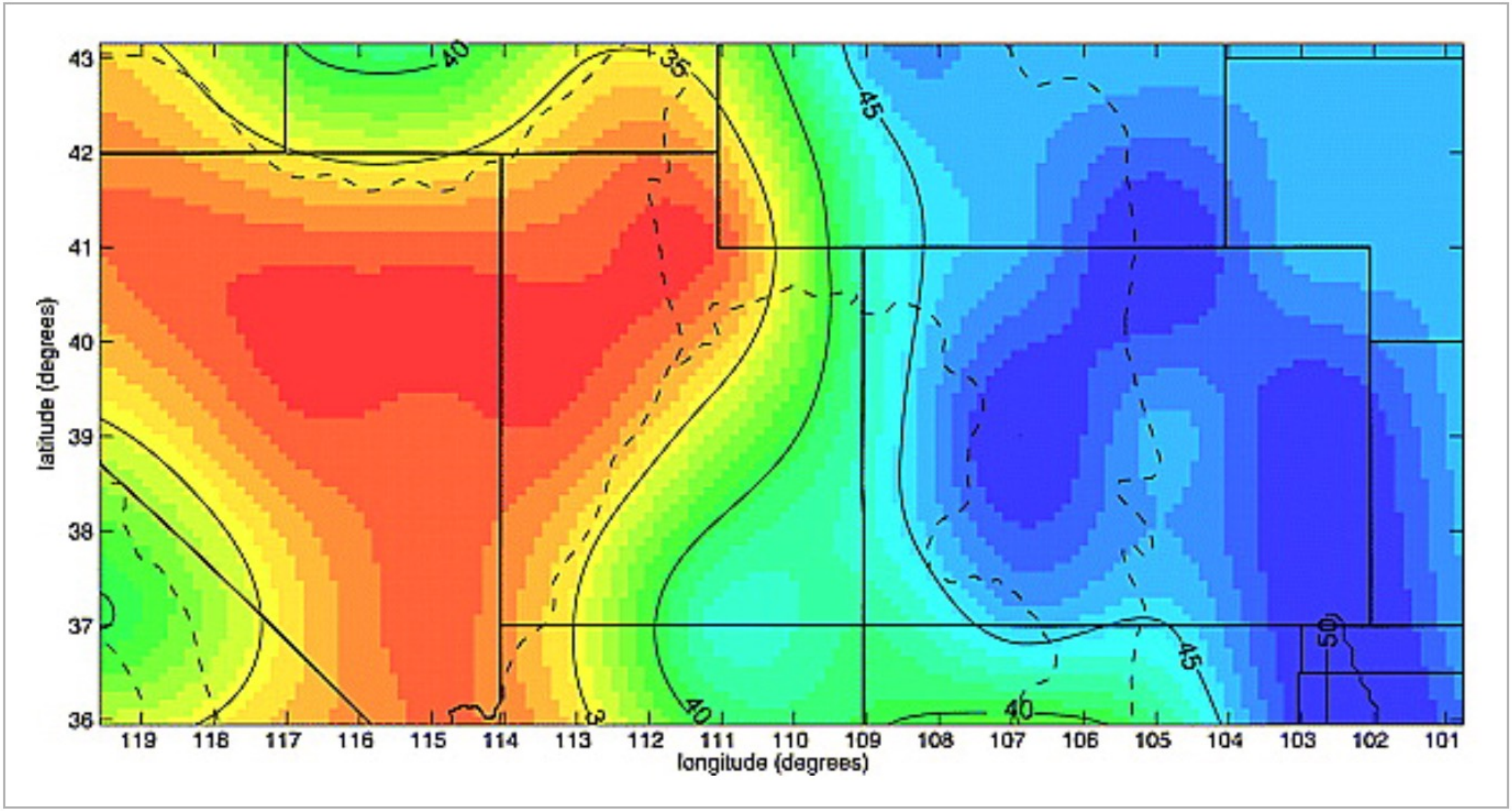


Older version of Previous with less resolution but displays broad scale features.

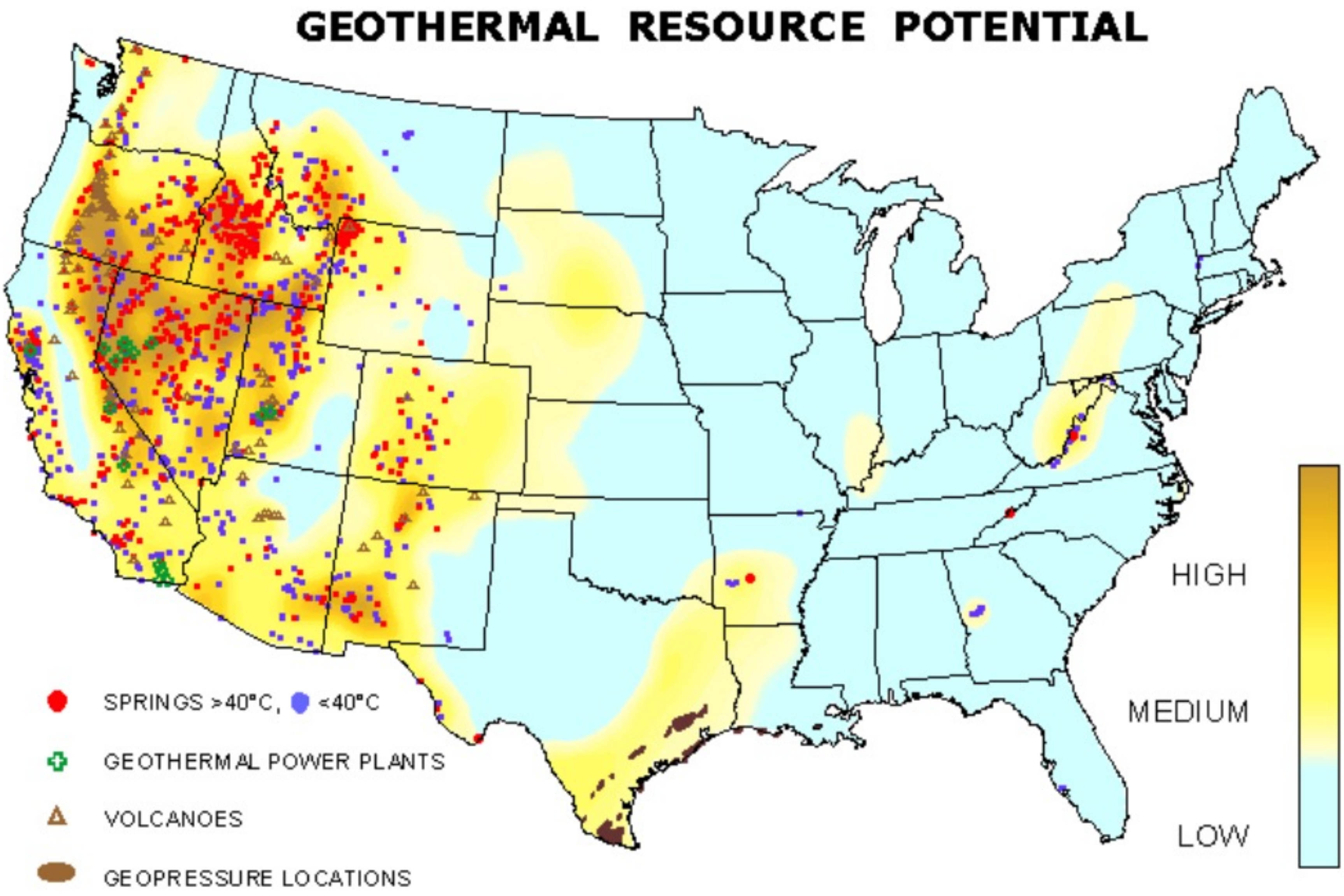
Map of Crustal Thickness (Depth to Moho). Values range from 30 to 50 km. Blue is thicker, Red is thinner.

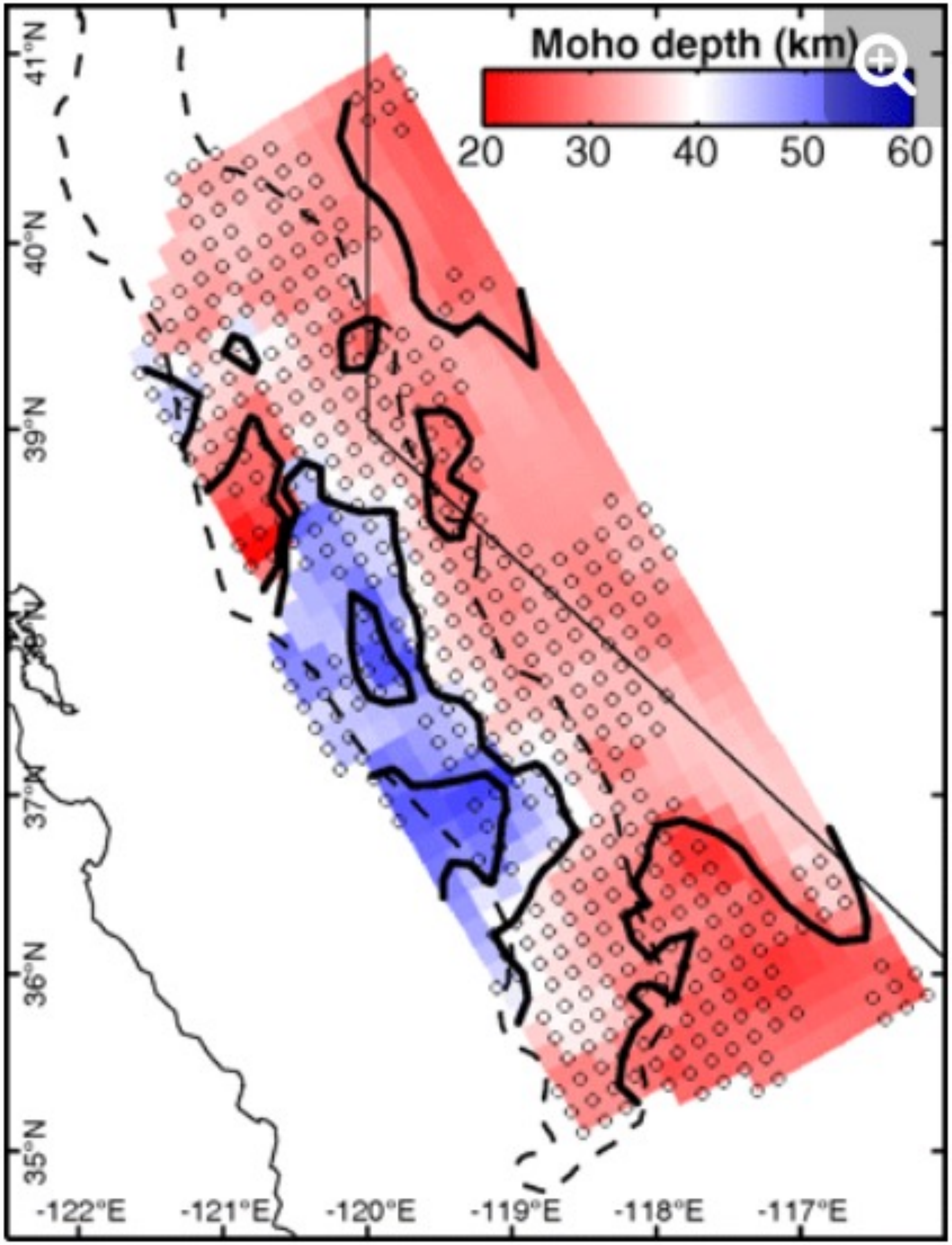
Images of crustal variations in the intermountain west

By: Gilbert, HJ; Sheehan, AF
JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH Volume: 109 Issue: B3 Article Number: B03306 Published: MAR 20 2004



Geothermal Energy in the USA

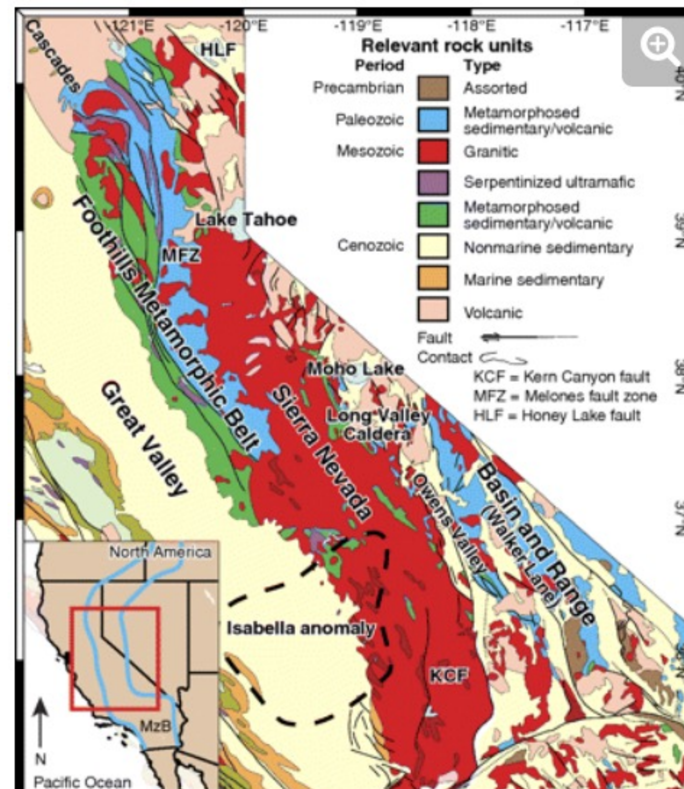


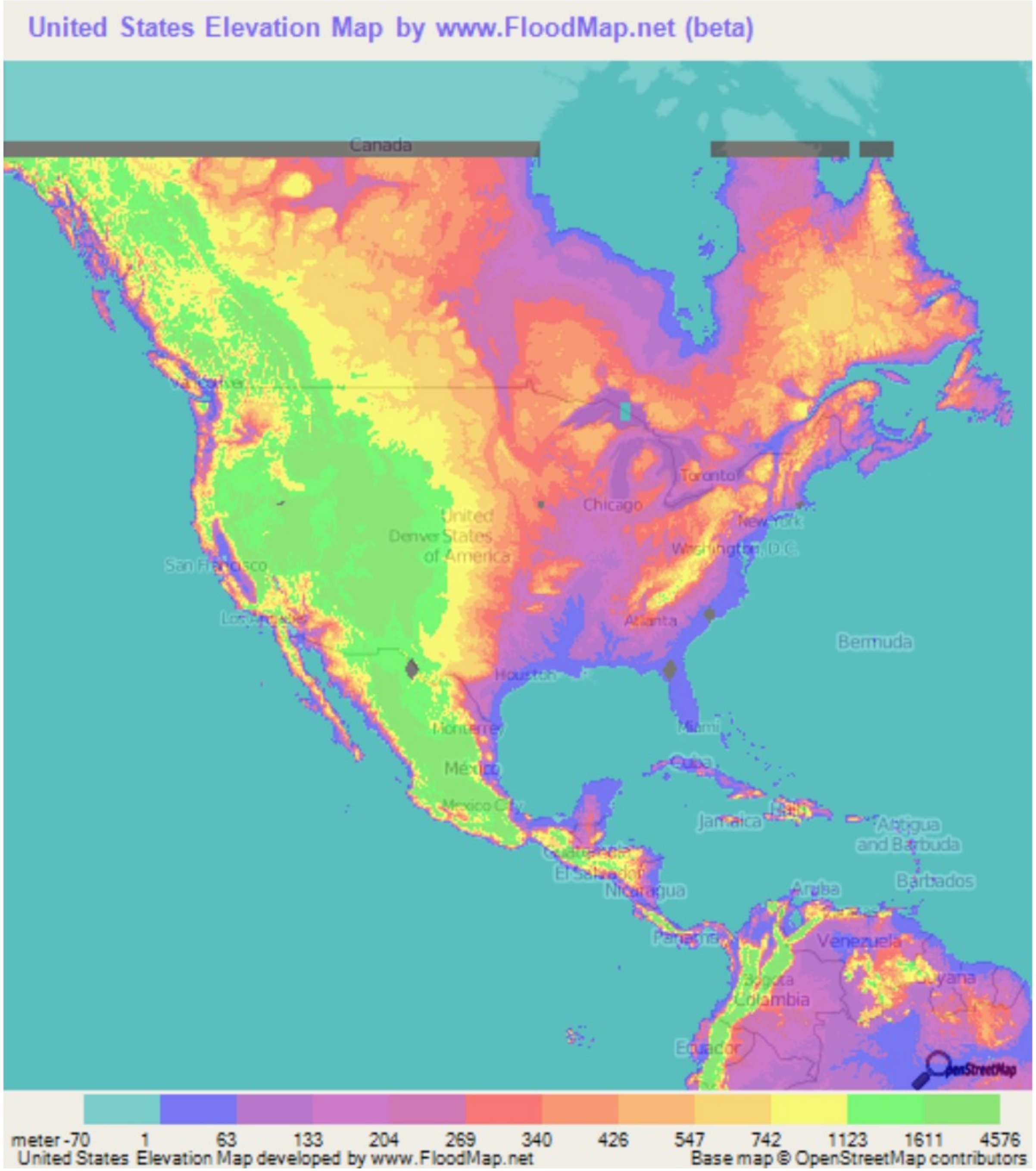


Beneath the Sierra Nevada

Absence of a root in southern

Structure of the Sierra Nevada from receiver functions and implications for lithospheric foundering
By: Frassetto, Andrew M.; Zandt, George; Gilbert, Hersh; et al.
GEOSPHERE Volume: 7 Issue: 4 Pages: 898-921 Published: AUG 2011





While Crust is ‘thin’ in Basin and Range – Elevations are high

Annu. Rev. Earth Planet. Sci. 1999. 27:417–62

The crust may be thin – but elevation of Basin and Range is High!

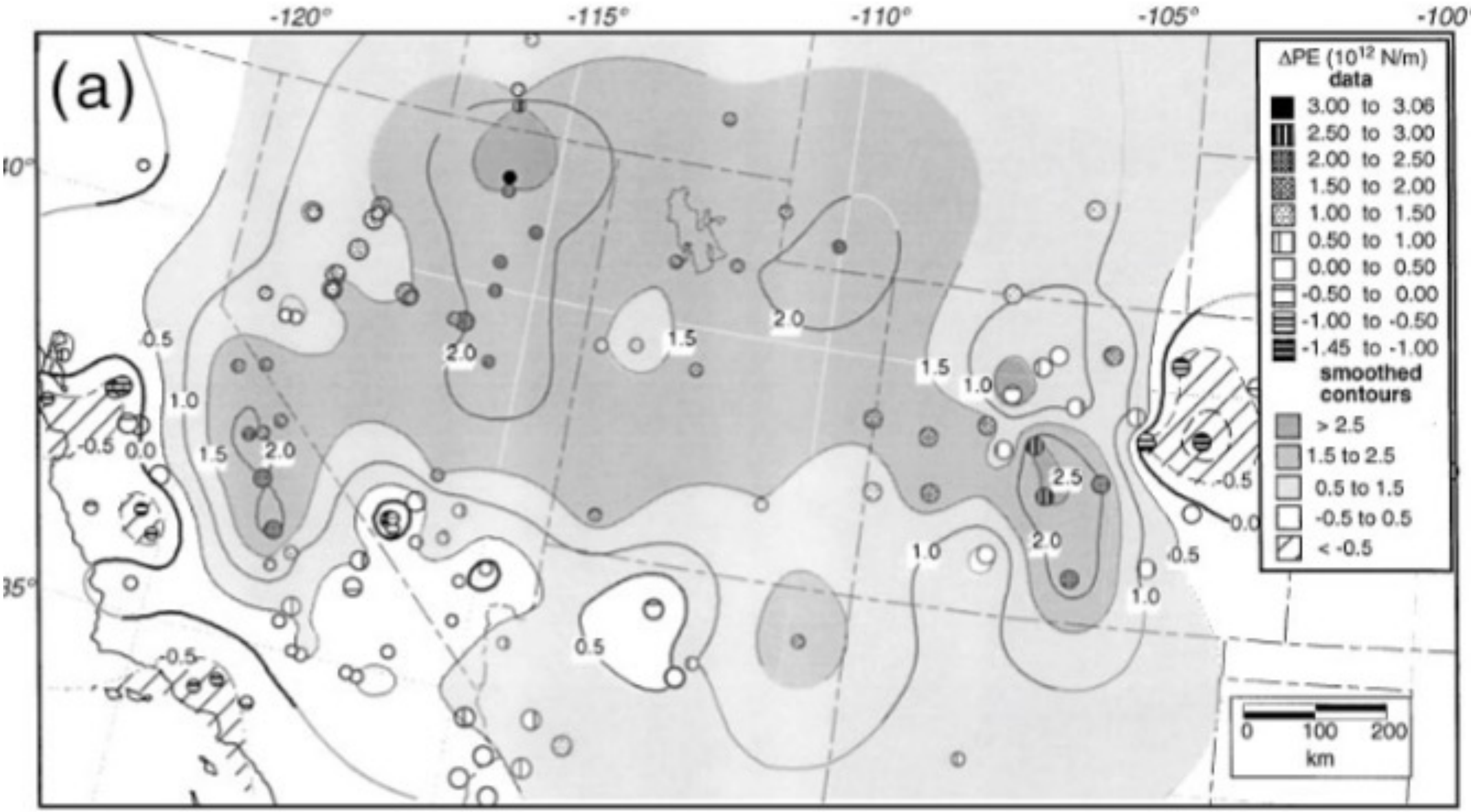


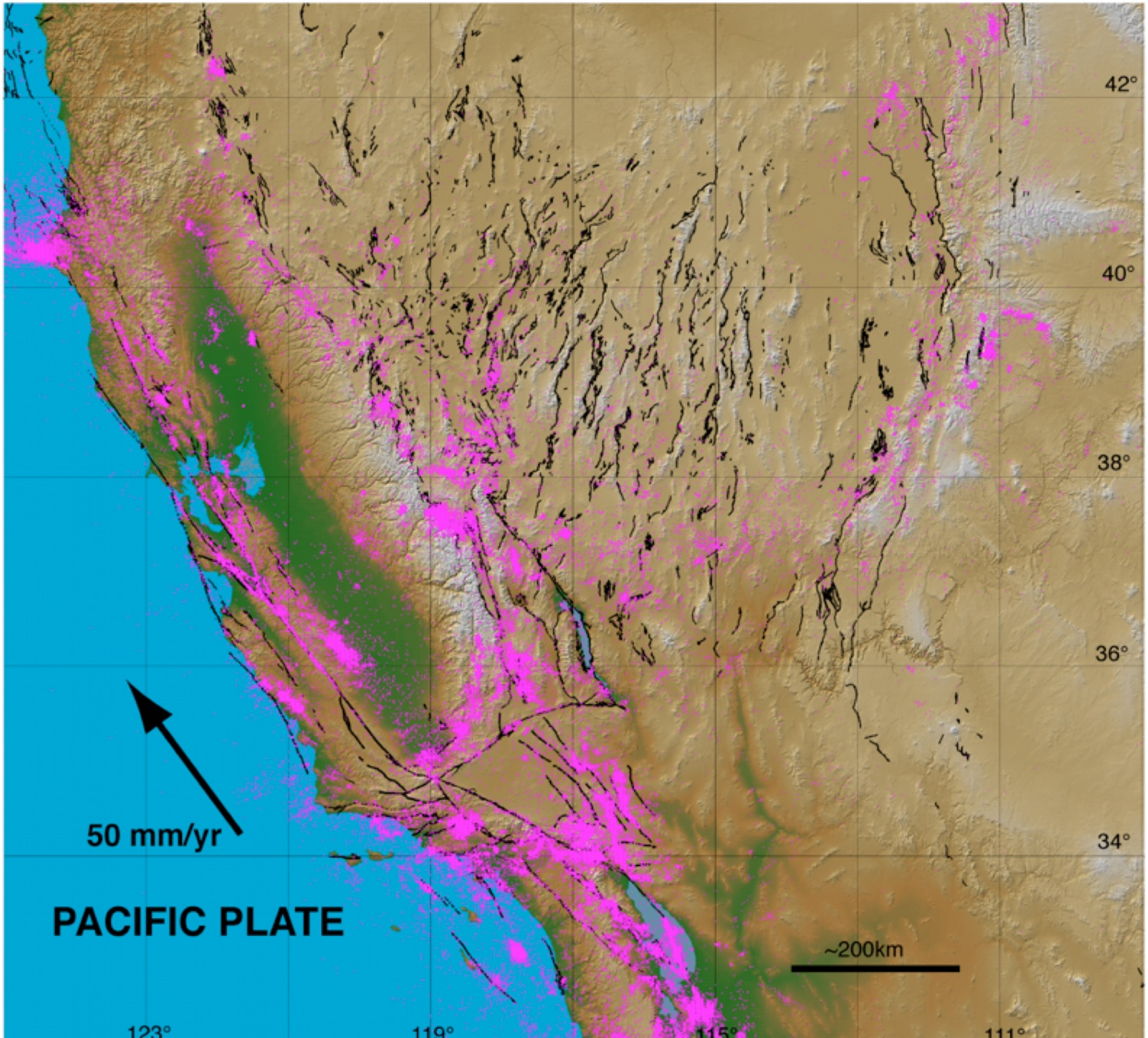
Figure 4 (*a*, *b*) Present-day distribution of gravitational potential energy (ΔPE) in western United States (*a*). Positive (negative) values of ΔPE indicate lithosphere in a state of extension (compres-

The high topography of the Basin and Range is not smooth – Between theWasatch and Sierra generally composed of northeast trending ranges and valleys

Valleys on average rest at about 1500m (4500 ft) and highest ranges exceed 3000 m (~10,000 ft)

?s -> when and how did B&R get high and when was topography created

Topography is not same as Relief...



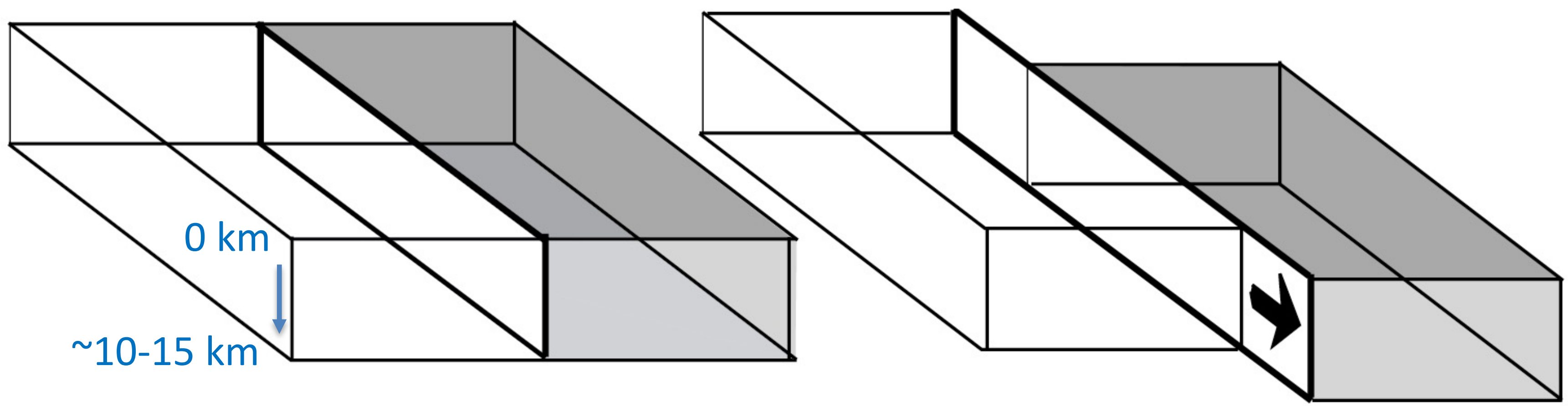
Western US seismicity is imprinted upon a system of active faults – the black lines.

An 'active' fault is loosely considered a fault that breaks Quaternary deposits or rocks – with the most active being recorded in offset and deformation of Holocene rocks

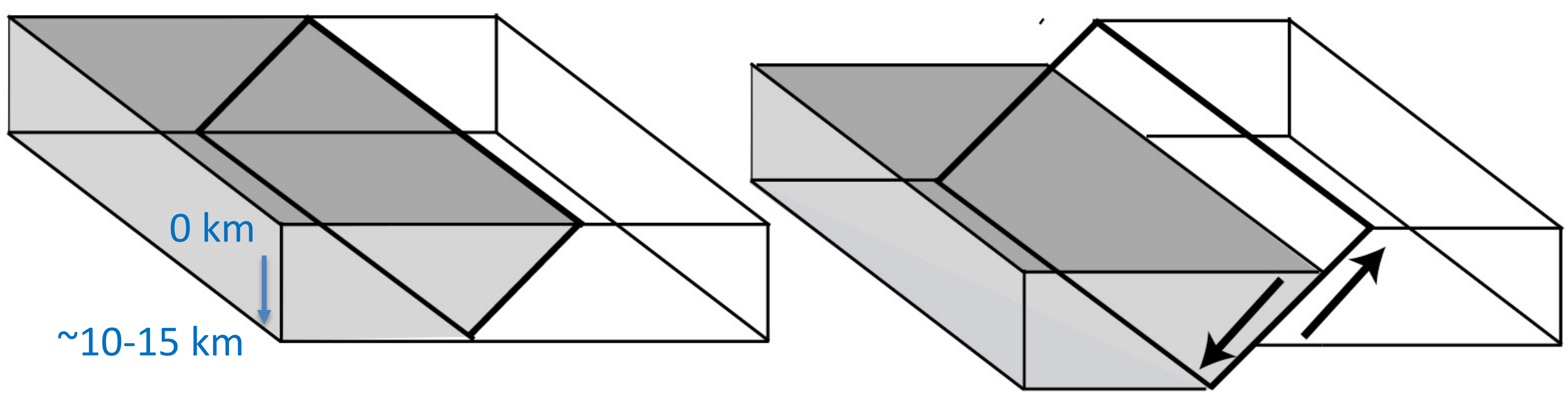
Repeated occurrence of displacement lead to distinct and readily recognized morphology

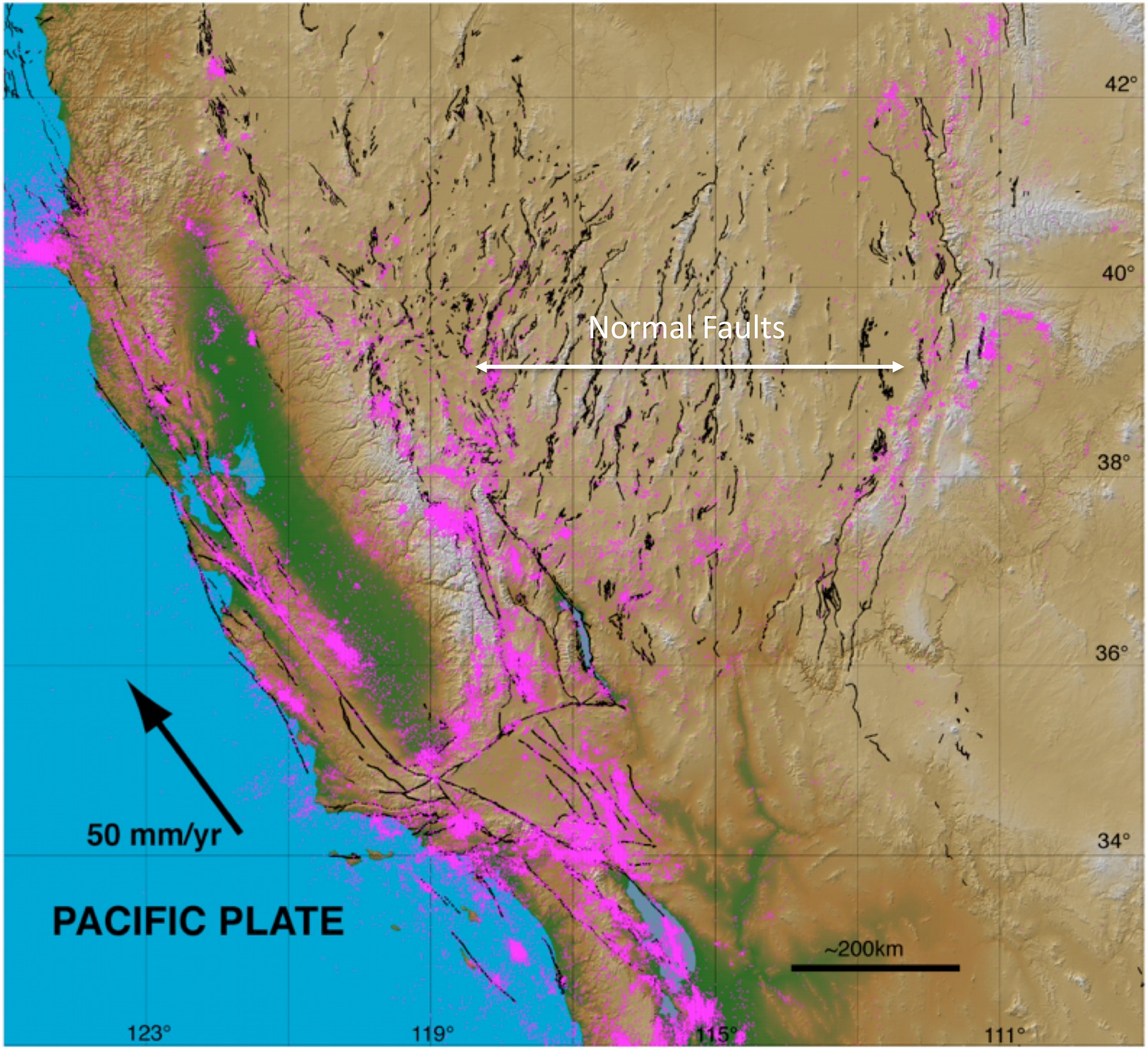
The idea of a ‘fault’ – quite simple – generally two types in western US.

The first - Strike-slip - where a block of the earth’s crust slide sideways with respect to block on other side.



A second - Normal- where on one side of the fault the earth moves up - and down on the other.

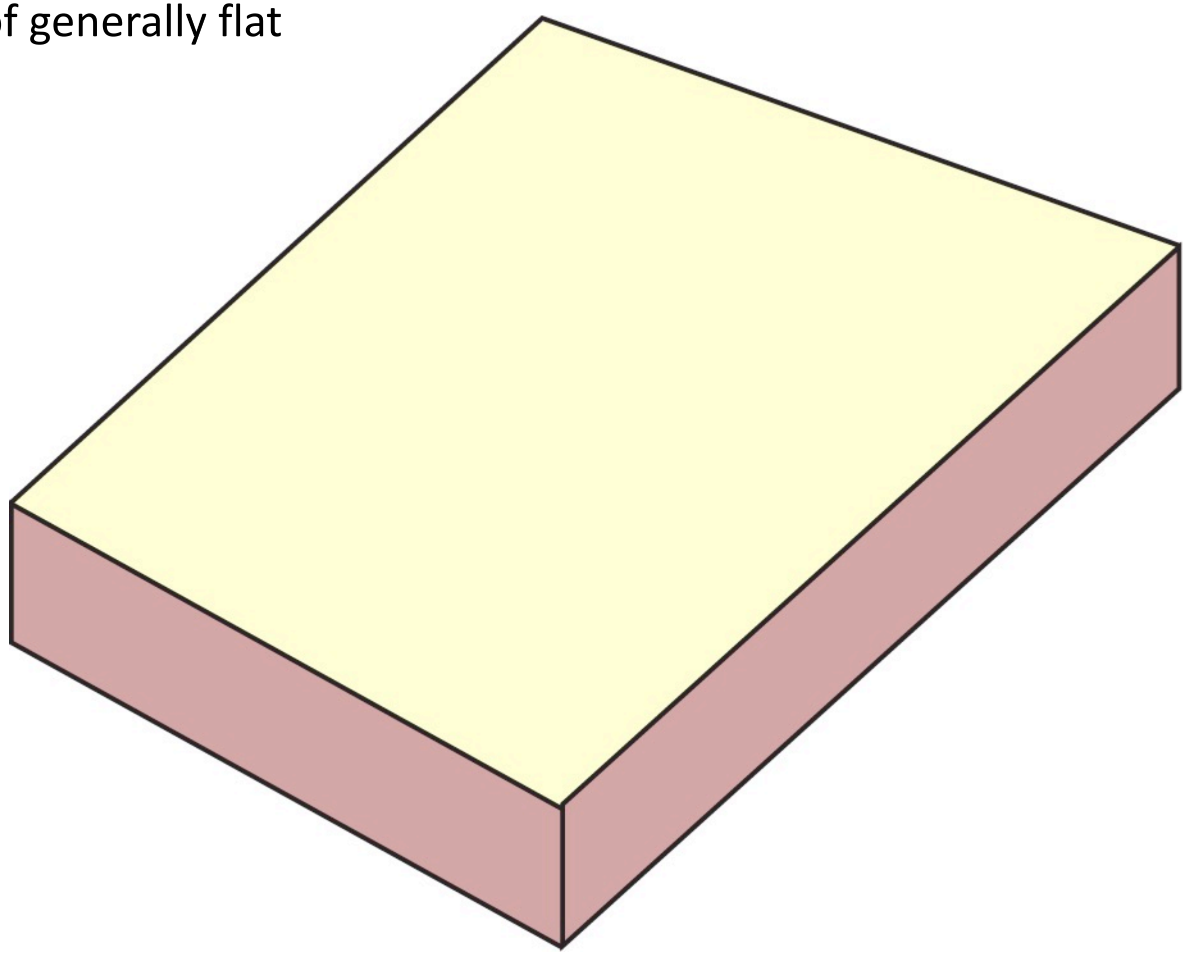




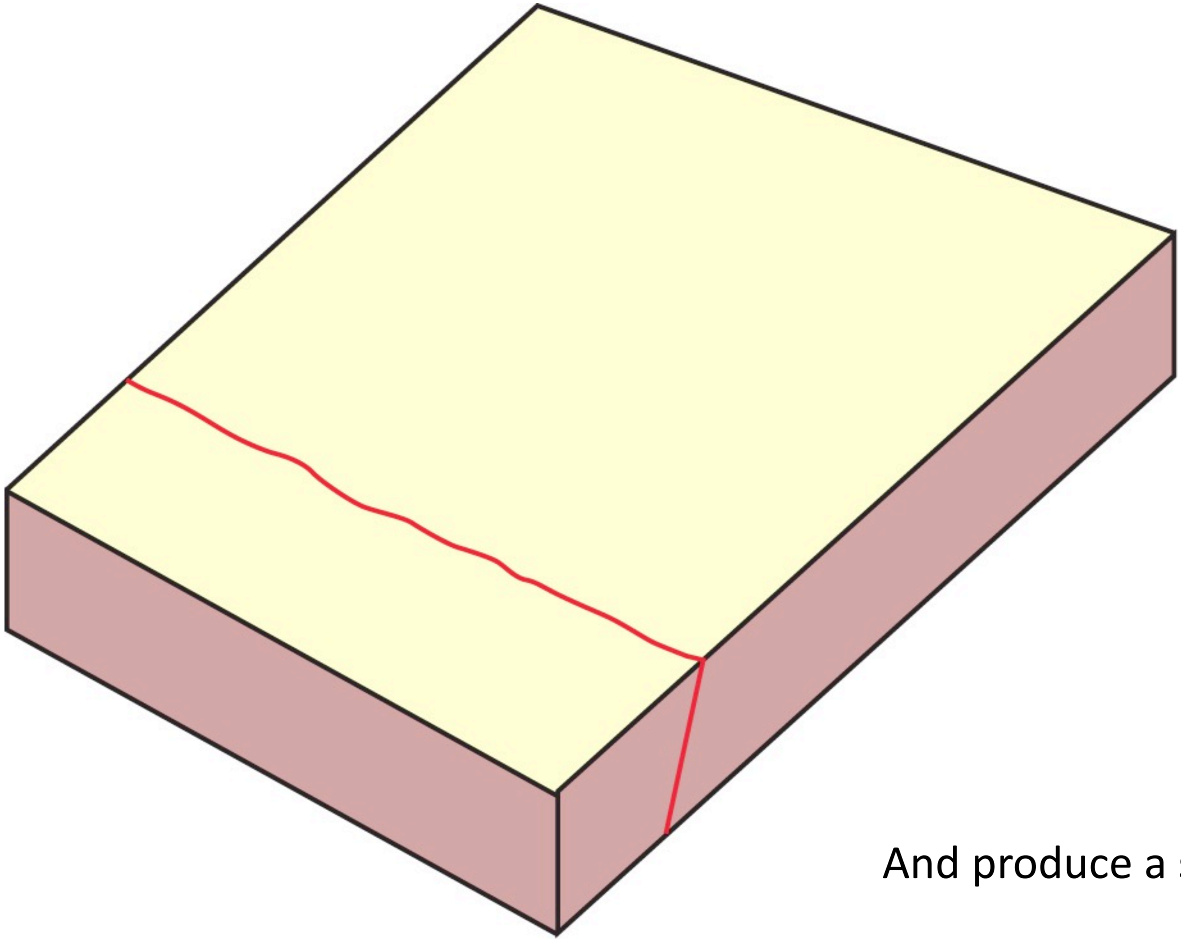
42°
40°
Normal Faults
38°
36°
34°
50 mm/yr
PACIFIC PLATE
~200km
123°
119°
115°
111°

Consider what happens when a normal fault interacts with surface during the course of repeated earthquake displacements....

Take a piece of generally flat ground

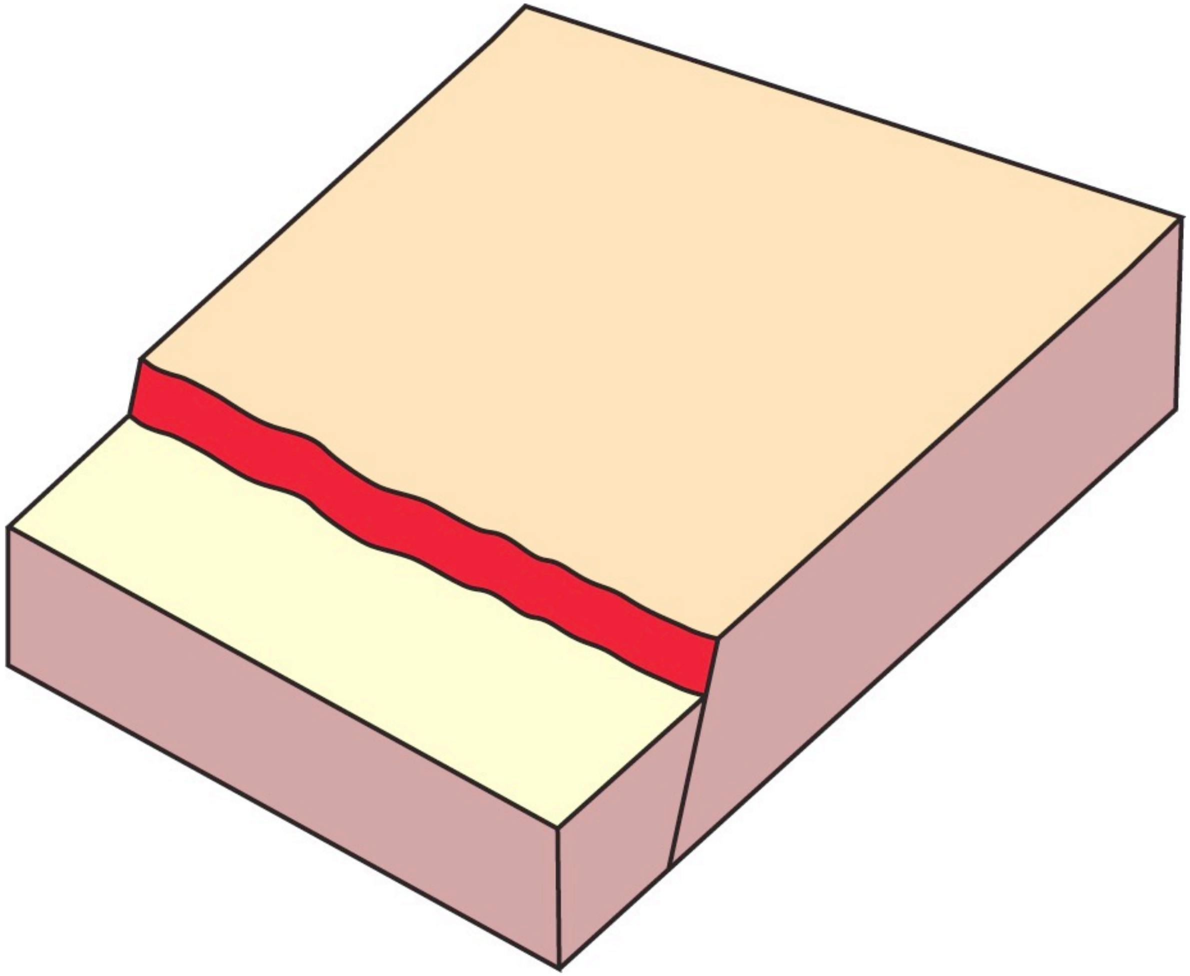


Let the fault slip…

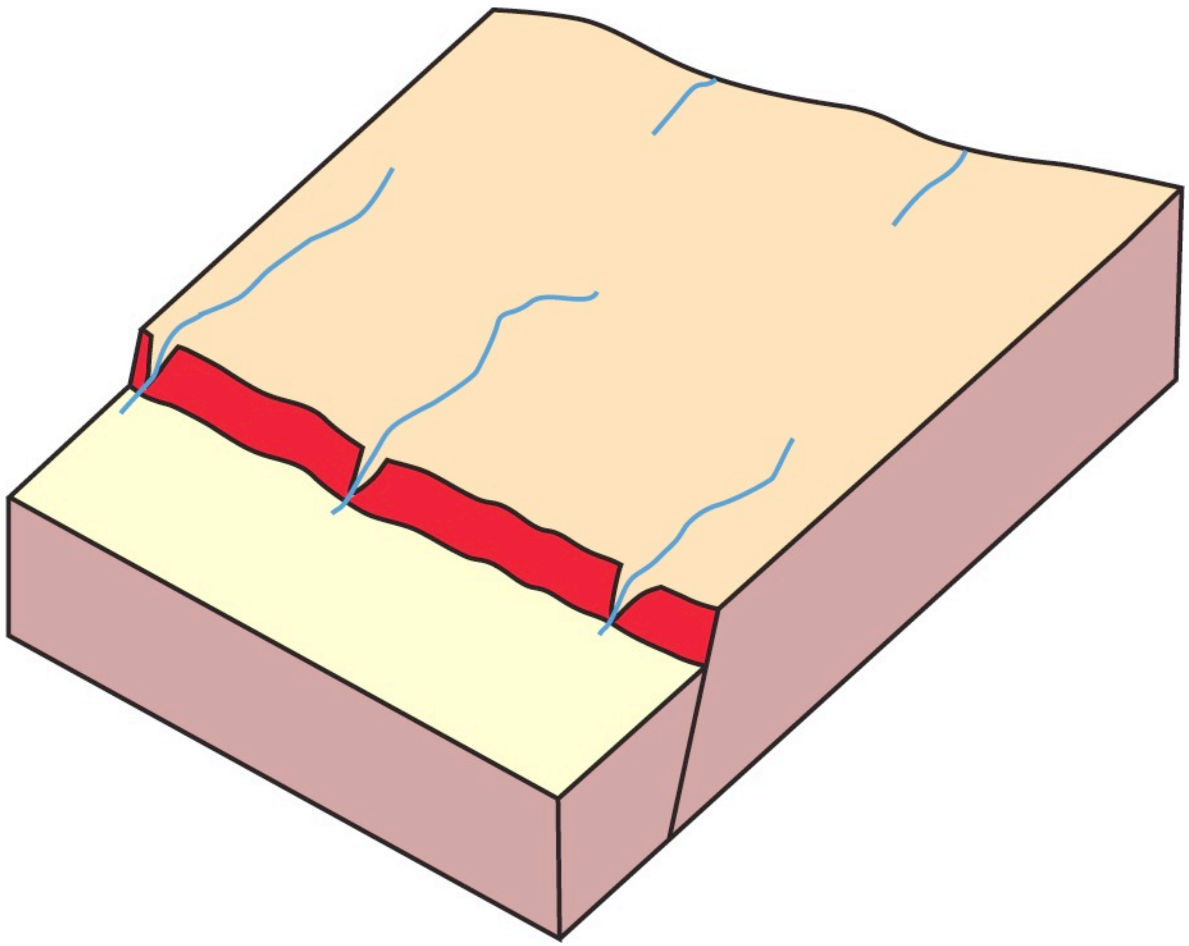


And produce a scarp…

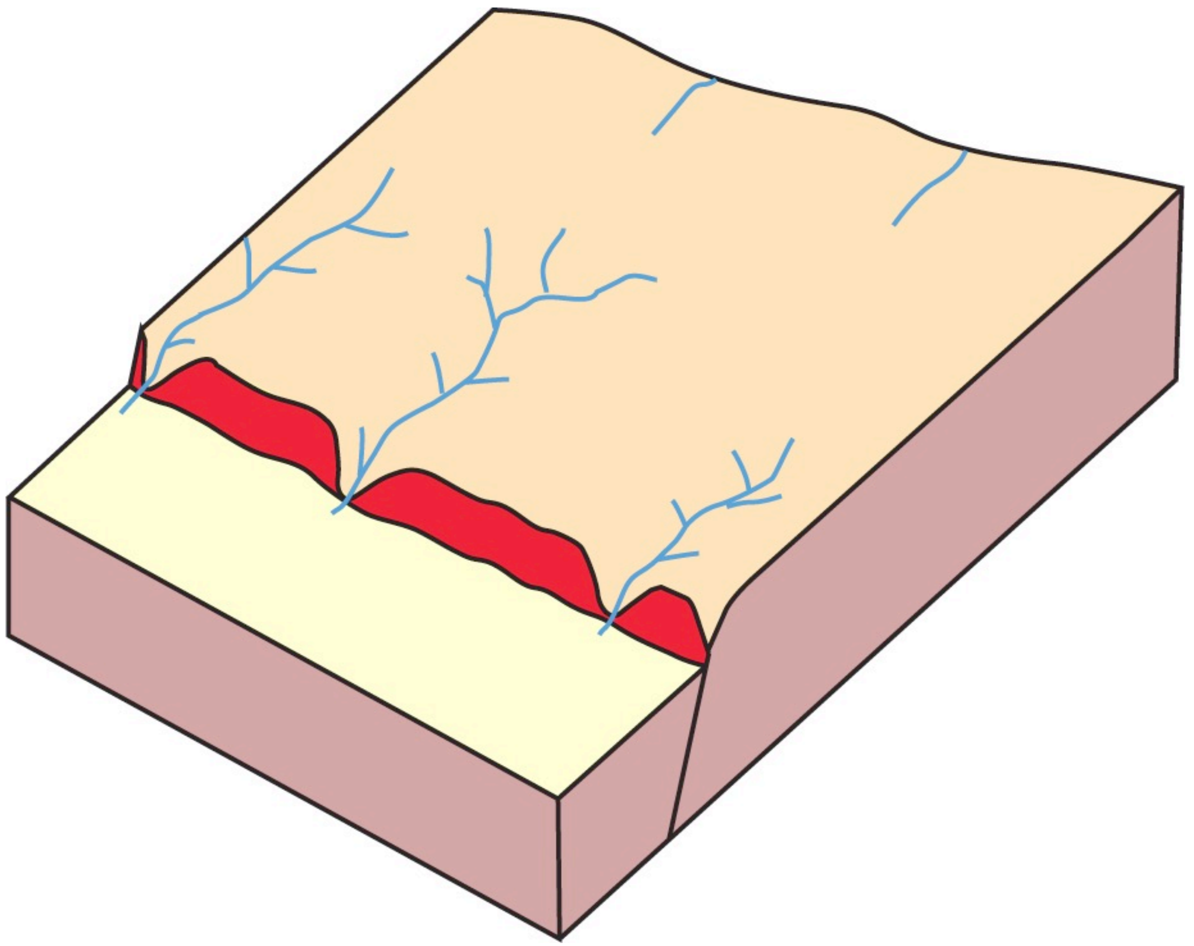
Now what happens… say, if
it rains…..



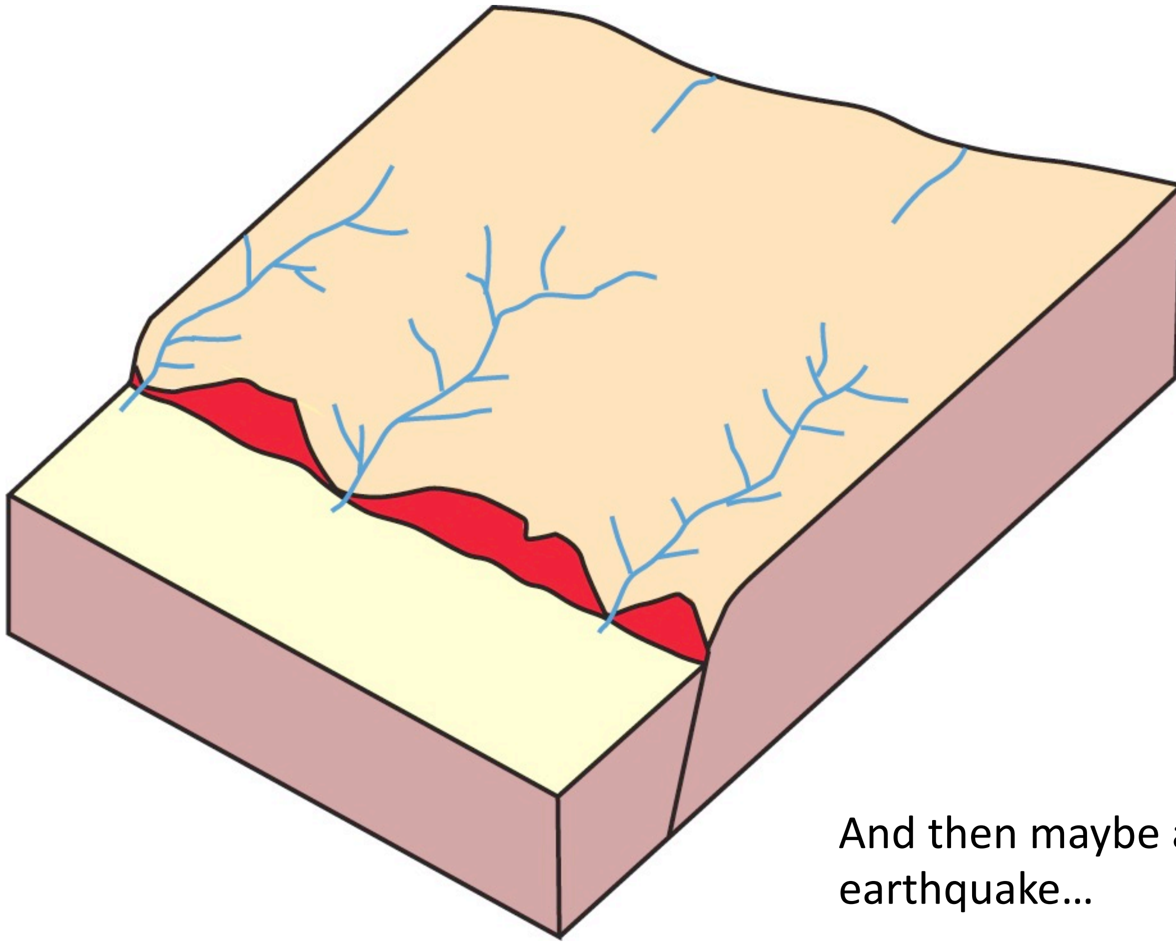
We get a little erosion….incision of the scarp



More rain - more incision -

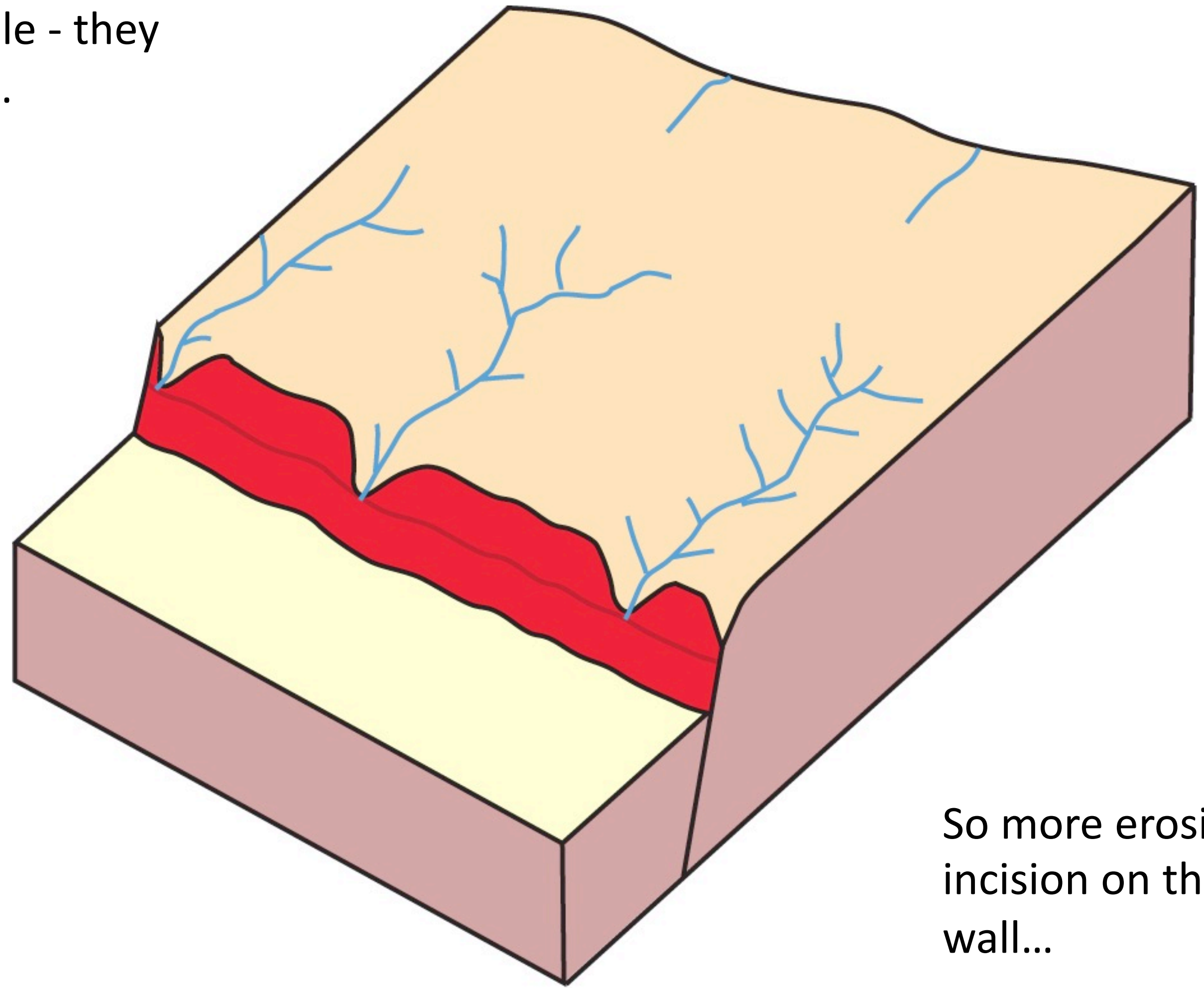


And development of small drainage basins…

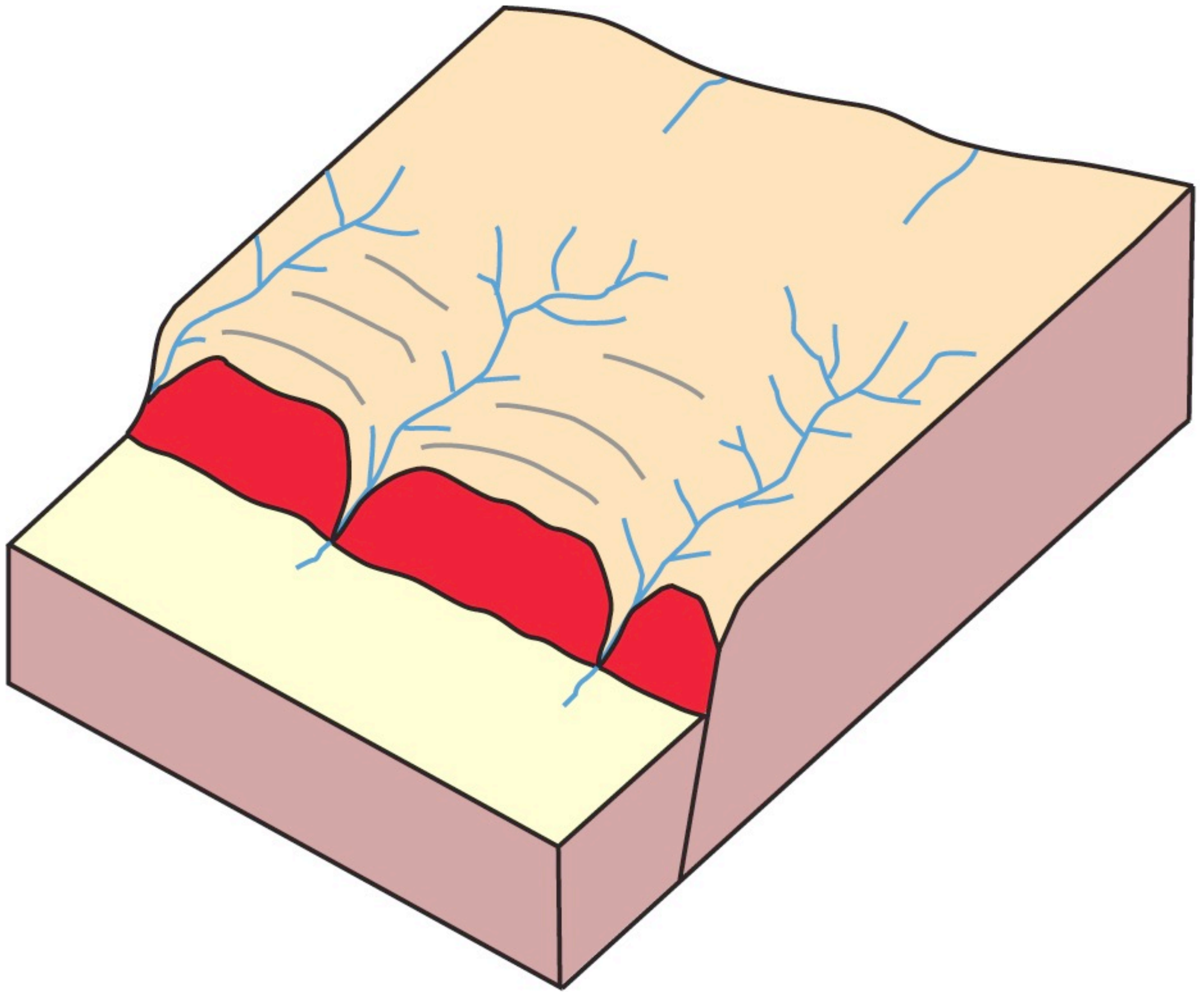


And then maybe another earthquake…

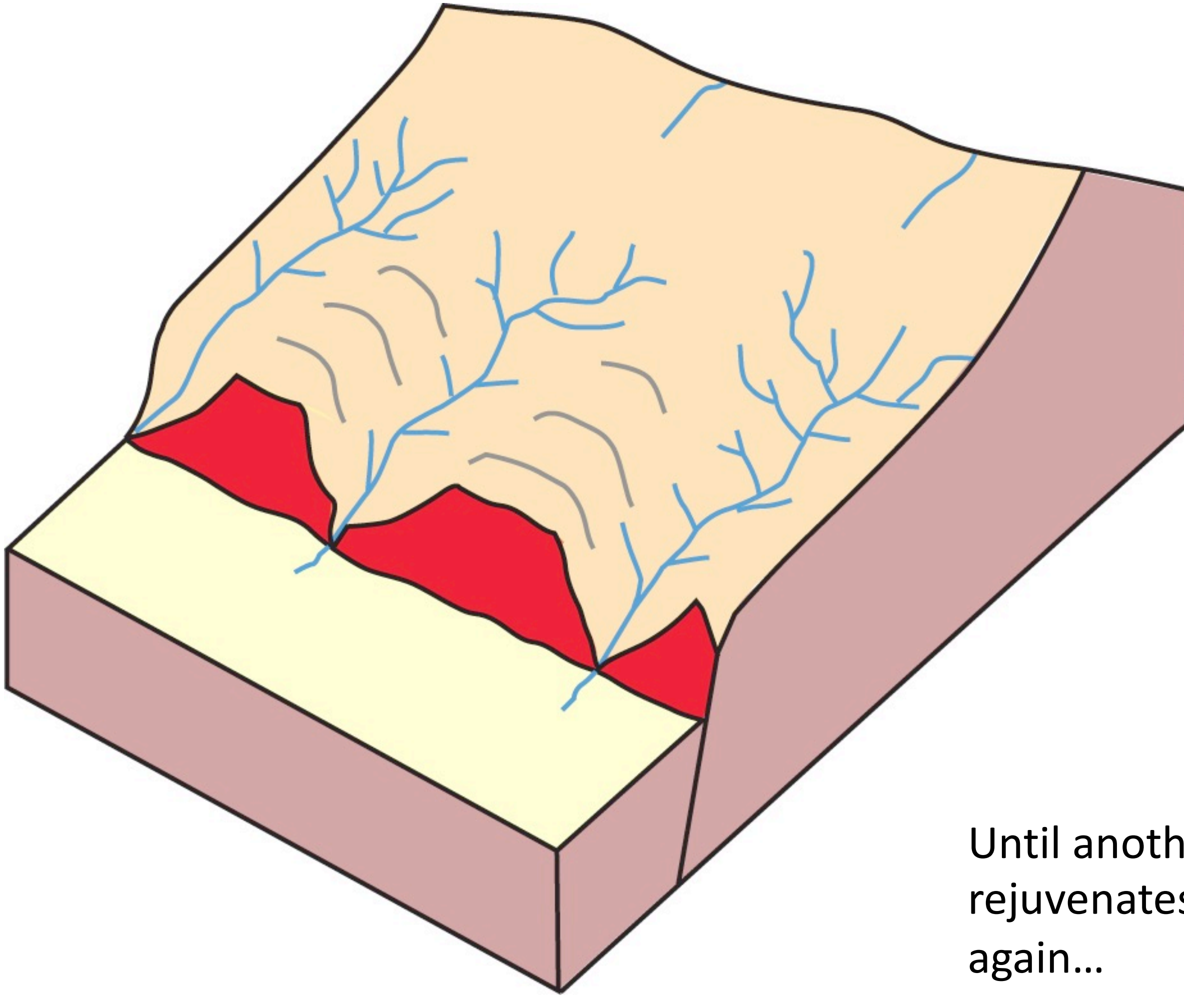
And the streams no longer have their longitudinal profile - they are out of grade…



So more erosion and incision on the hanging wall…

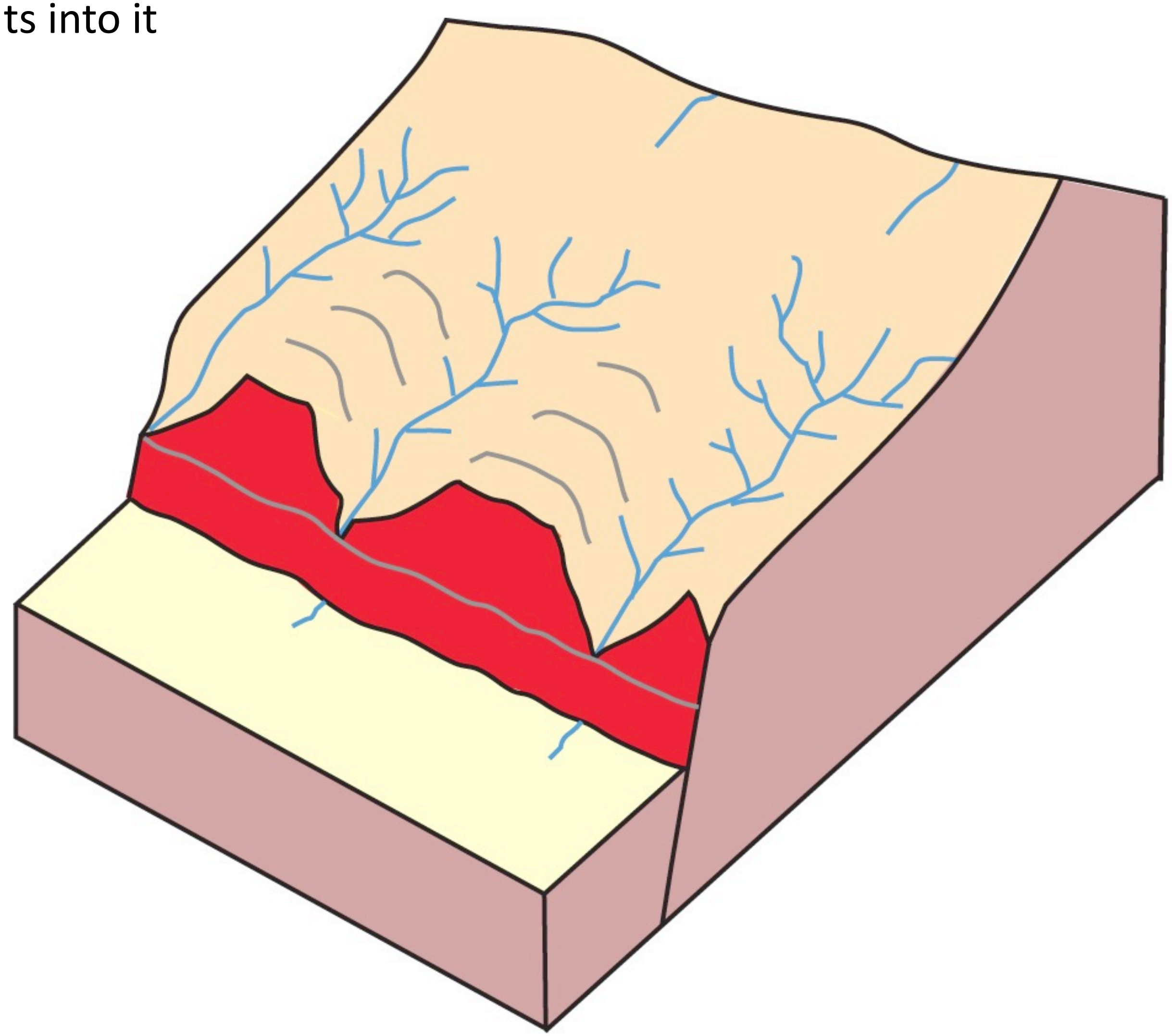


And the process continues

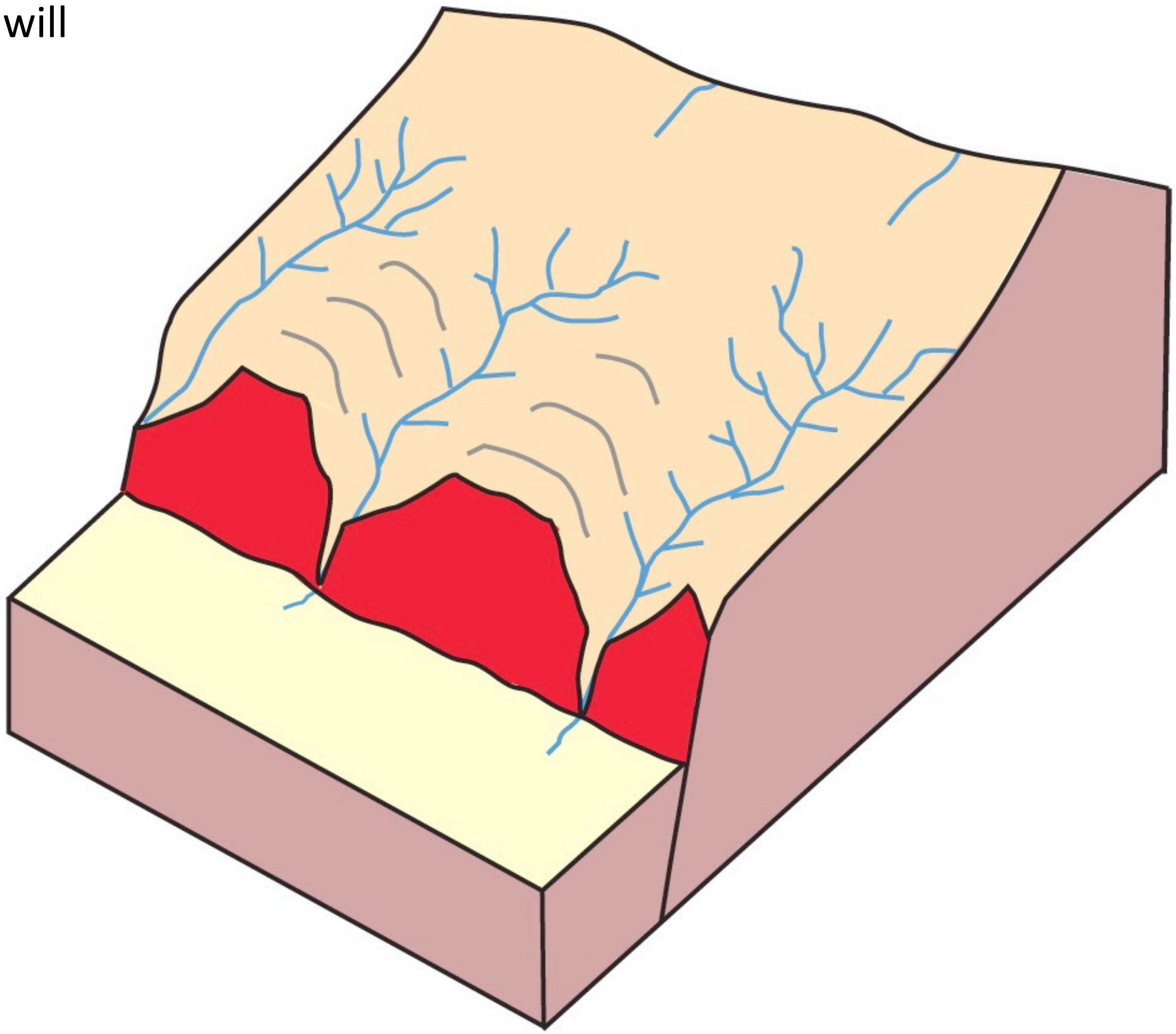


Until another earthquake rejuvenates things again…

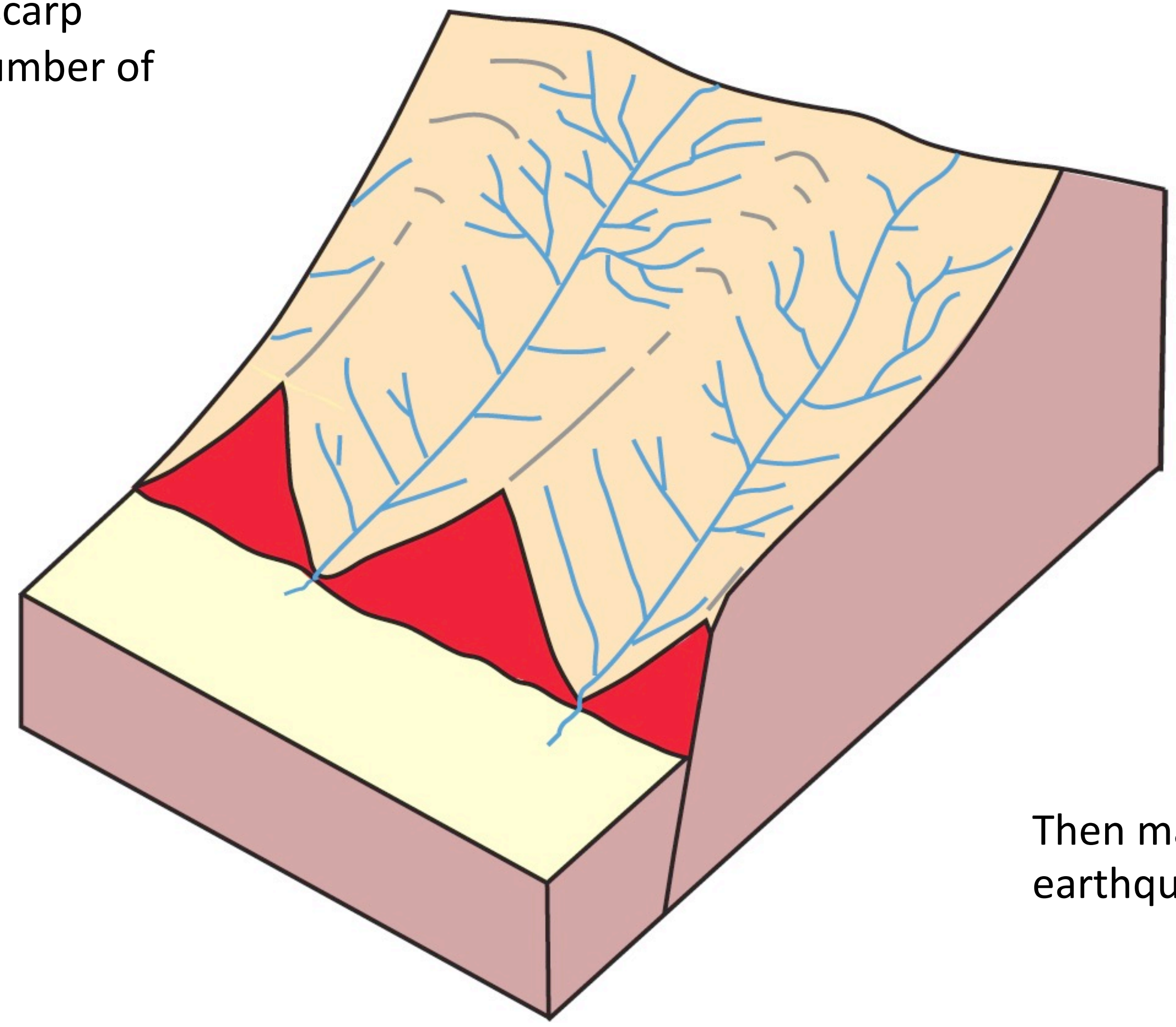
The mountain goes ‘up’
- the incision cuts into it



More incision - the drainage basins will grow…

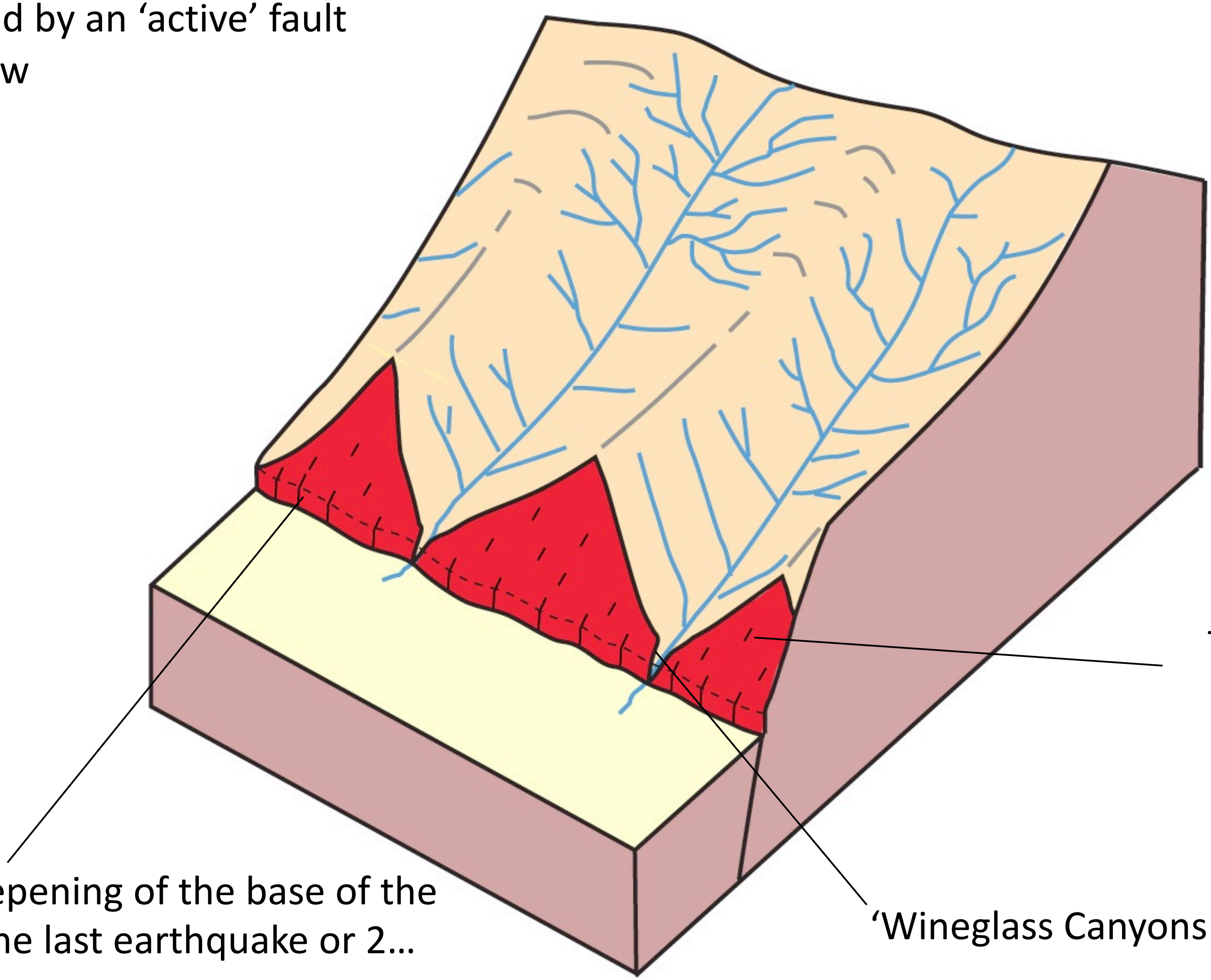


Until the ridges are sharp and the scarp appears as a number of triangles…

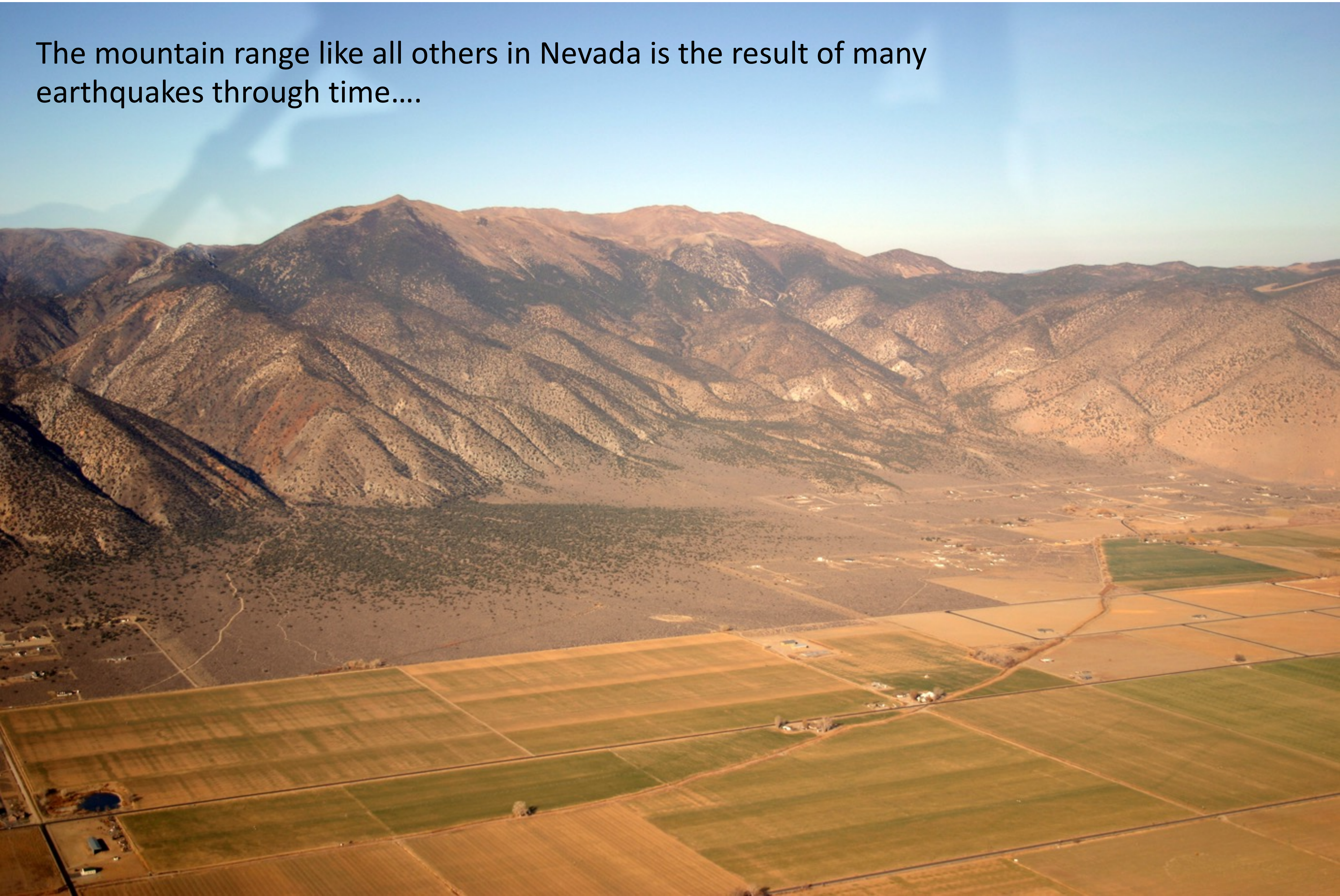


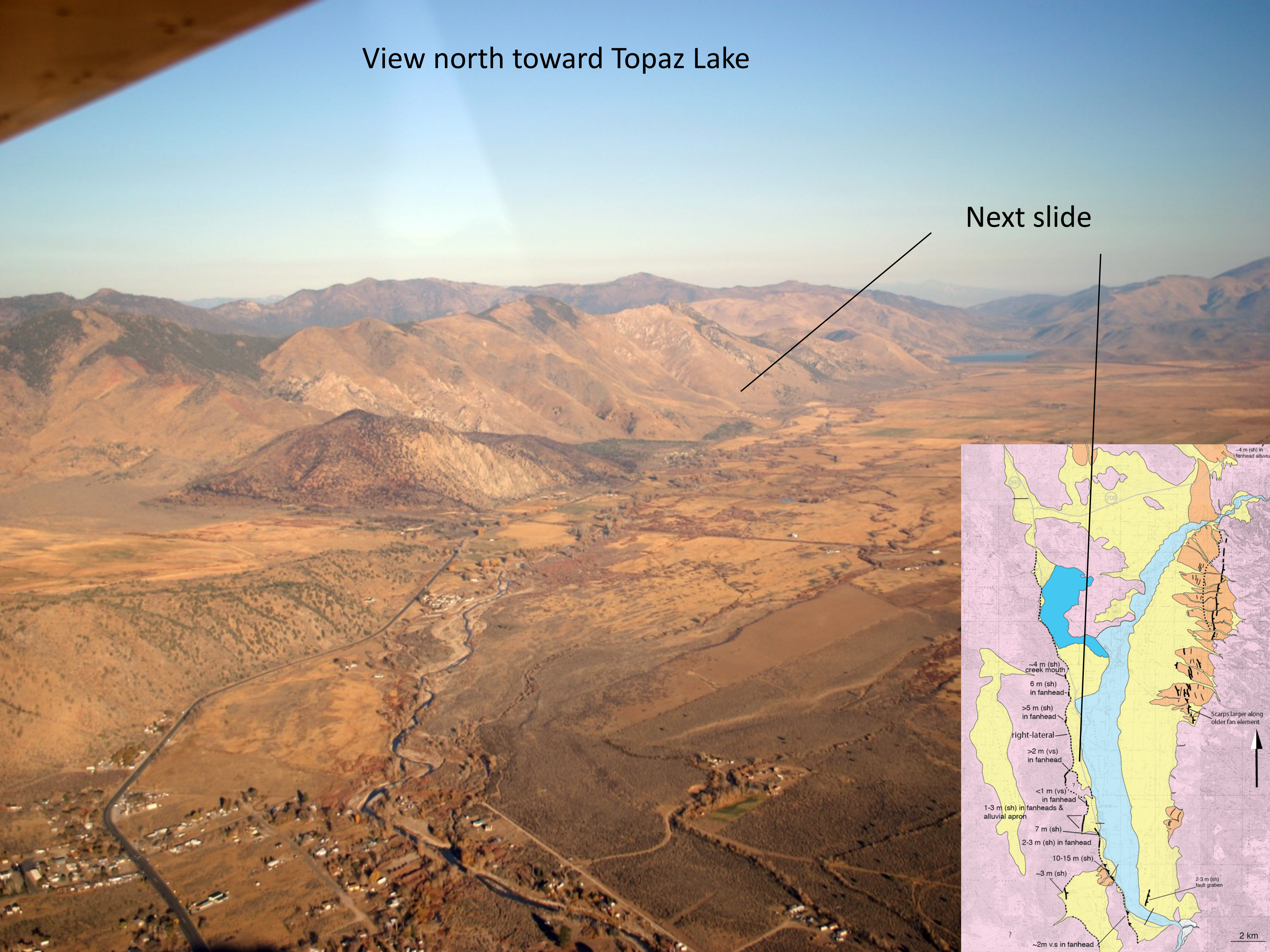
Then maybe another earthquake…

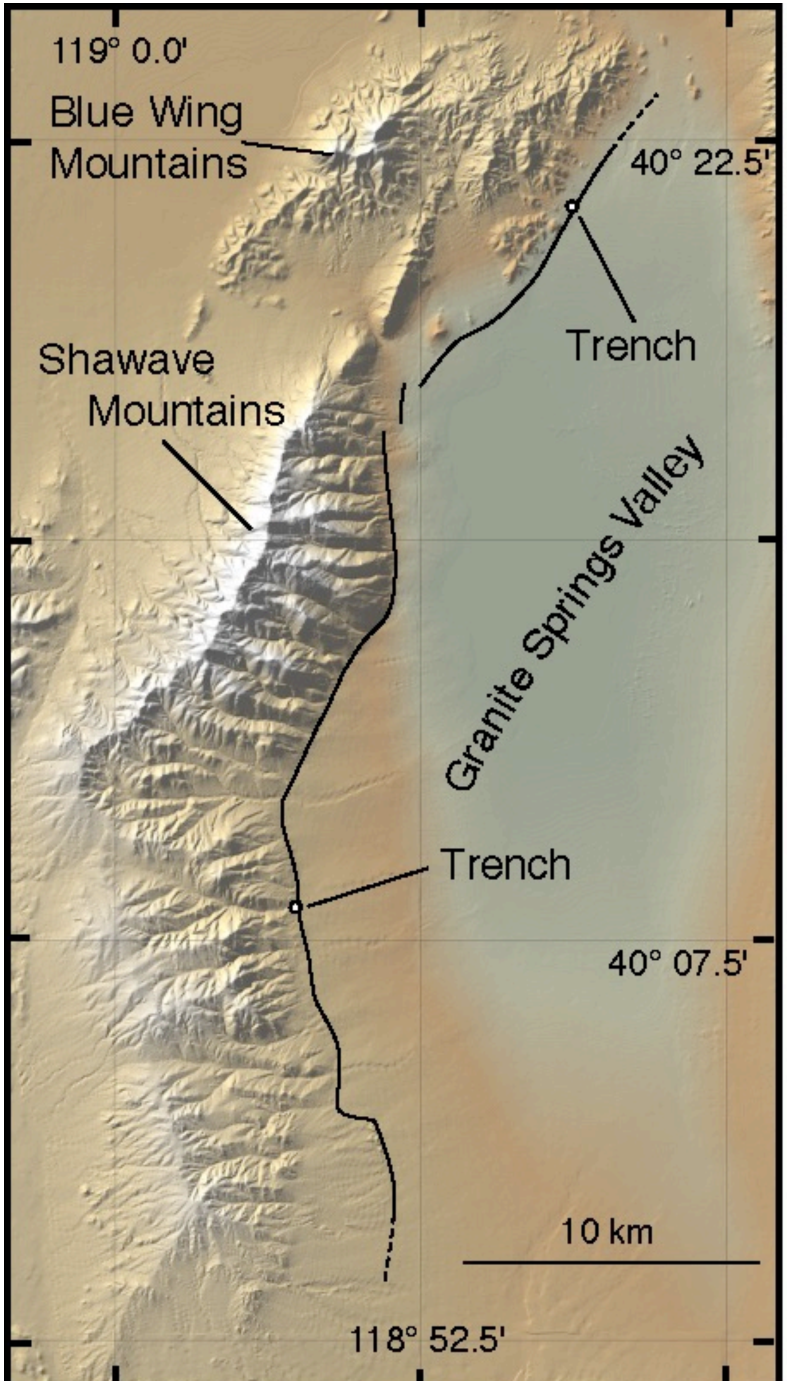
And a mountain front bounded by an 'active' fault will show



View westward across Smith Valley to Pine Nuts…

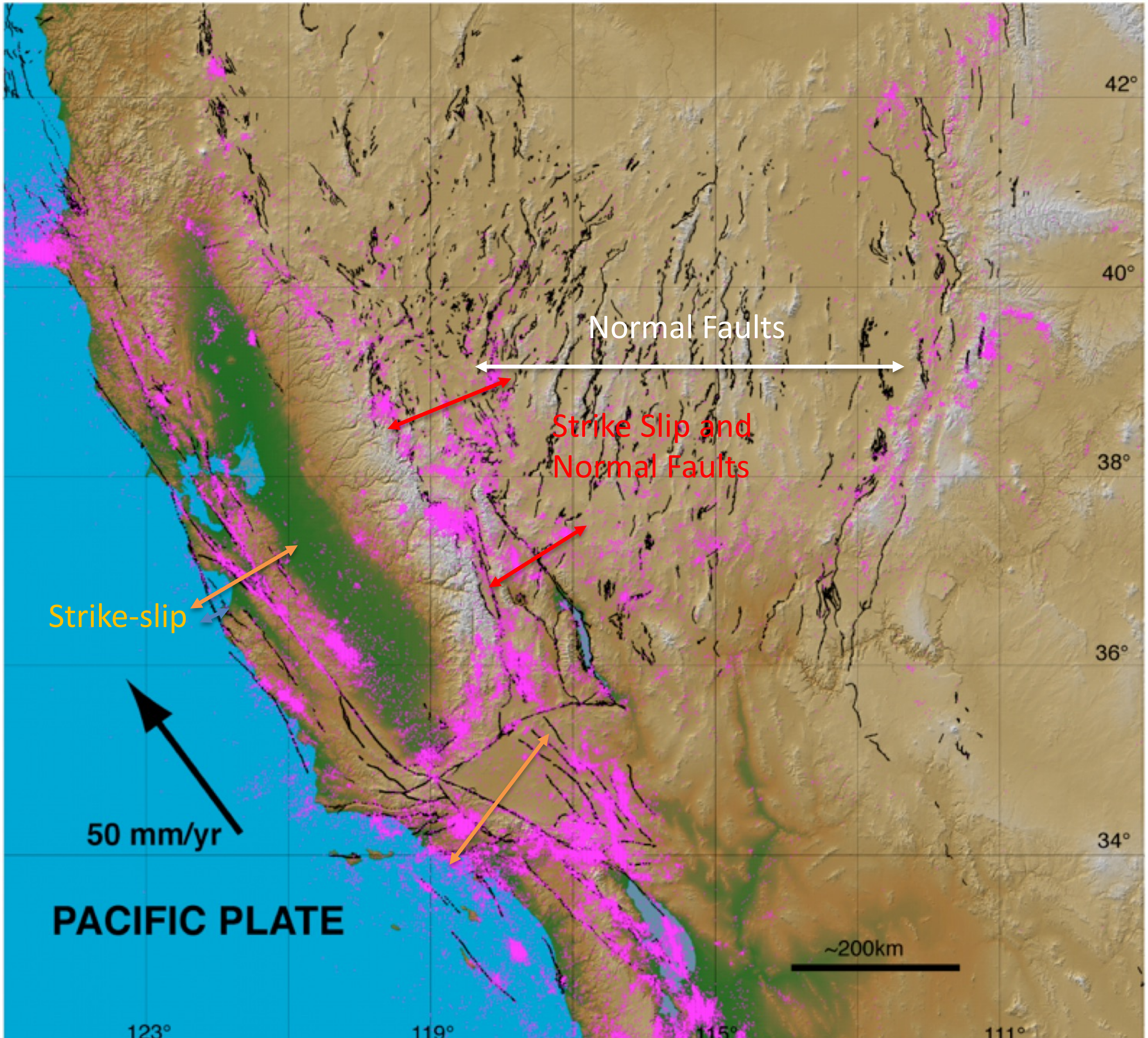



View north toward Topaz Lake
Next slide
~4 m (sh) in
fanhead alluviu
208
~4 m (sh)
creek mouth
6 m (sh)
in fanhead
>5 m (sh)
in fanhead
right-lateral
>2 m (vs)
in fanhead
<1 m (vs)
in fanhead
1-3 m (sh) in fanheads &
alluvial apron
7 m (sh)
2-3 m (sh) in fanhead
10-15 m (sh)
~3 m (sh)
~2m v.s in fanhead
Scarps larger along
older fan element
2-3 m (sh)
fault graben
2 km


119° 0.0'
Blue Wing Mountains
40° 22.5'
Trench
Shawave Mountains
Granite Springs Valley
Trench
40° 07.5'
10 km
118° 52.5'

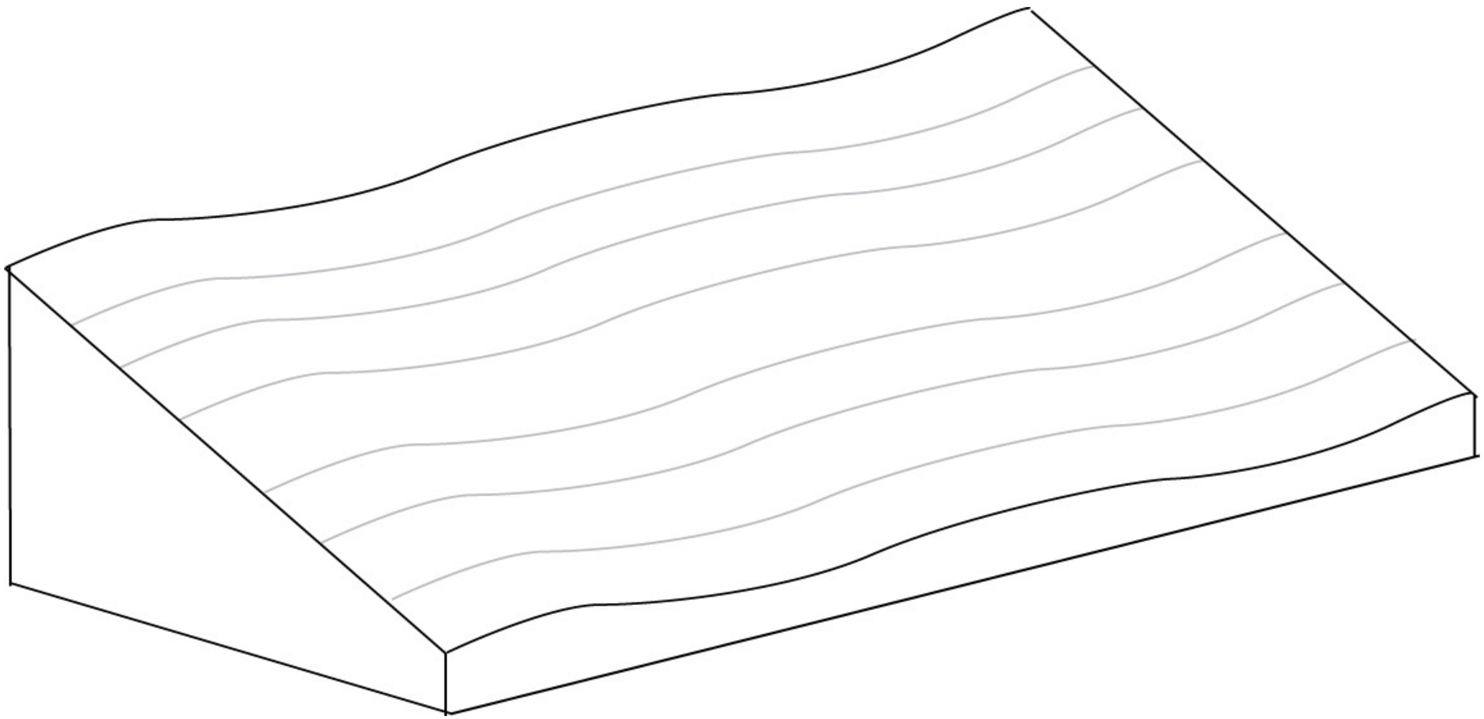

Trench


Trench

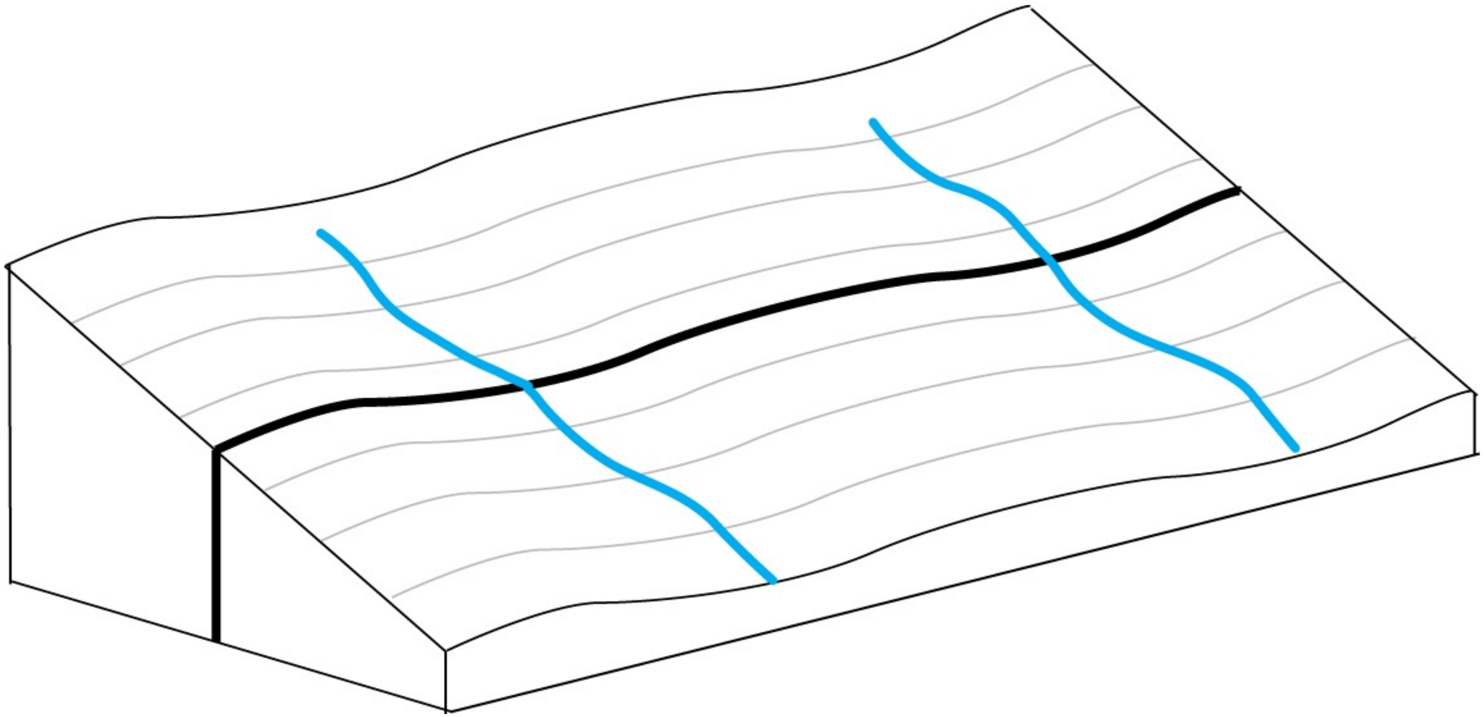

42°
40°
38°
36°
34°
Normal Faults
Strike Slip and
Normal Faults
Strike-slip
50 mm/yr
PACIFIC PLATE
~200km
123°
119°
115°
111°

Morphology- shape

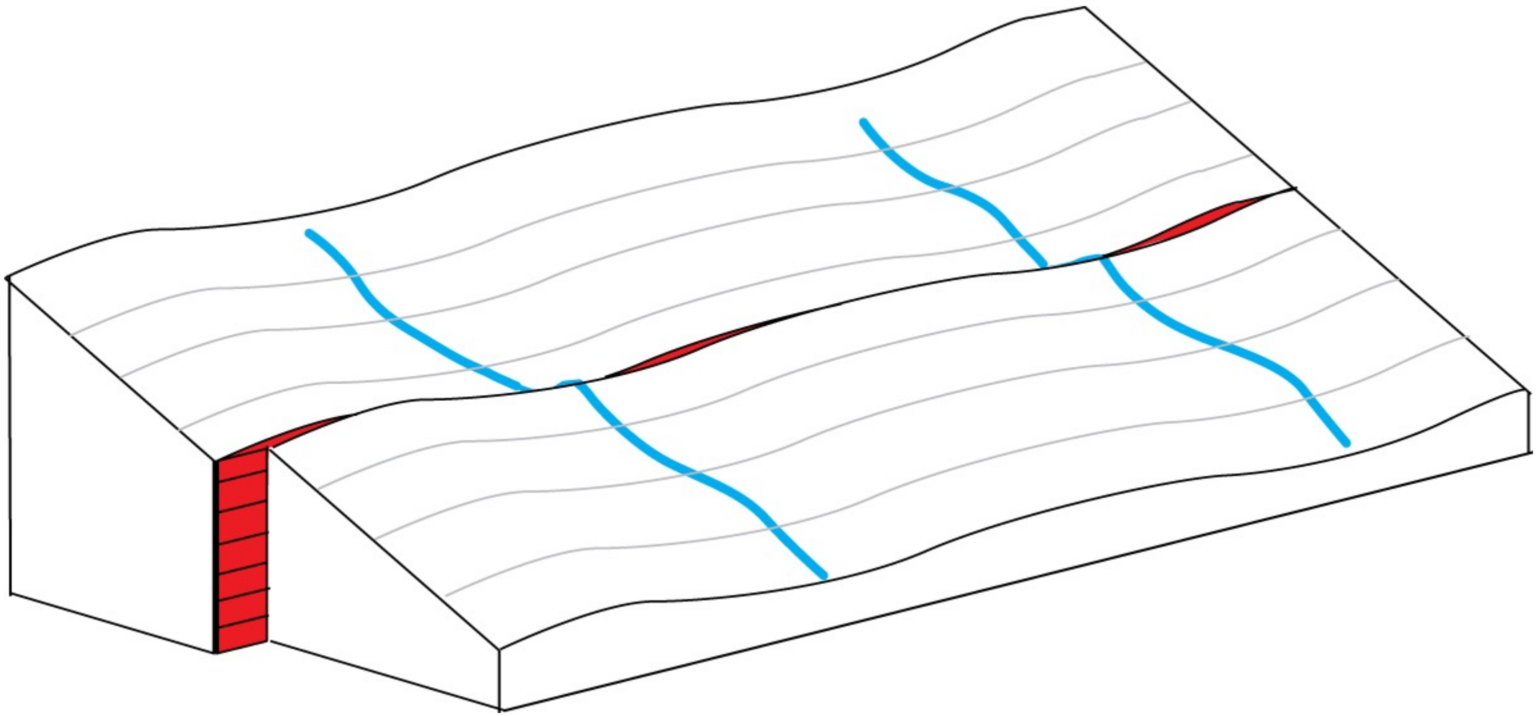
Geomorphology - processes that shape earth surface



Consider relatively smooth sloping surface

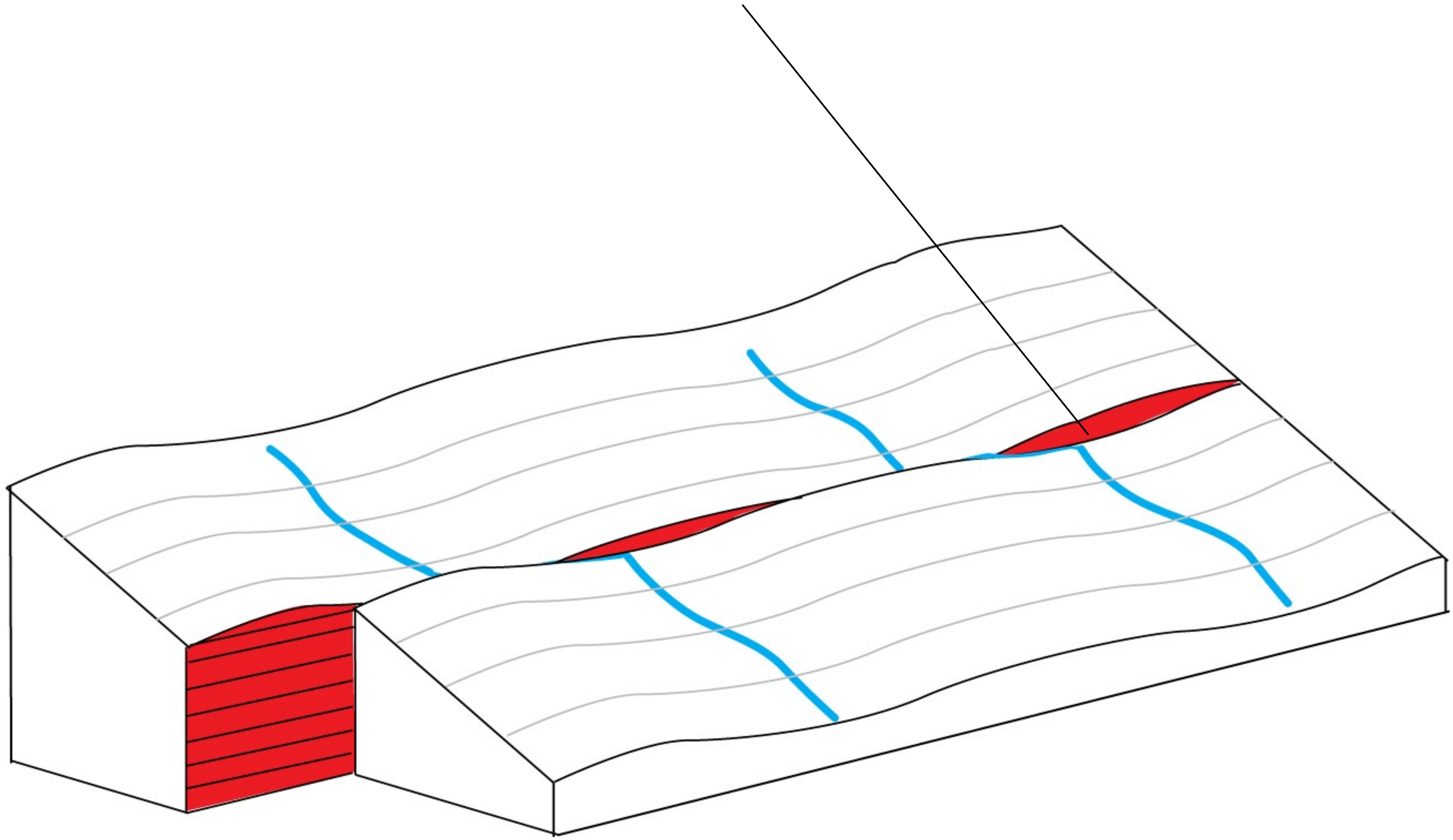


Introduce a fault and some streams flowing down the surface

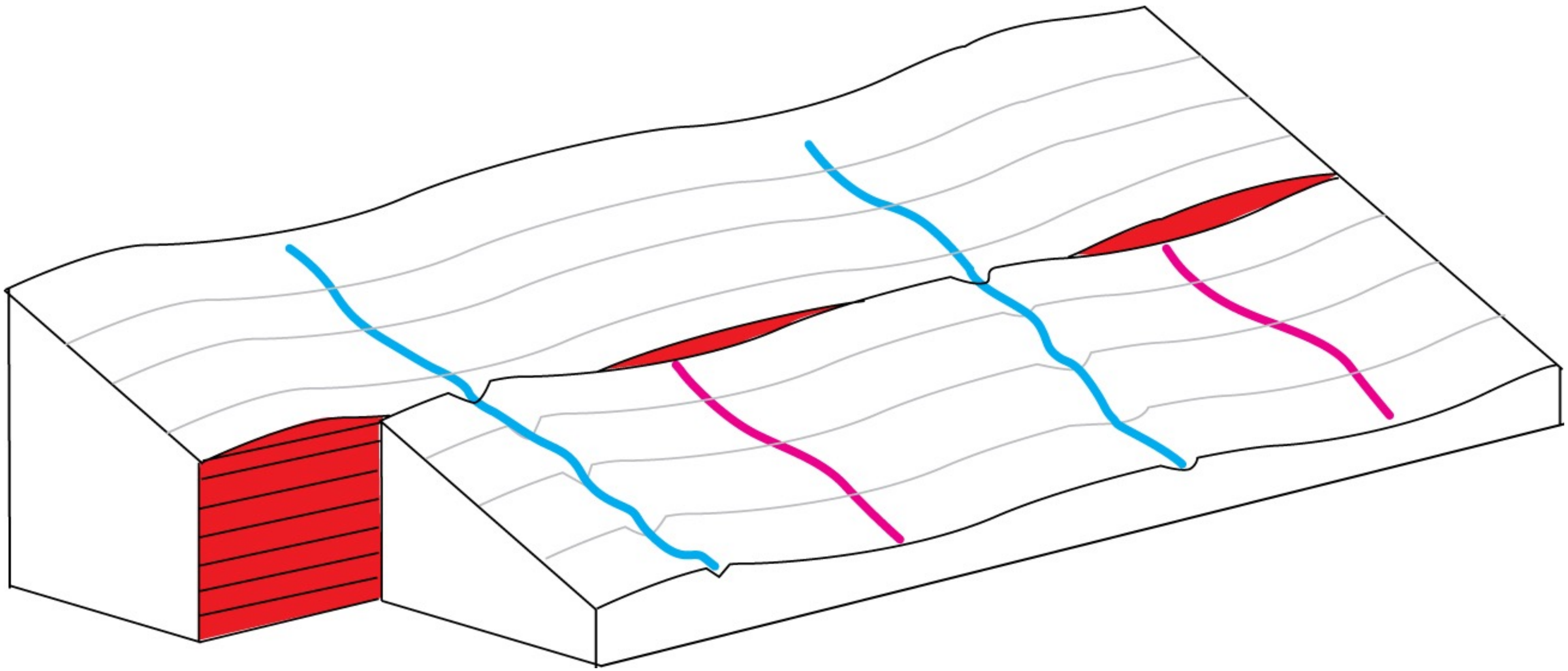


Let earth slip laterally (horizontally) across the fault - an earthquake

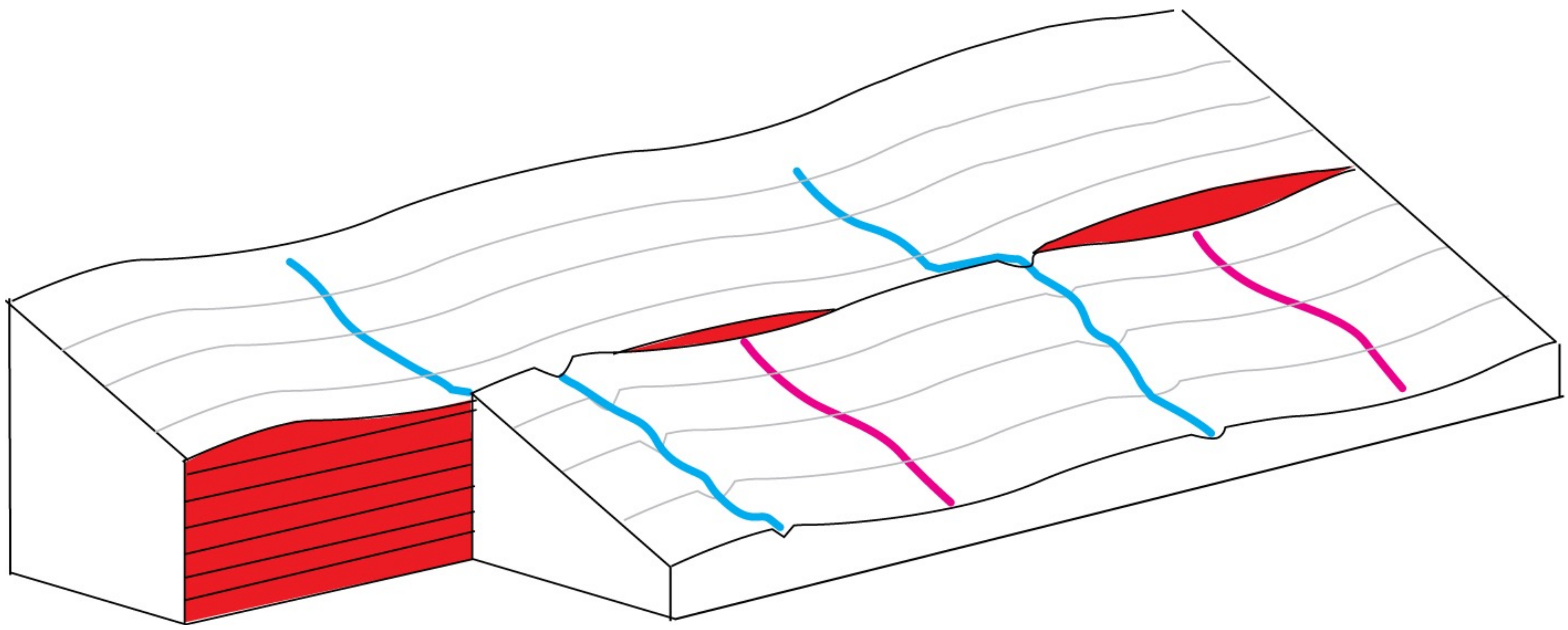
Scarp - abrupt change in topography....



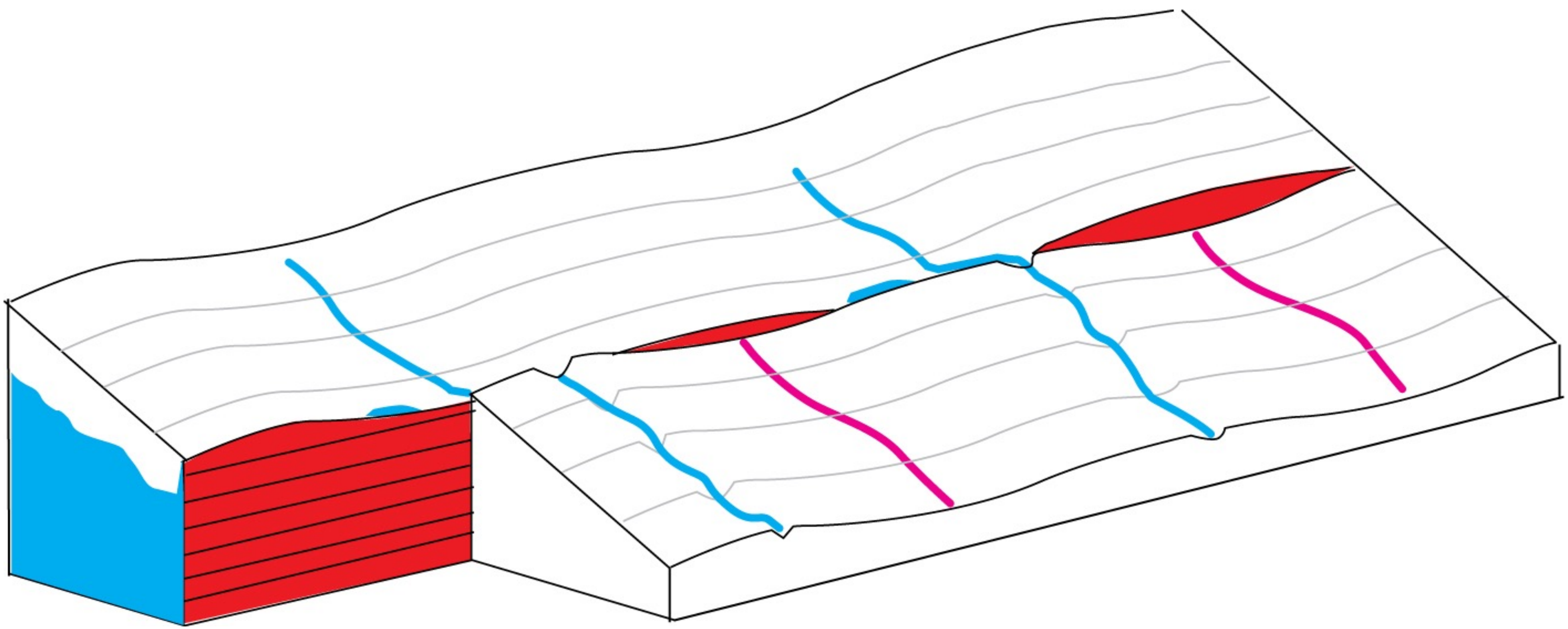
and again.. another earthquake



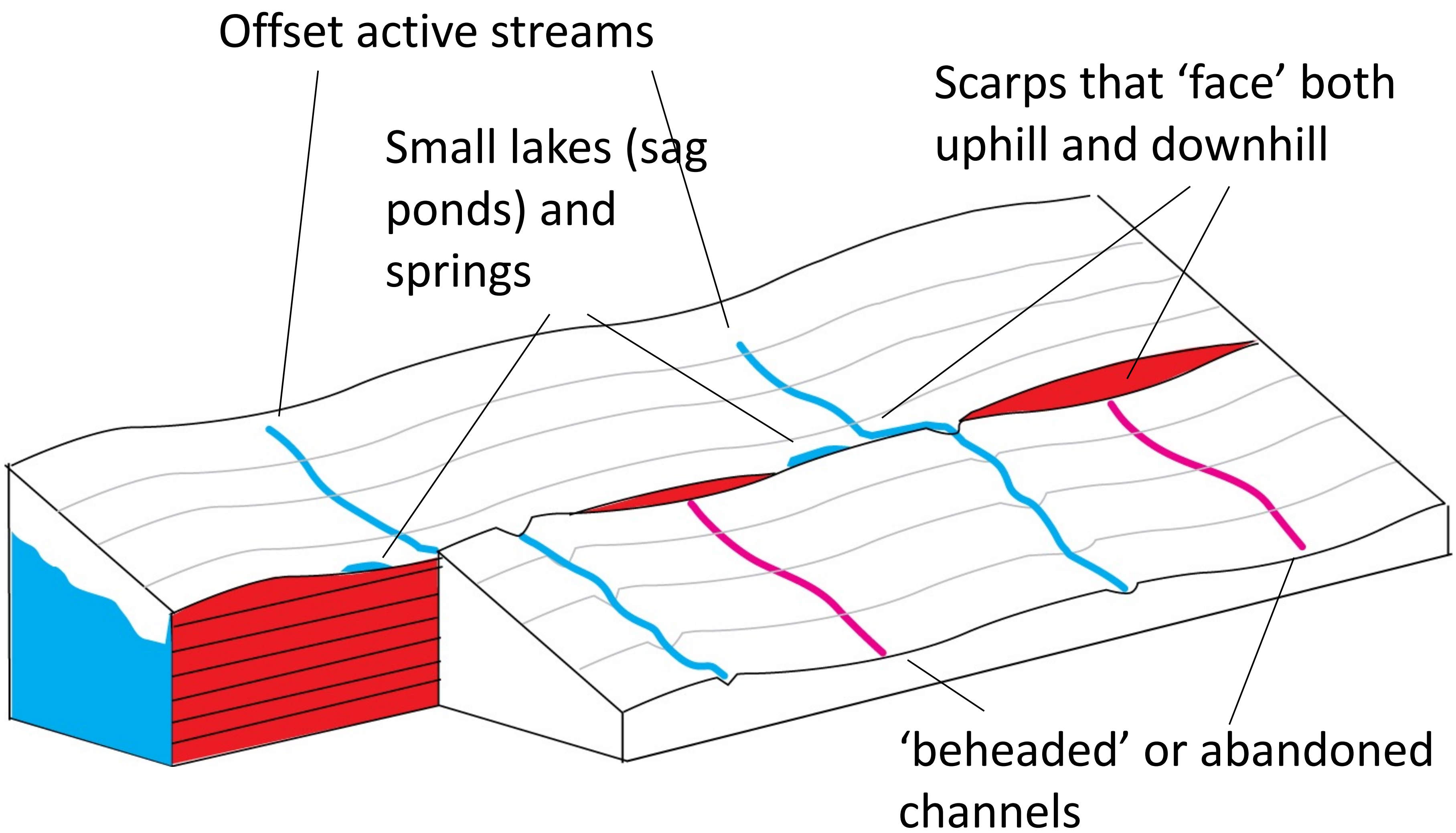
and then maybe a bigger than usual rain…



and then let earth slip some more laterally…

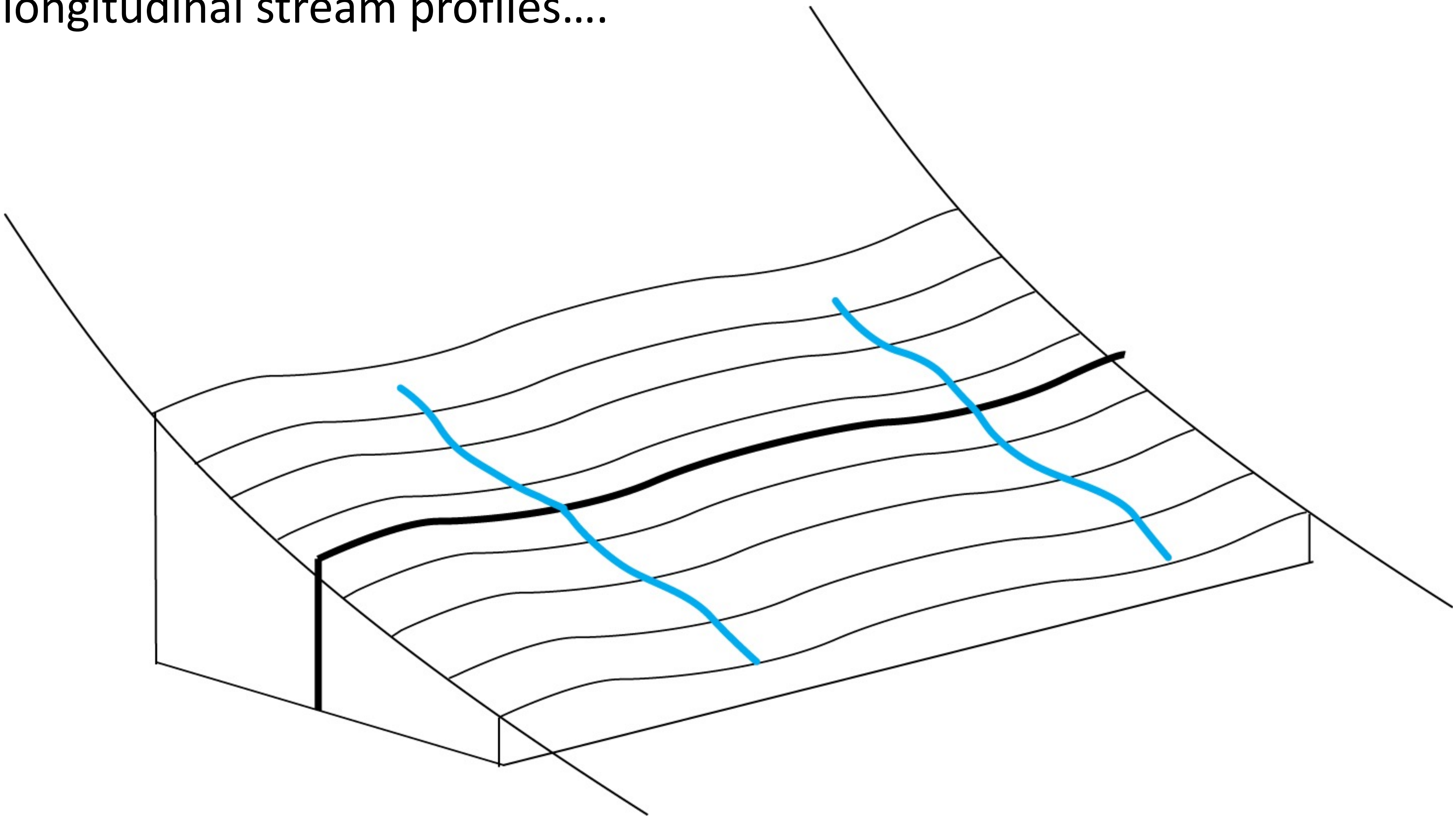


and then think about the water table too…

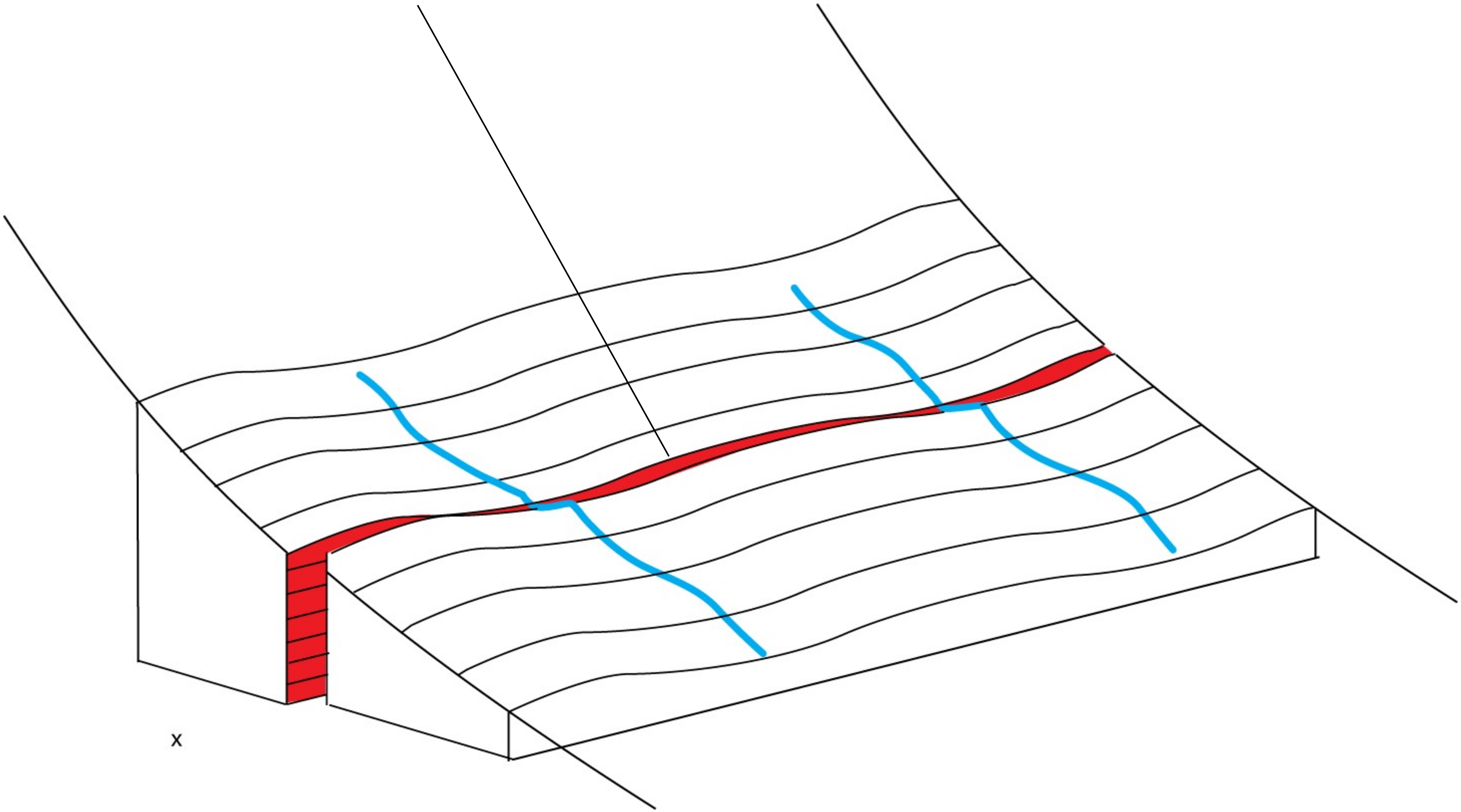


What are we left with? How has shape changed?

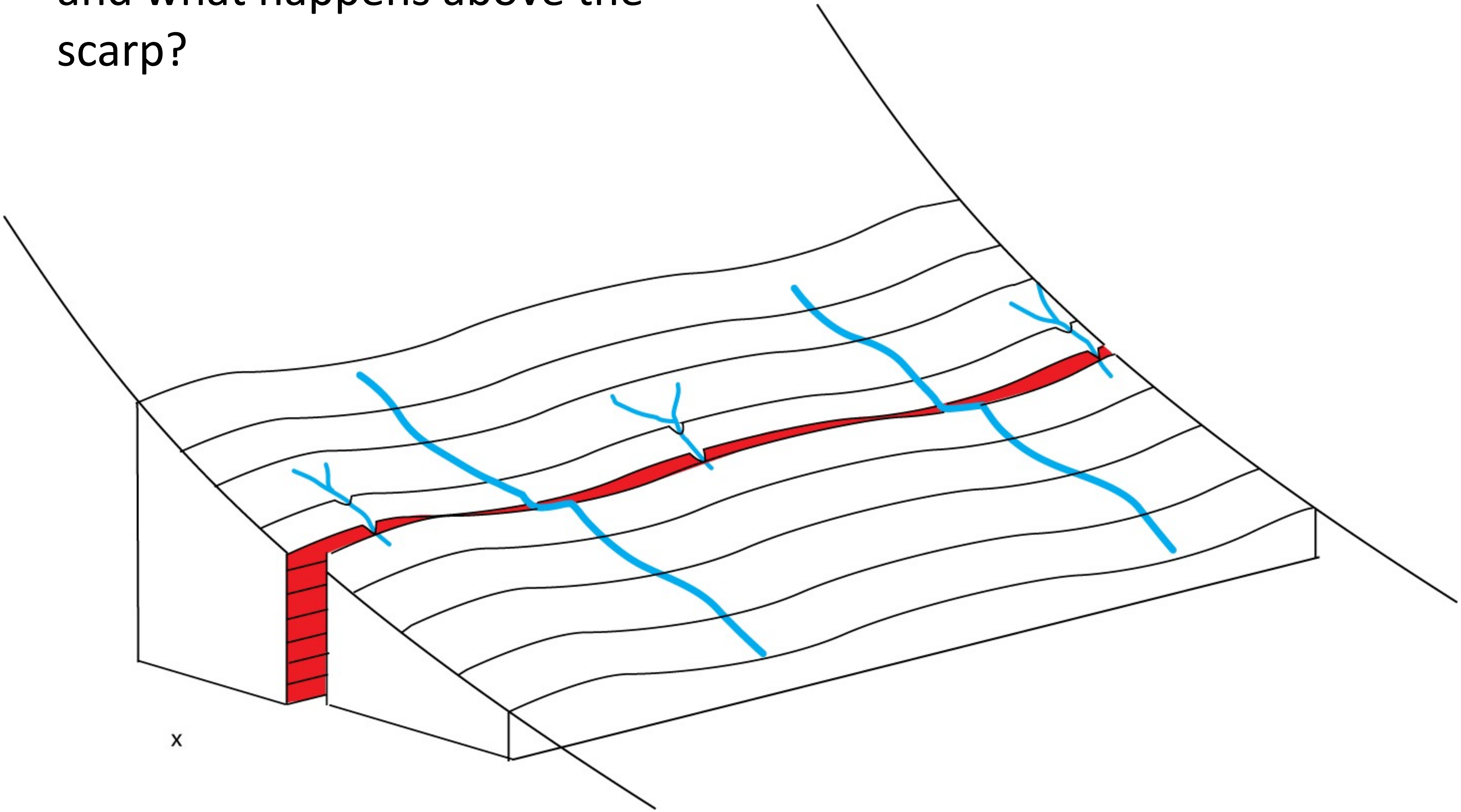
Now - let's suppose that there is also some vertical displacement - and recall idea of base-level and longitudinal stream profiles….



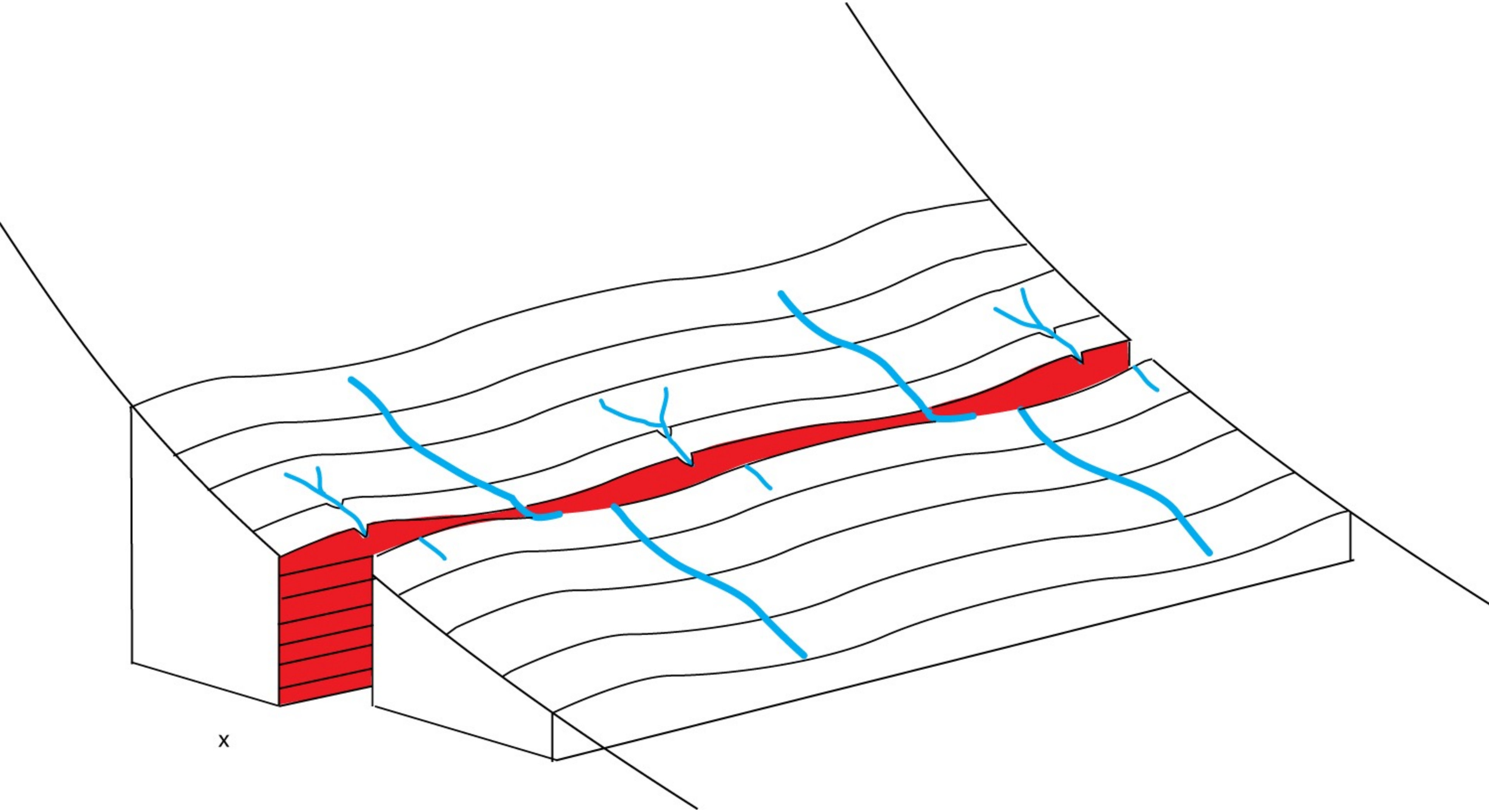
The displacement makes only scarps that face one-way in the downhill direction



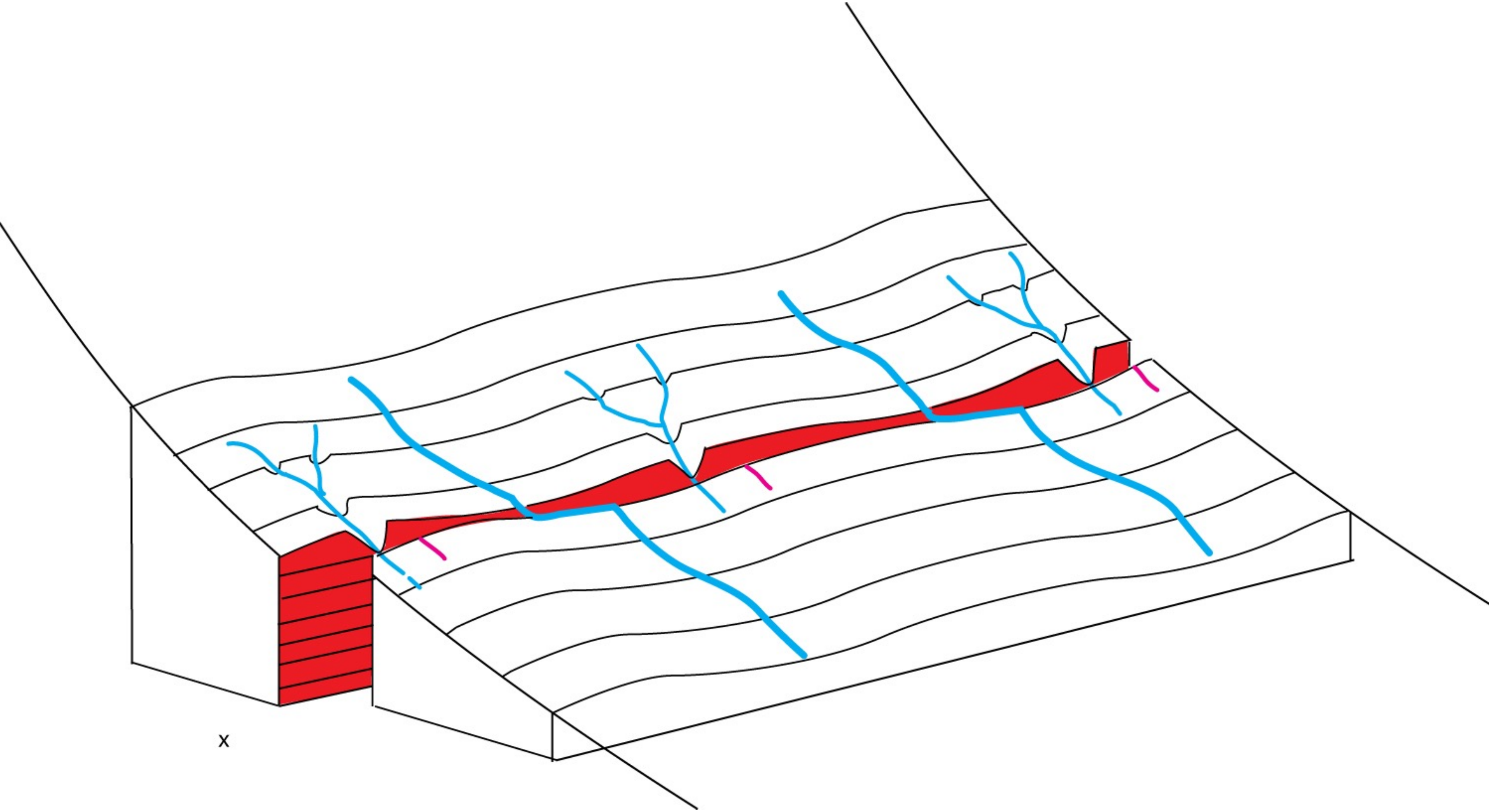
Now we add a little more rain - and what happens above the scarp?



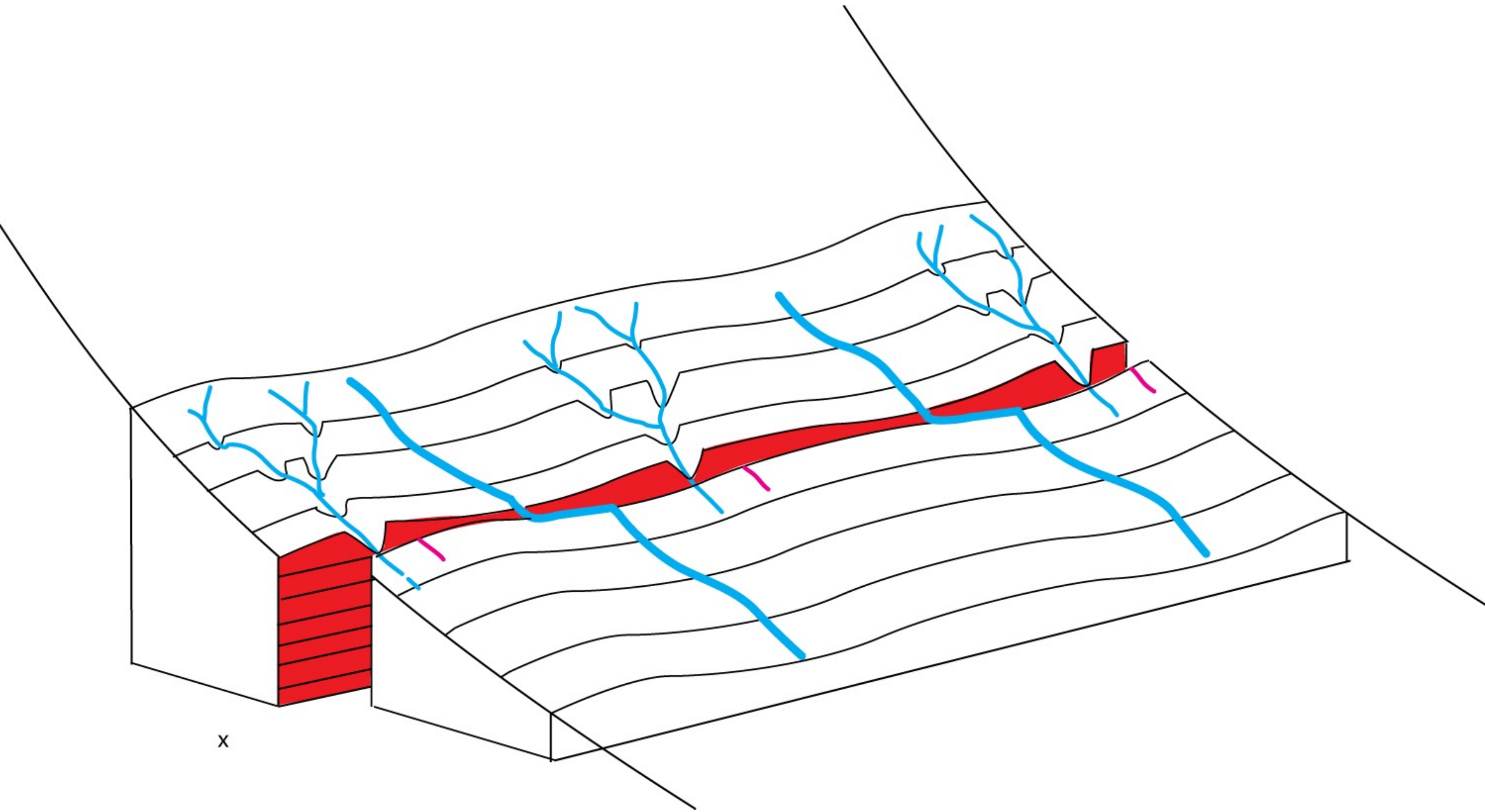
And let things slip again in an earthquake (or two- or three…



And let time pass and the processes that go with it - more rain and erosion....

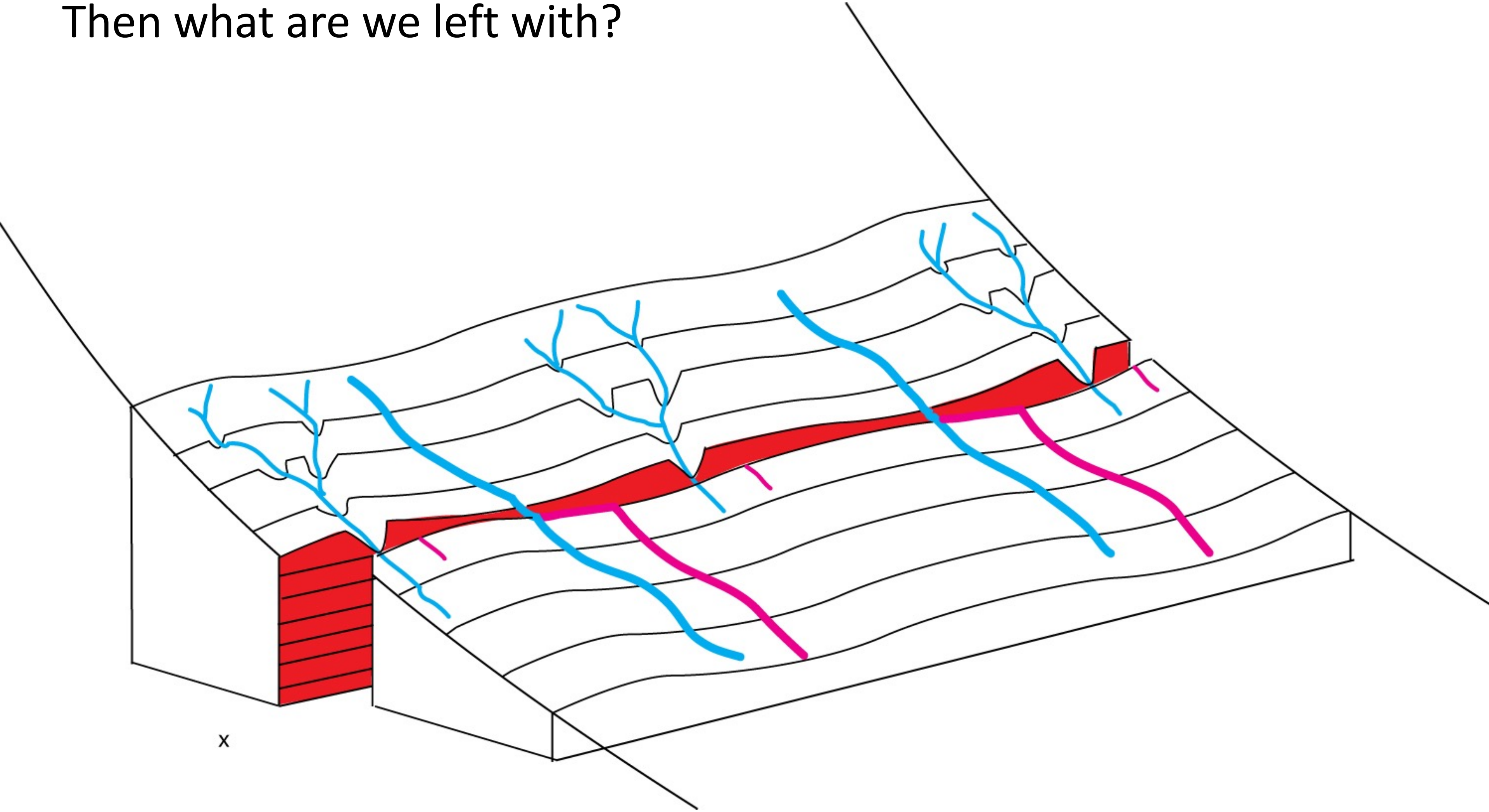


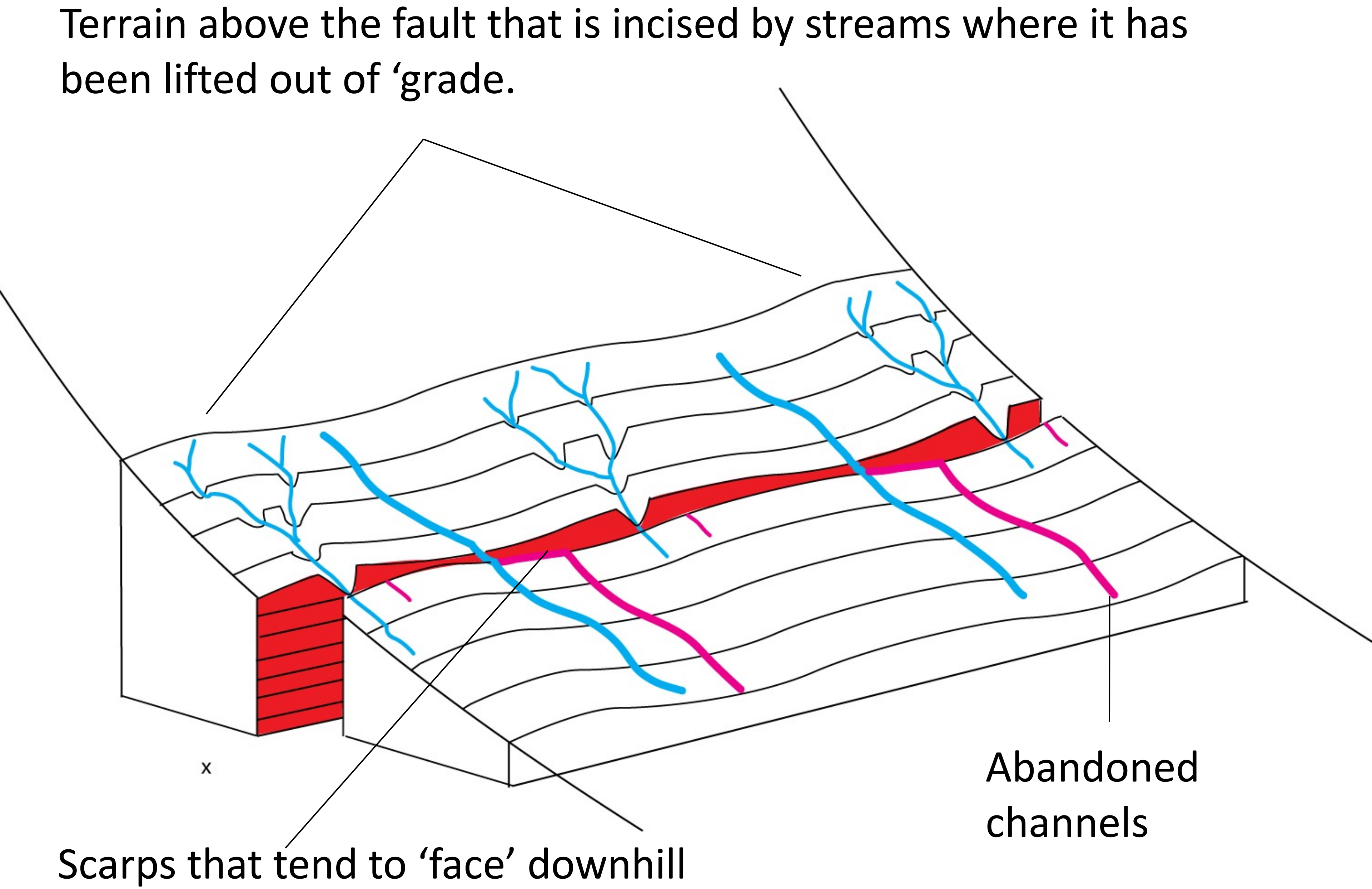
and more time…



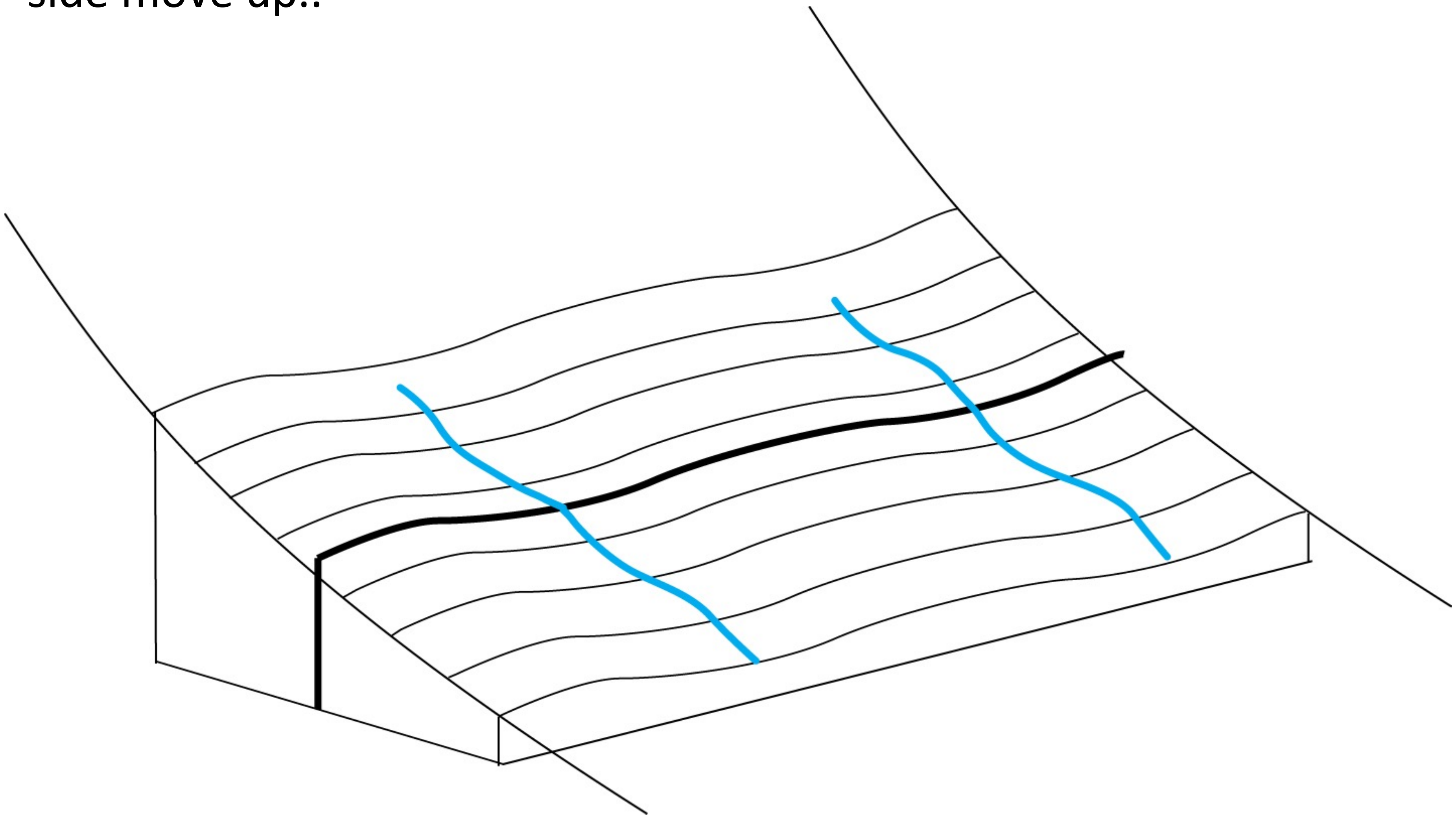
And then maybe a bigger than usual storm….

Then what are we left with?

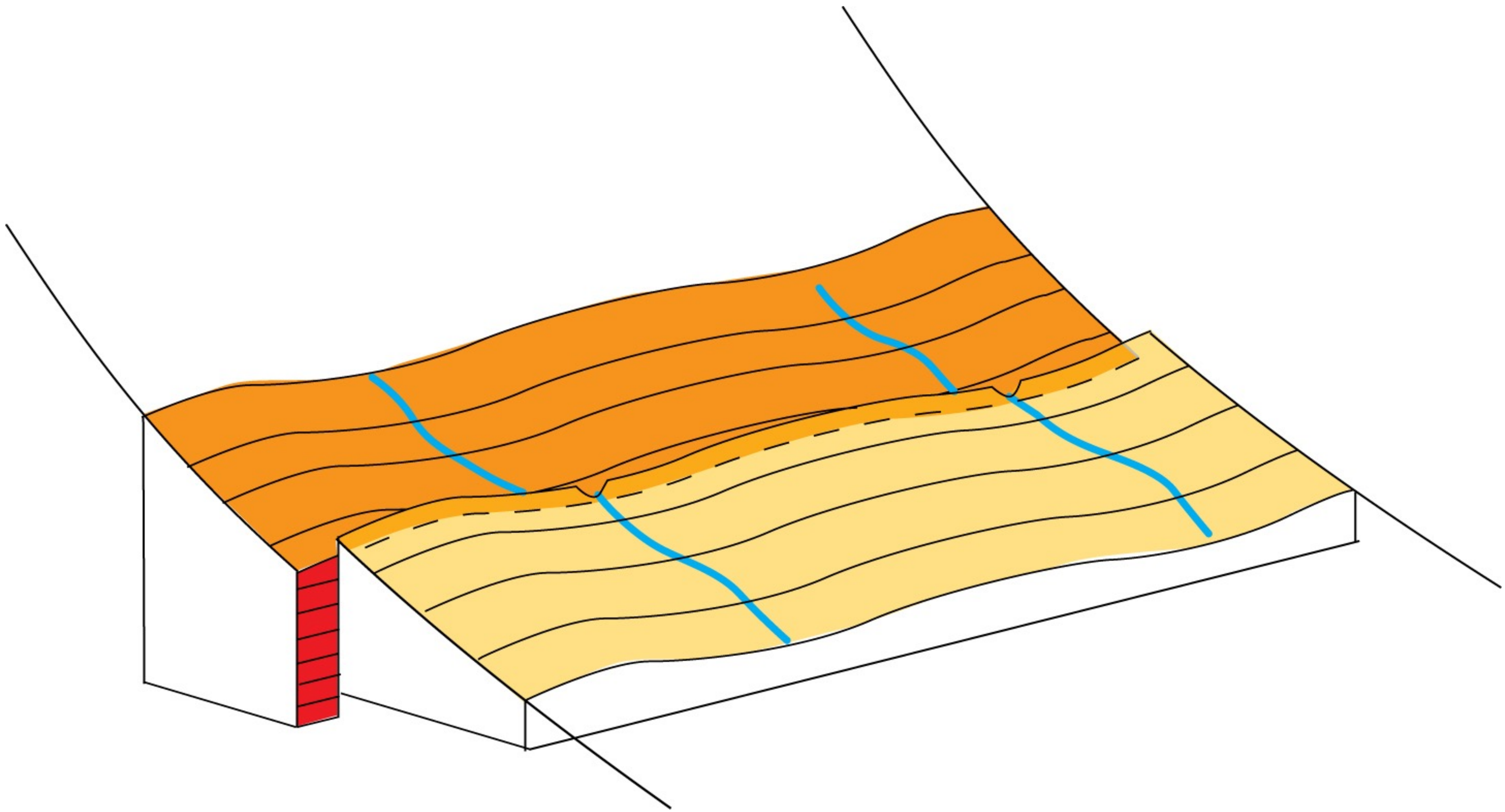



Terrain above the fault that is incised by streams where it has been lifted out of 'grade.
x
Abandoned channels
Scarps that tend to 'face' downhill

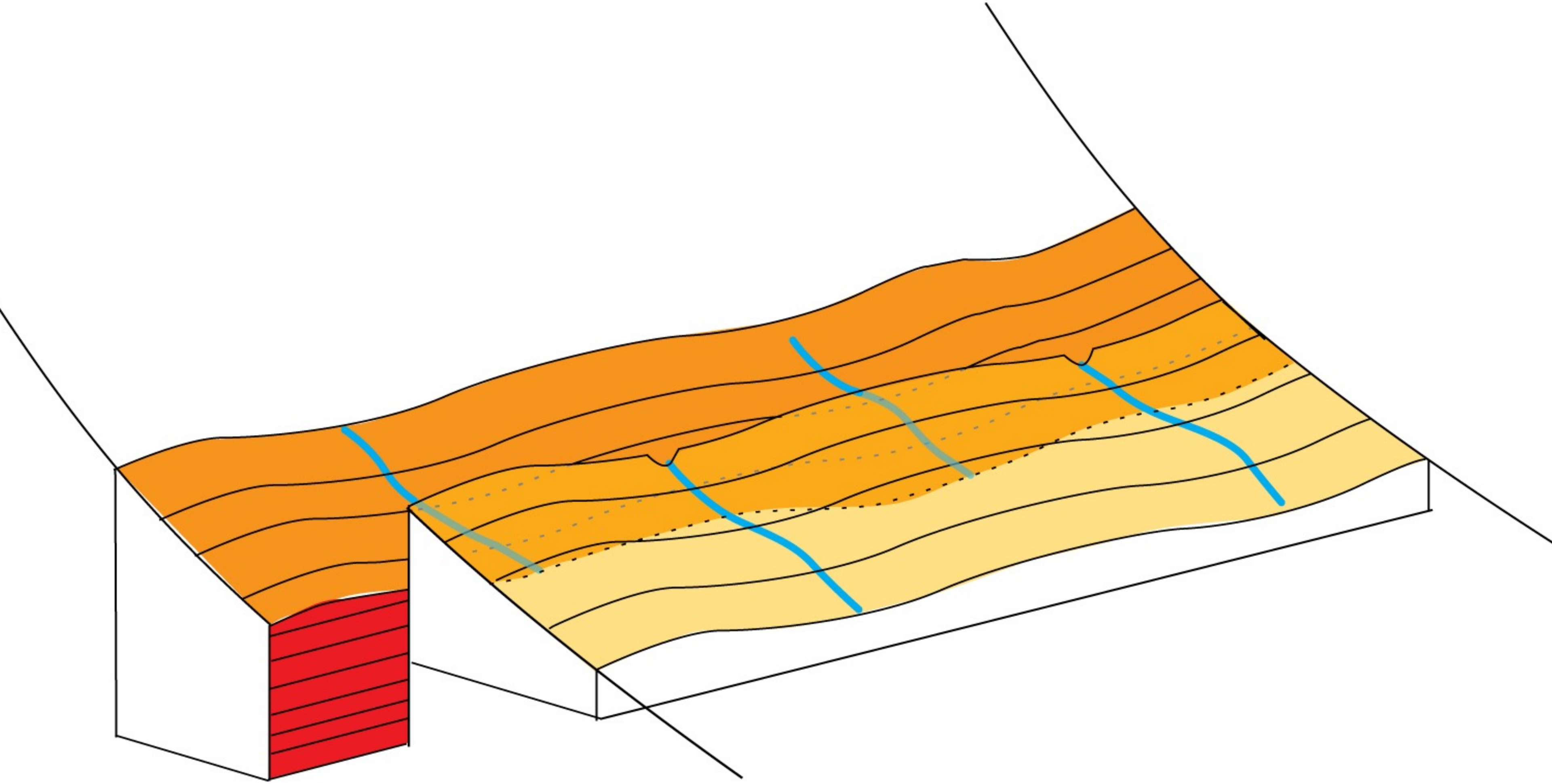
Let's start again - but let downhill side move up..



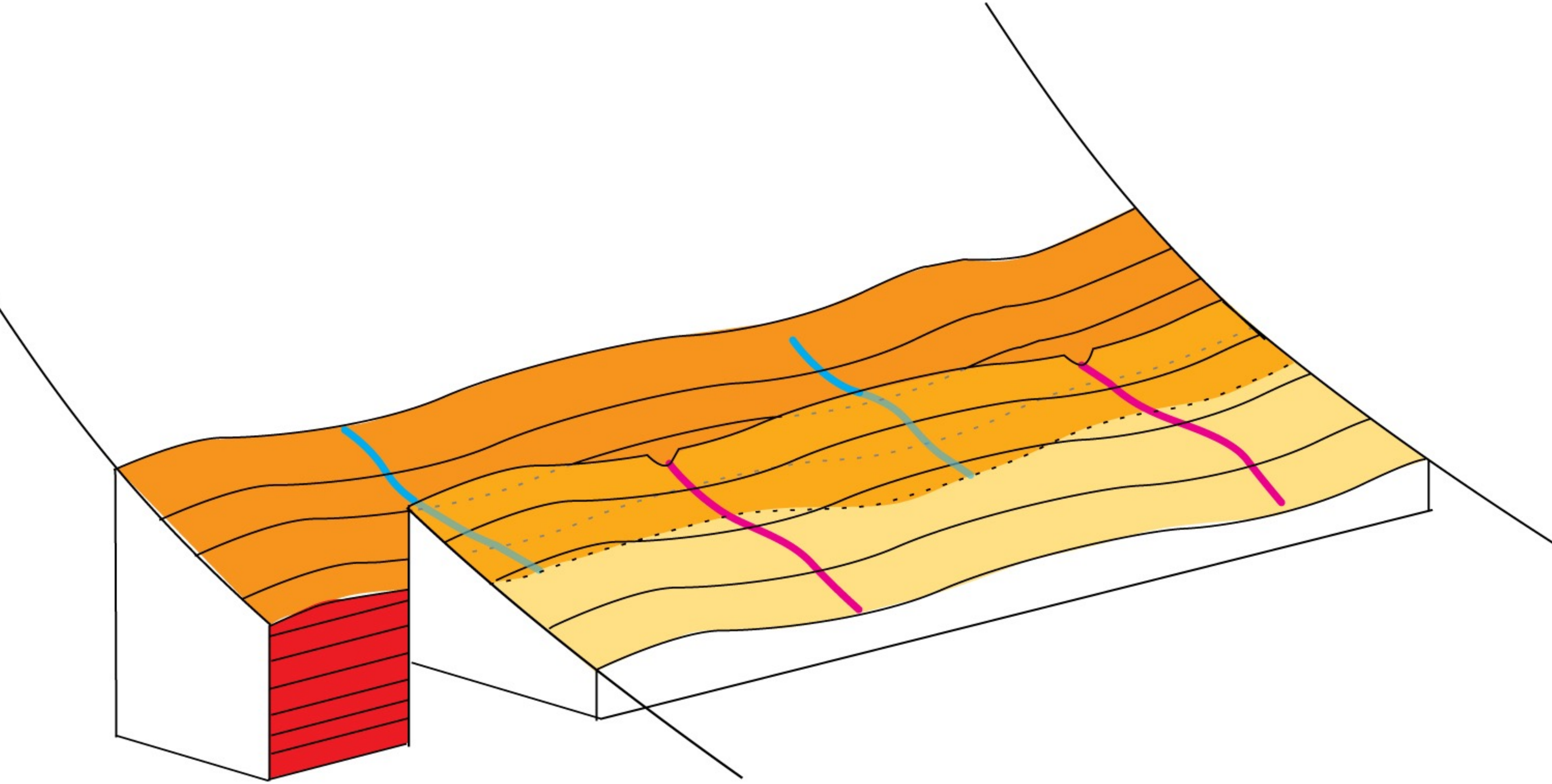
Now all scarps 'face' uphill…



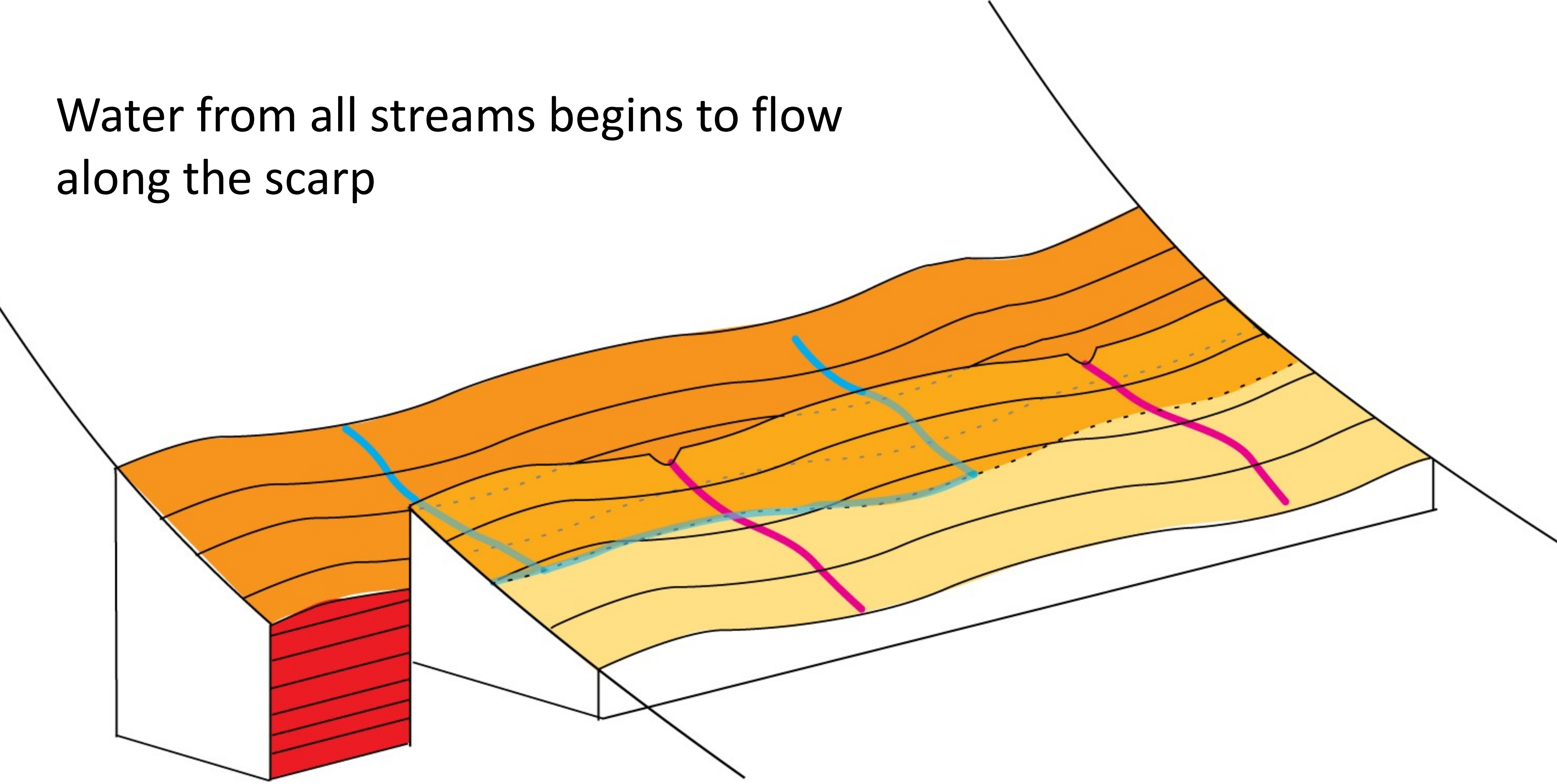
Let it slip even more …. What's gonna happen…



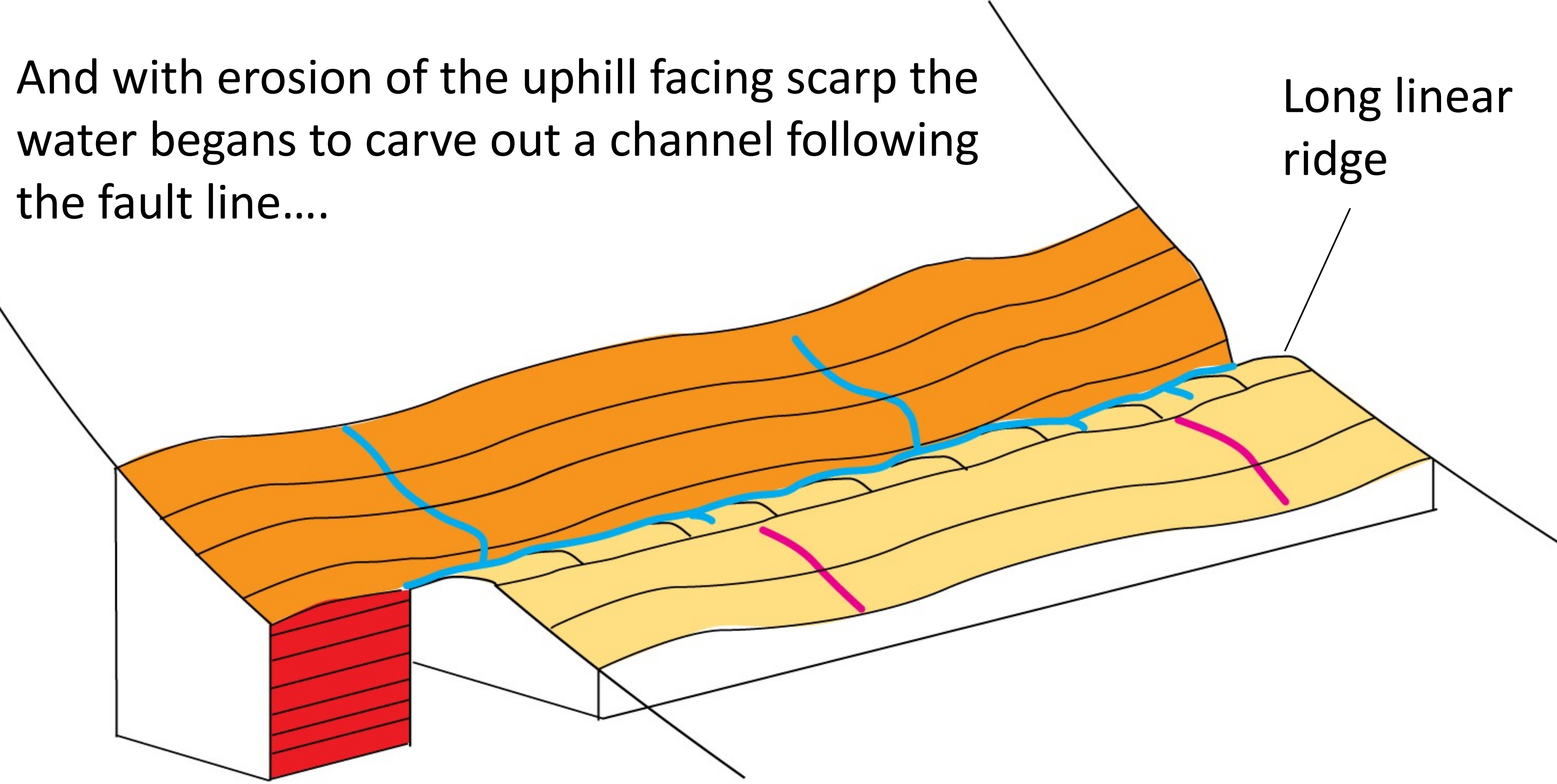
Water cannot flow past the scarp - streams on downhill side now abandoned….

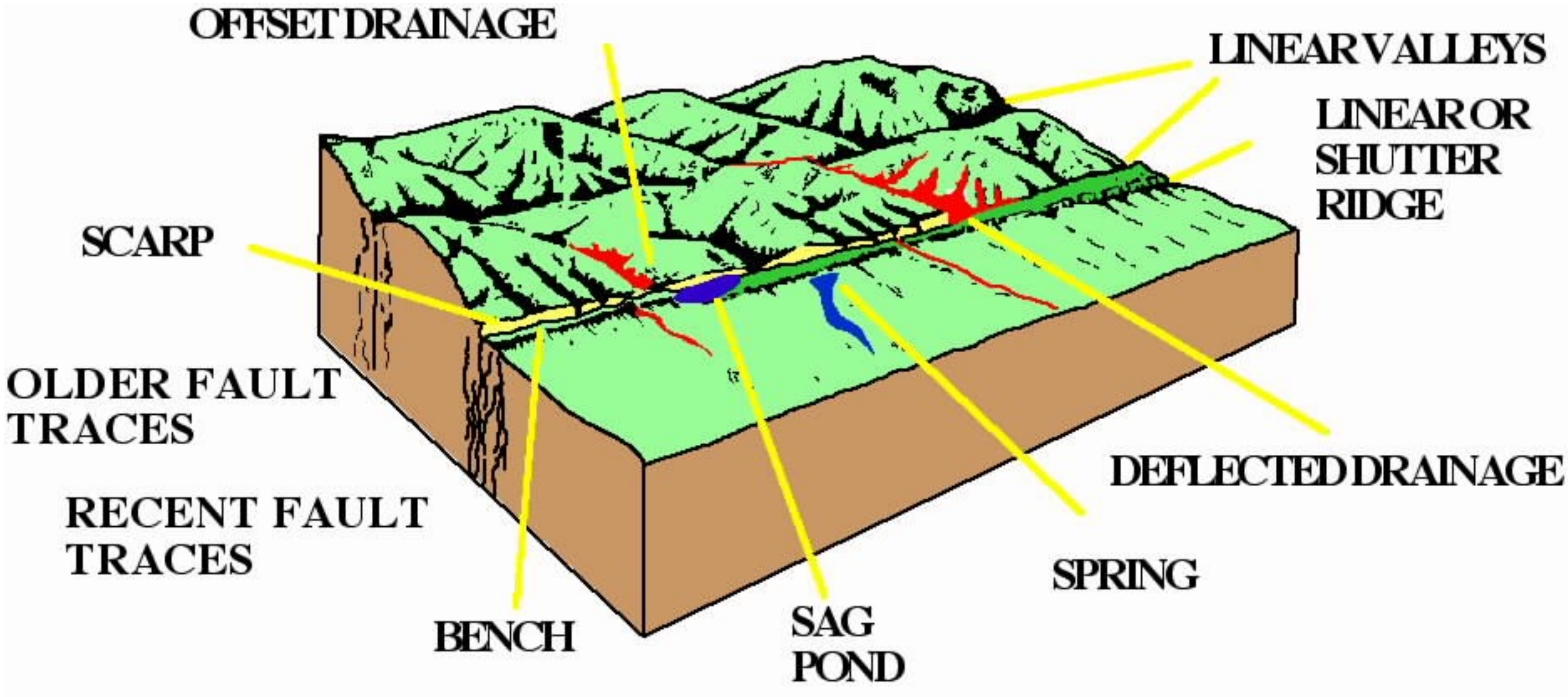


Water from all streams begins to flow along the scarp

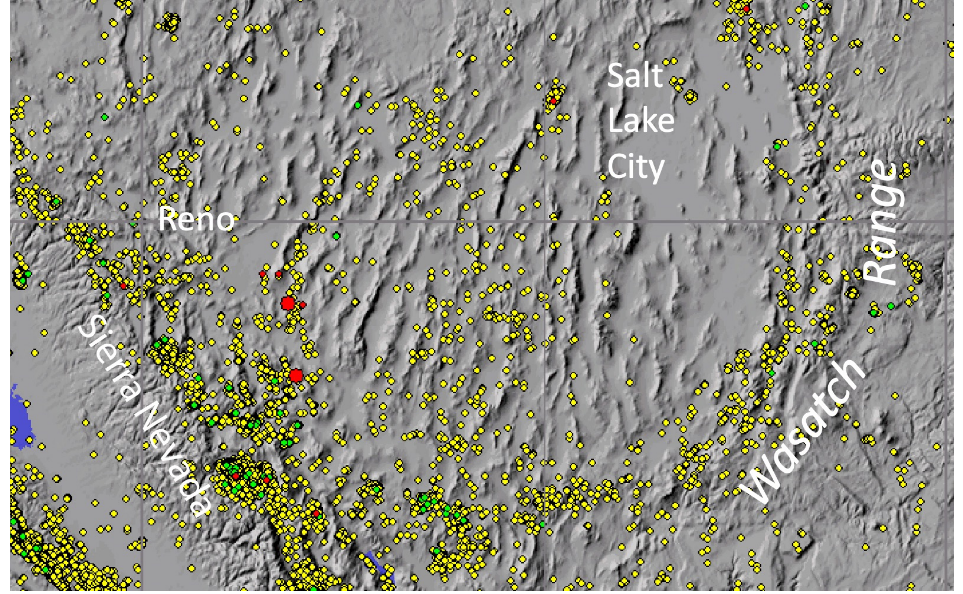


And with erosion of the uphill facing scarp the water begans to carve out a channel following the fault line....

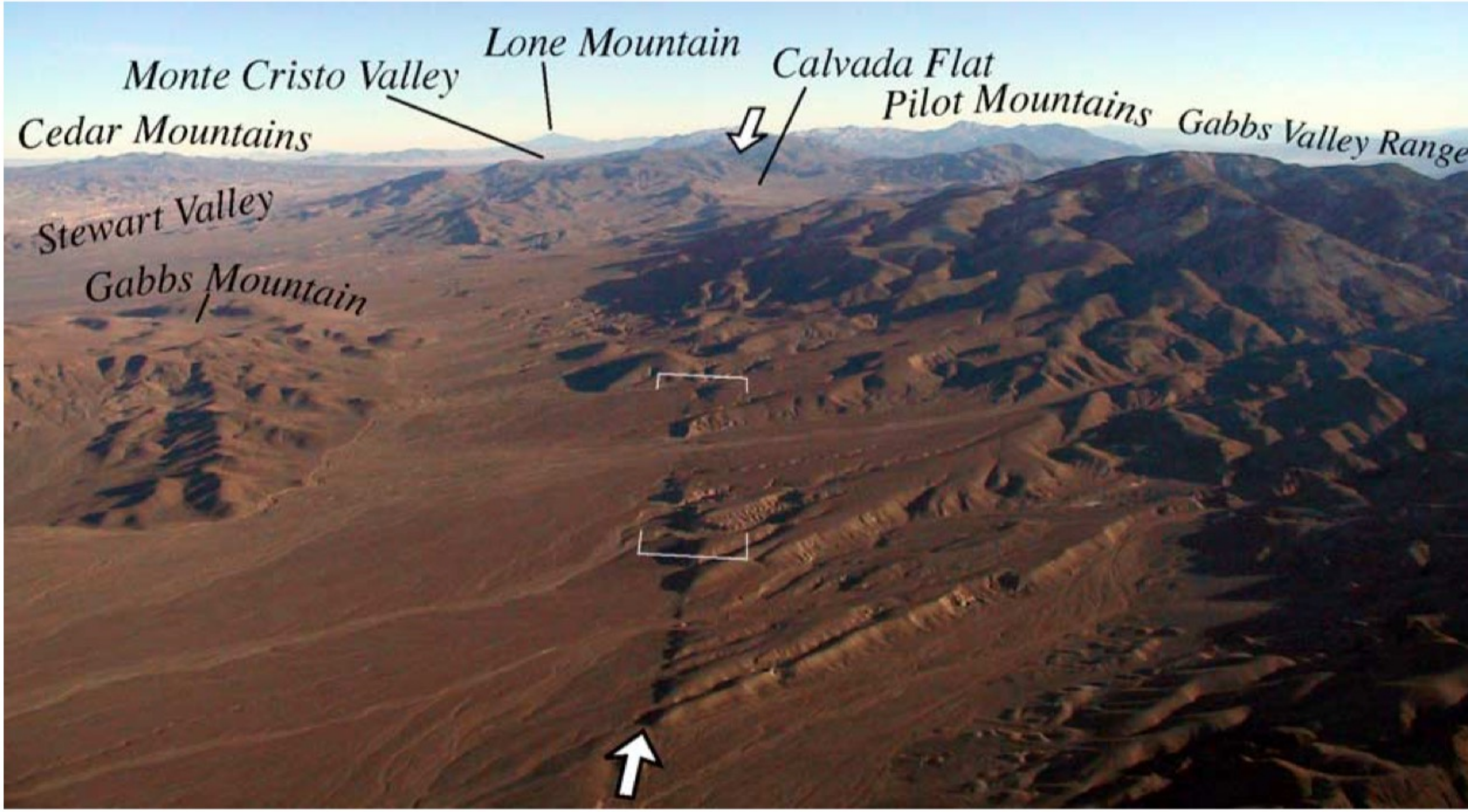




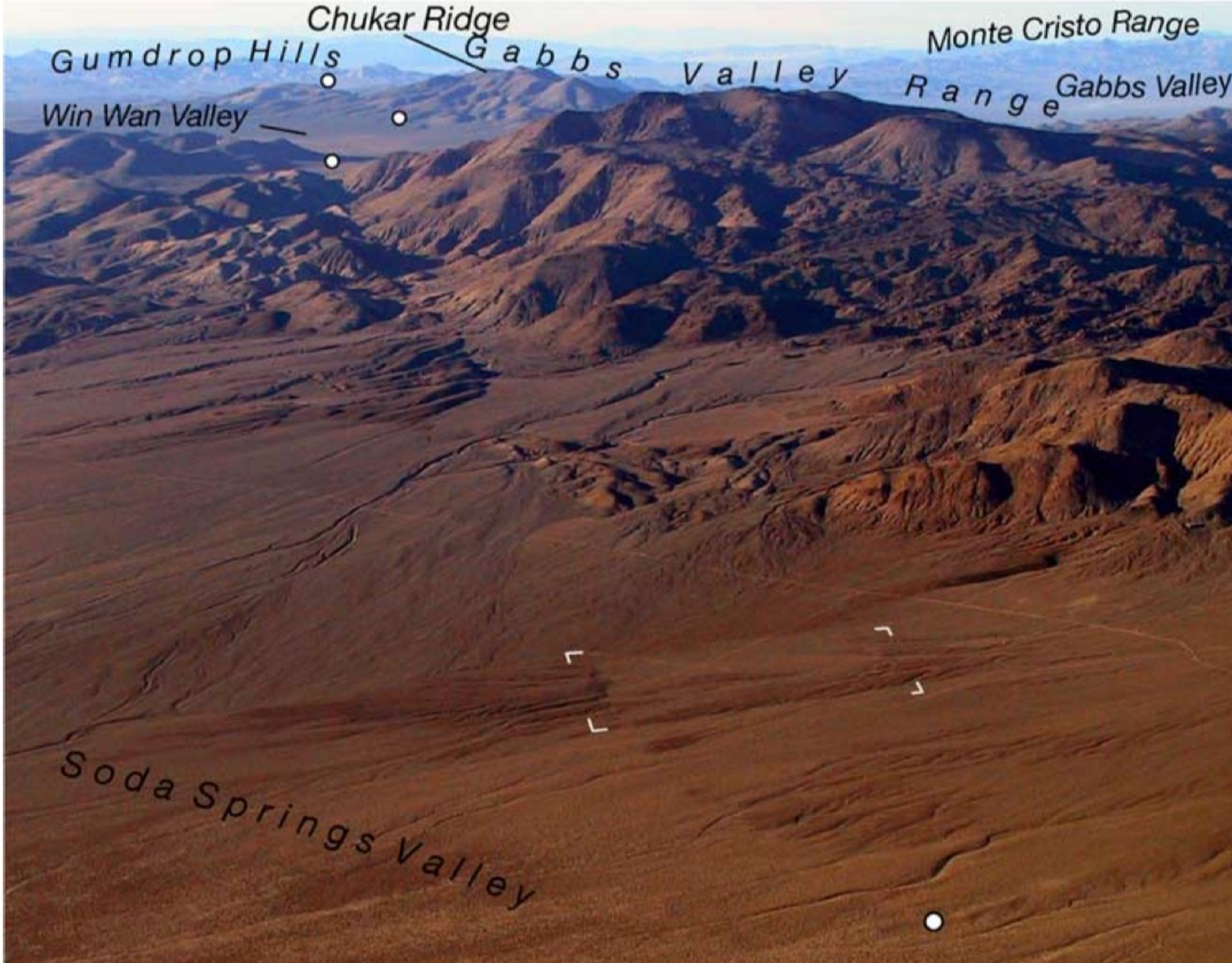
MORPHOLOGY OF STRIKE-SLIP FAULT ZONES



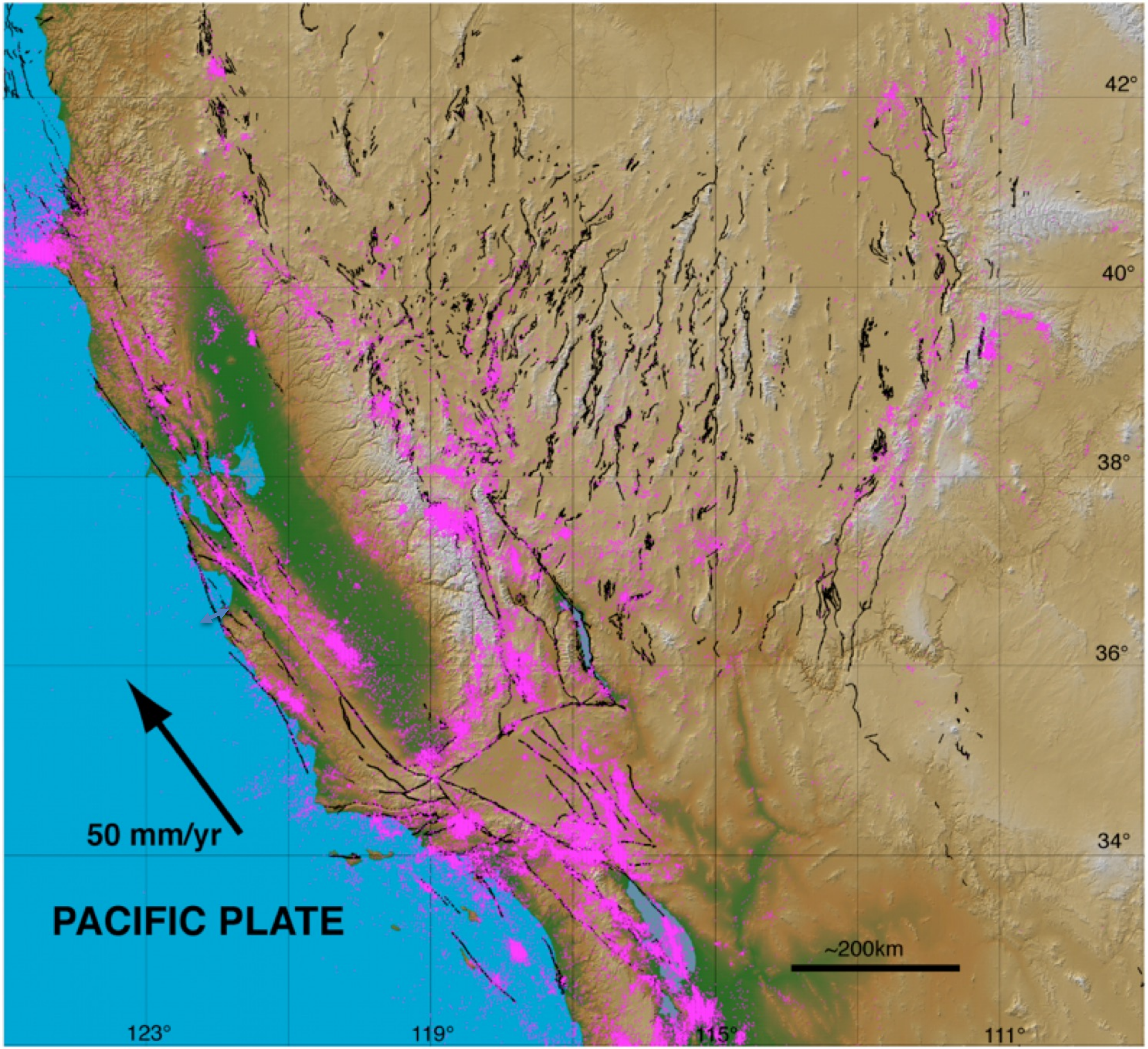
A morphologic and physiographic expression quite different from Basin and Range normal faulting



Lone Mountain
Monte Cristo Valley
Calvada Flat
Pilot Mountains
Cedar Mountains
Gabbs Valley Range
Stewart Valley
Gabbs Mountain


Chukar Ridge
Gumdrop Hills
Gabbs Valley Range
Monte Cristo Range
Gabbs Valley
Win Wan Valley
Soda Springs Valley


Pyramid Lake
Anajo Island



So that's where the black lines come from....