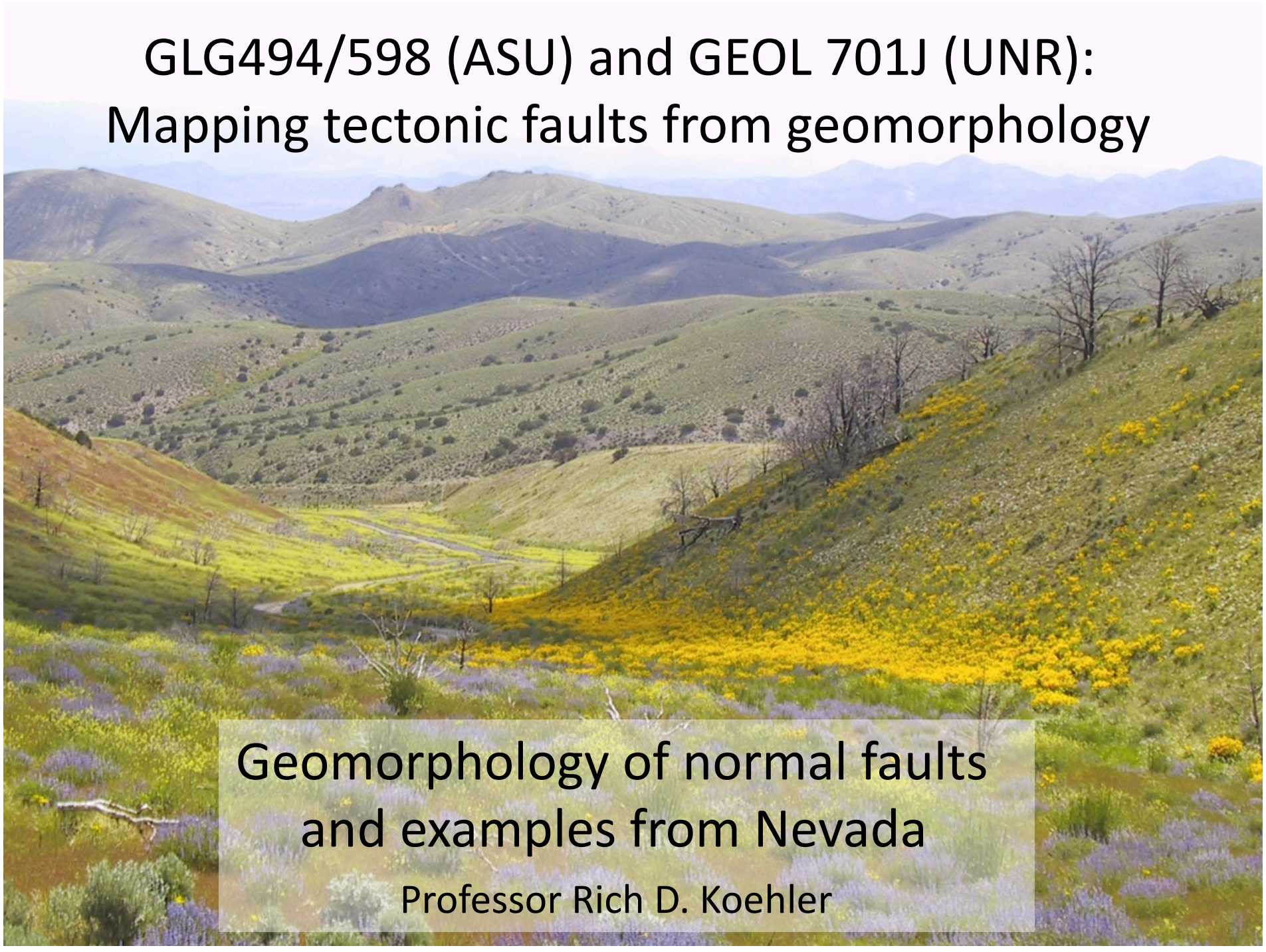
GLG494/598 (ASU) and GEOL 701J (UNR): Mapping tectonic faults from geomorphology

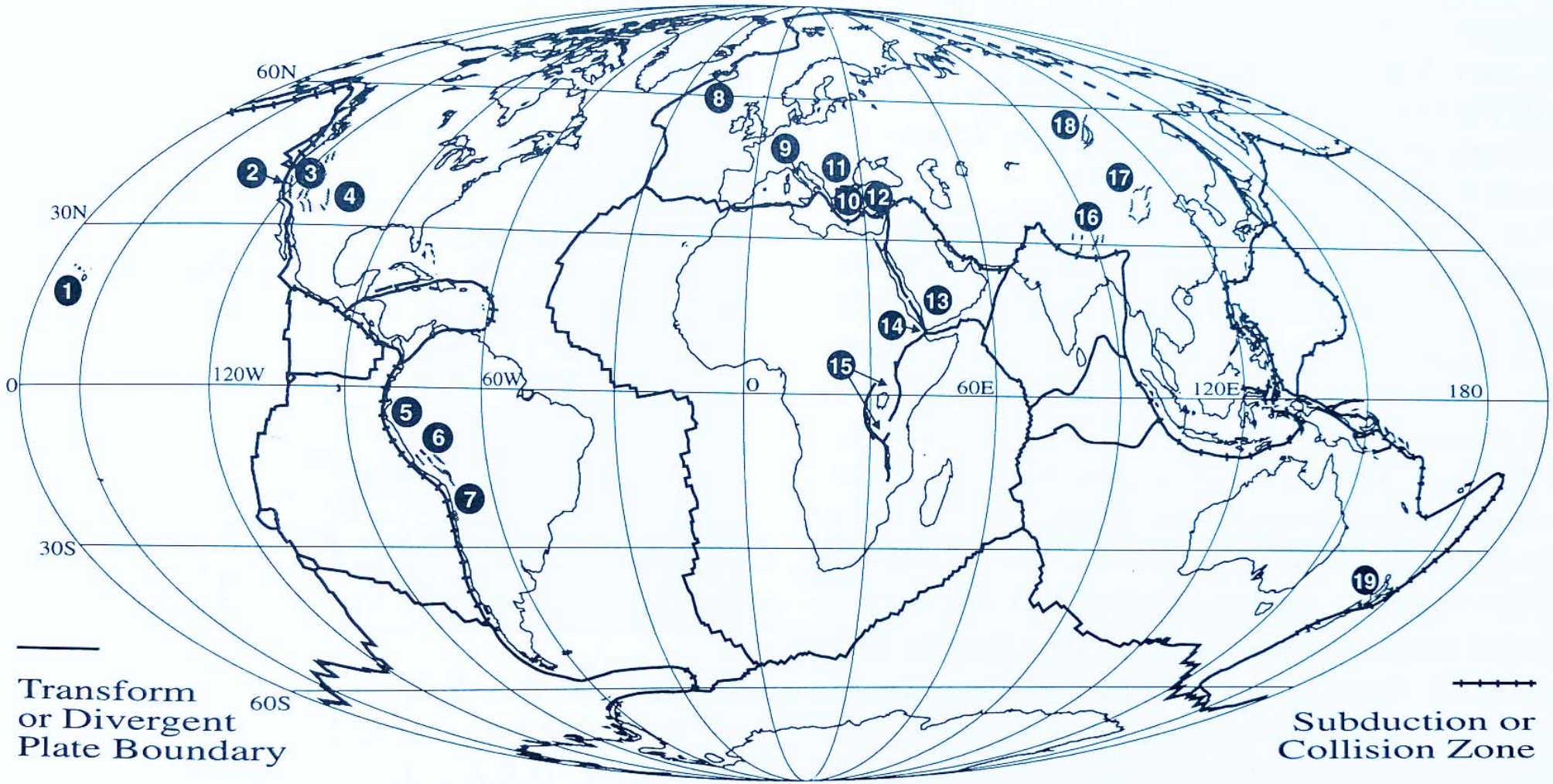


Geomorphology of normal faults and examples from Nevada

Professor Rich D. Koehler

Outline of topics

- Normal faulting environments
- Basin and Range Province
- Geomorphic features along active normal faults
- Historical ruptures: surface map expression
- Examples of mapping normal faults



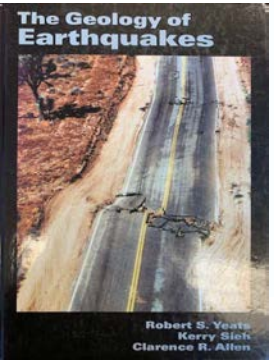


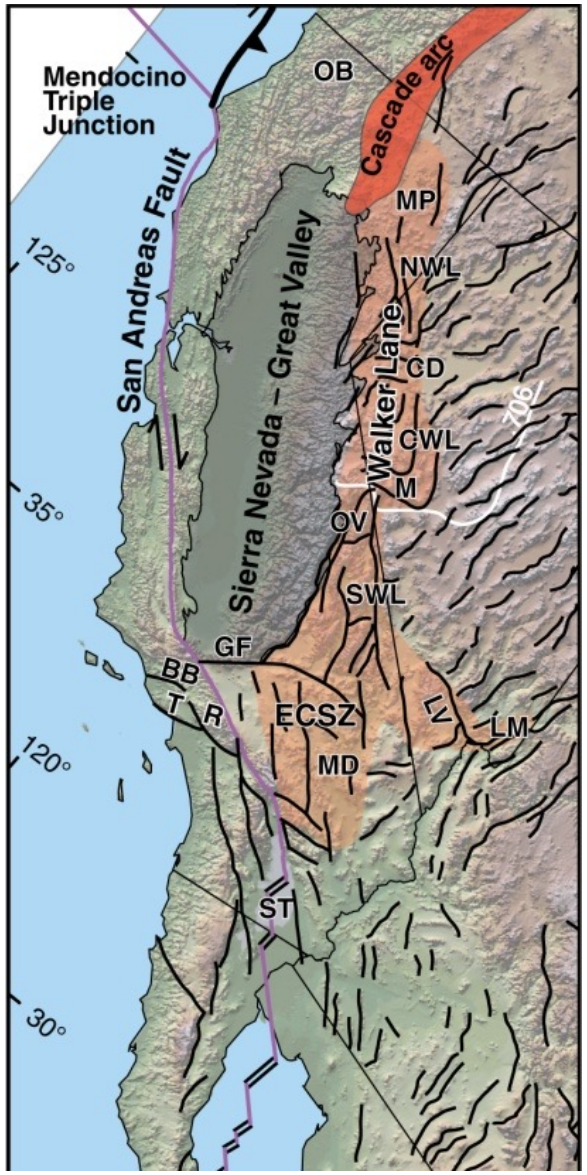
Figure 9–1. Locations of major active onshore normal-fault systems: 1. Hawaii; 2. Sierra foothills; 3. Basin and Range; 4. Rio Grande Rift; 5. Gulf of Guayaquil; 6. Altiplano; 7. Mejillones Peninsula; 8. Iceland; 9. Apennines; 10. Greece; 11. Bulgaria; 12. Western Anatolia; 13. North Yemen; 14. Afar Triangle; 15. East African rift valleys; 16. Southern Tibet; 17. Ordos; 18. Baikal rift system; 19. Taupo Volcanic Zone.

- Origin due to crustal extension.
- Maximum compressive stress is vertical.
- Commonly in areas with high heat flow and
  relatively low velocity upper mantle.

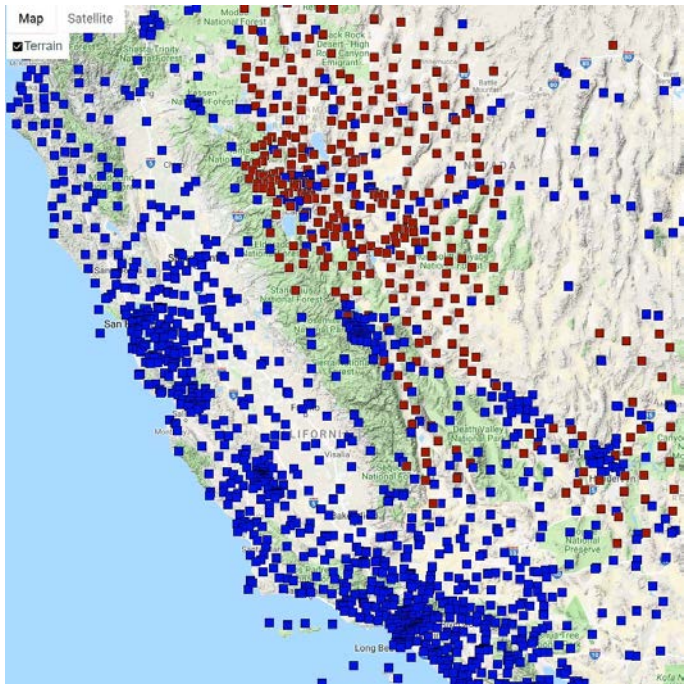
Geologic environments include:

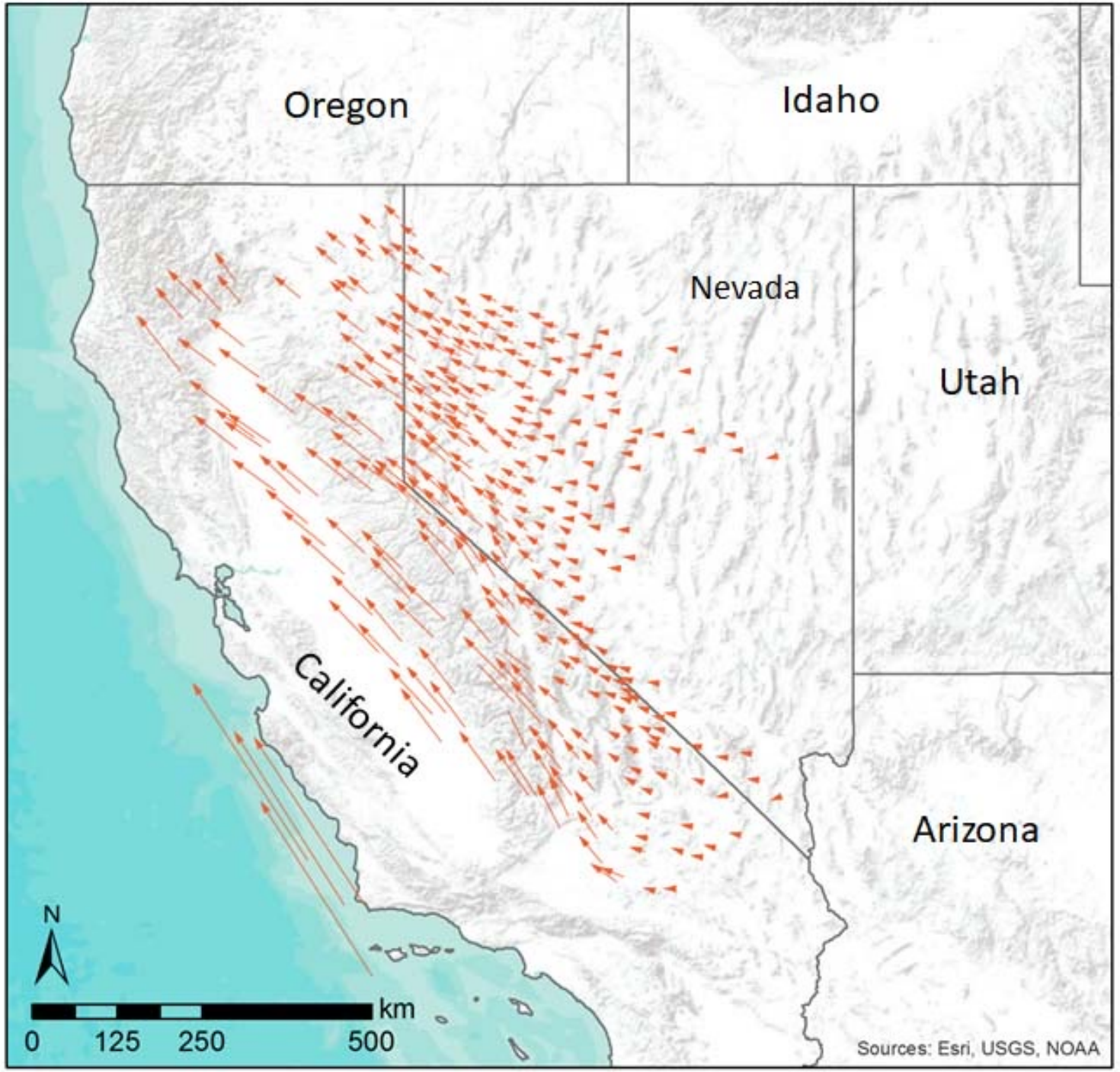
- Spreading centers
- Back arc basins
- Intracontinental rift systems
- Areas inboard of continent/continent collision.
- Subduction zones (due to flexing and horizontal compression)

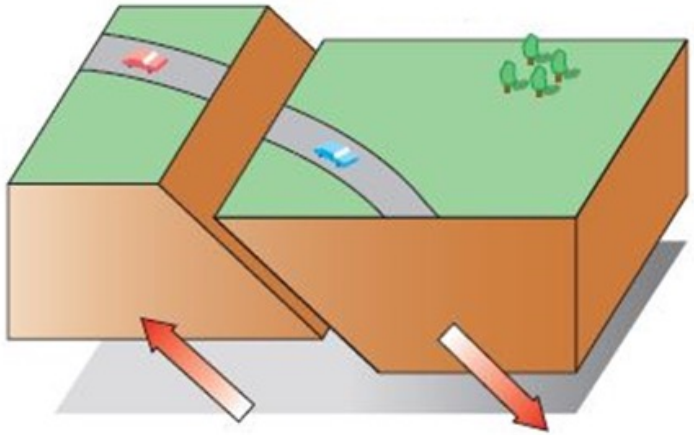
Basin and Range Province

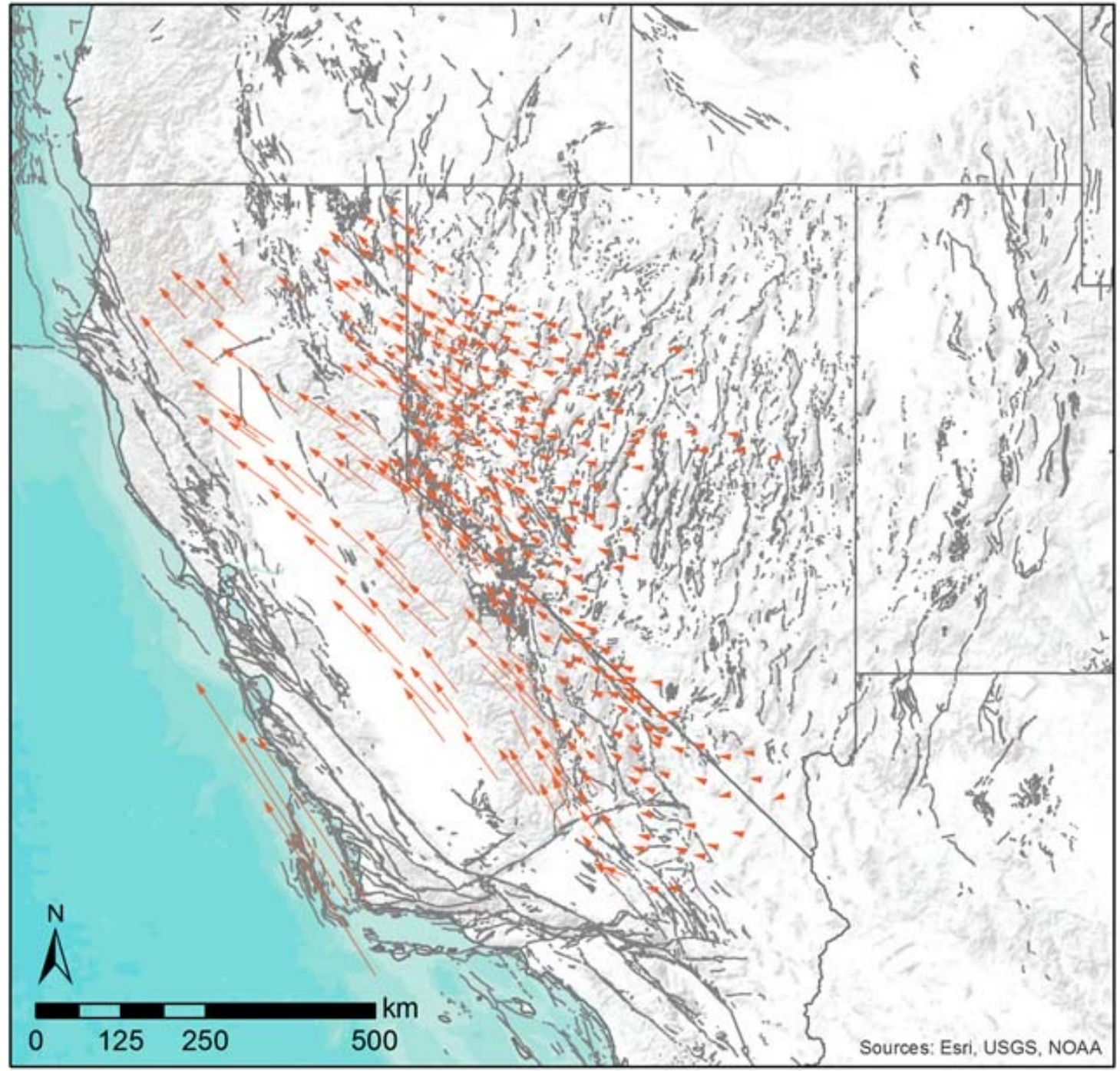


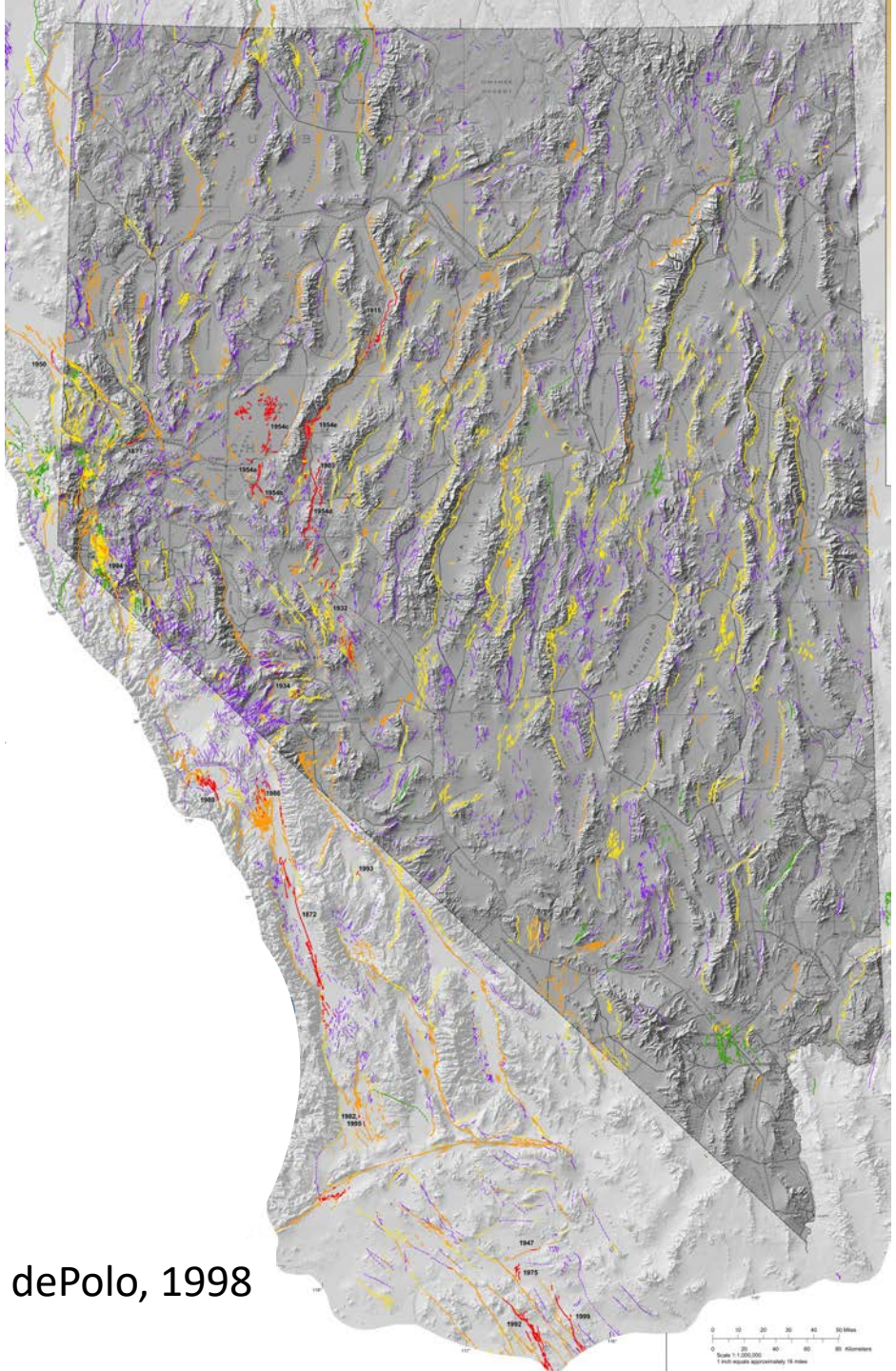
Mountain and basin topography is the result of
Progressive extension and normal fault displacement


Map
Satellite
Terrain


Oregon
Idaho
Nevada
Utah
California
Arizona
N
km
0
125
250
500
Sources: Esri, USGS, NOAA




N
km
0
125
250
500
Sources: Esri, USGS, NOAA



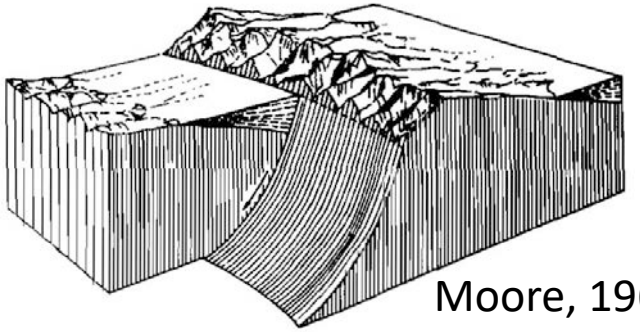
dePolo, 1998

Quaternary fault map of Nevada

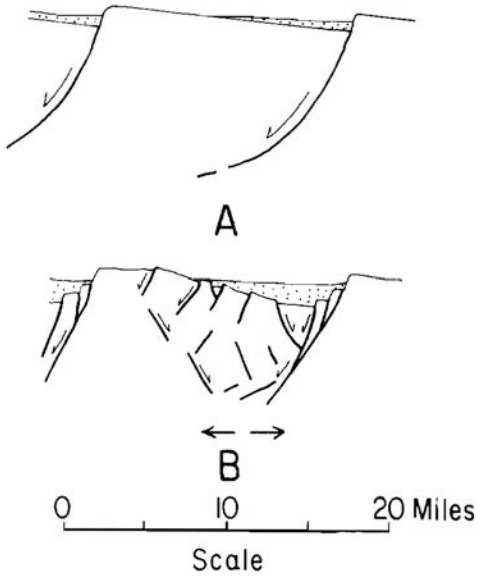
- Purple – Quaternary <1.8 ma
- Green – mid Quaternary <750 ka
- Yellow- latest Quaternary <130 ka
- Orange – latest Pleistocene-Holocene <15 ka
- Red - Historic

Models of Basin and Range faulting

Tilted block model

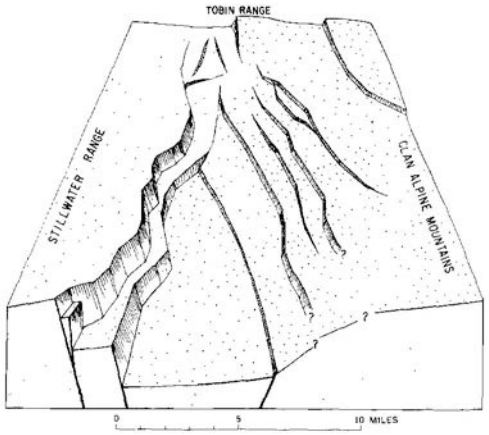


Moore, 1960

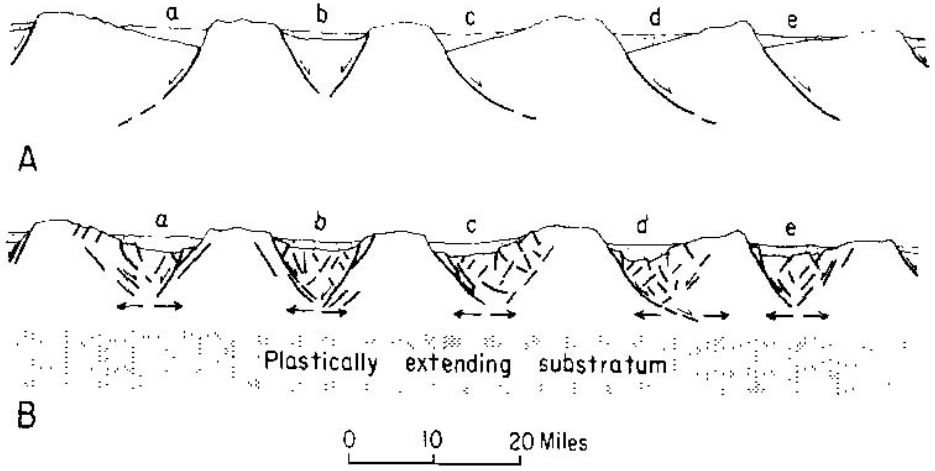


Asymmetrical graben

Tilted block model
With basin sediment removed

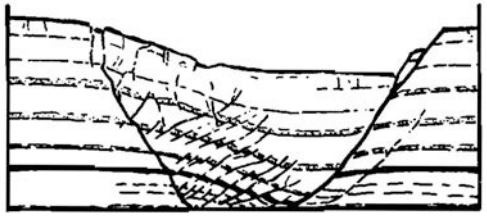


Burke, 1967

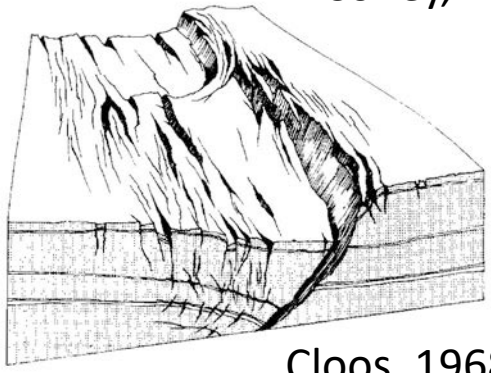


Stewart, 1971

Clay models

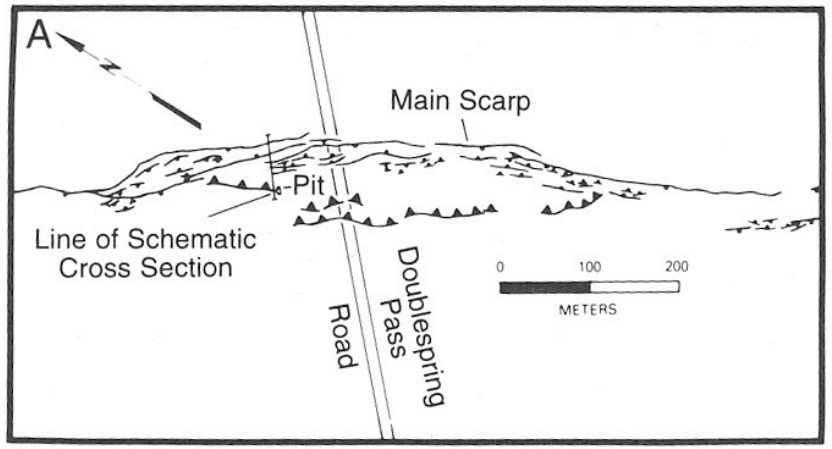


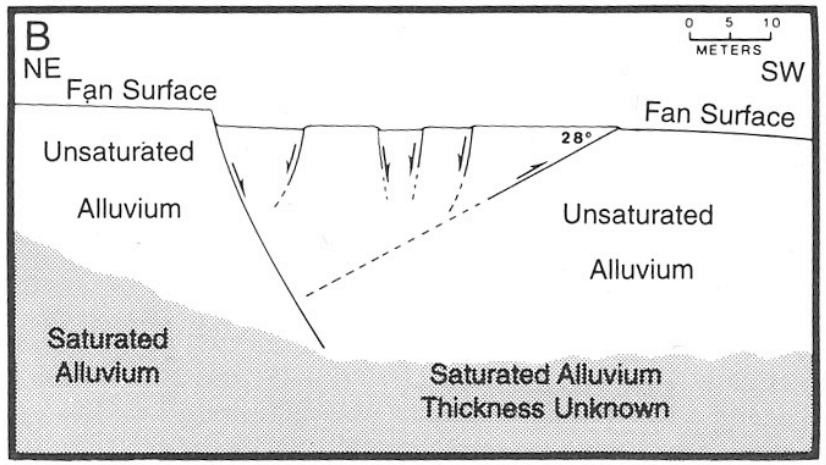
Coney, 1969

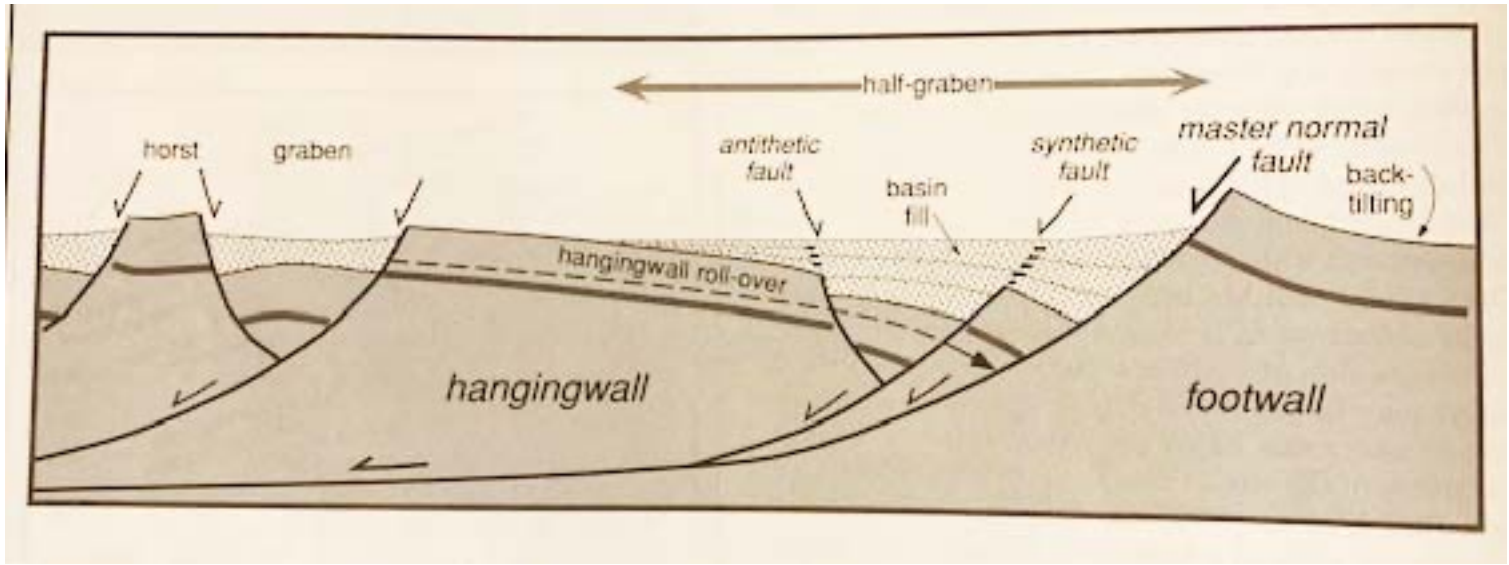


Cloos, 1968

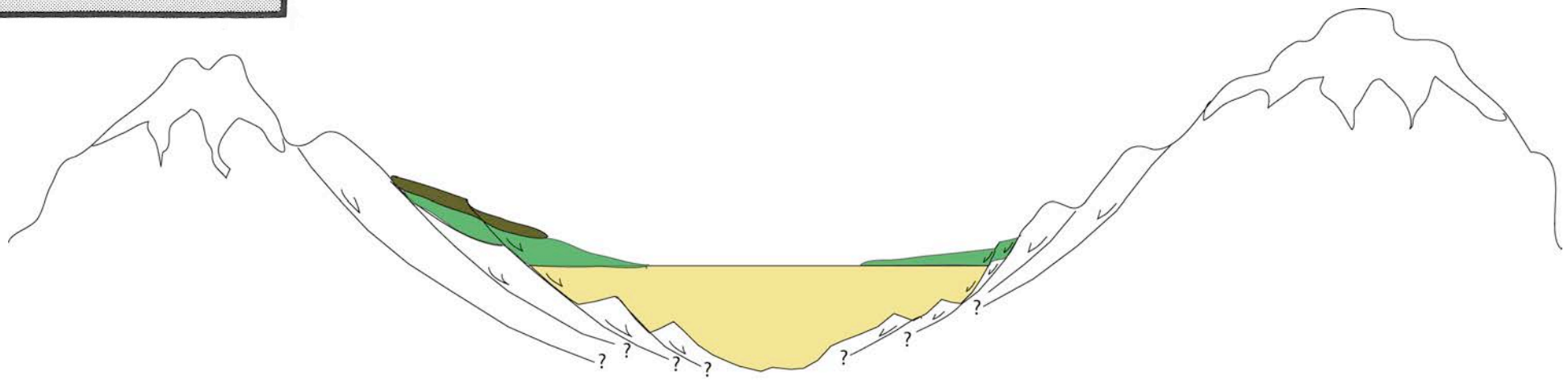
Basin and Range structure some combination of tilted blocks and horst and graben formation.





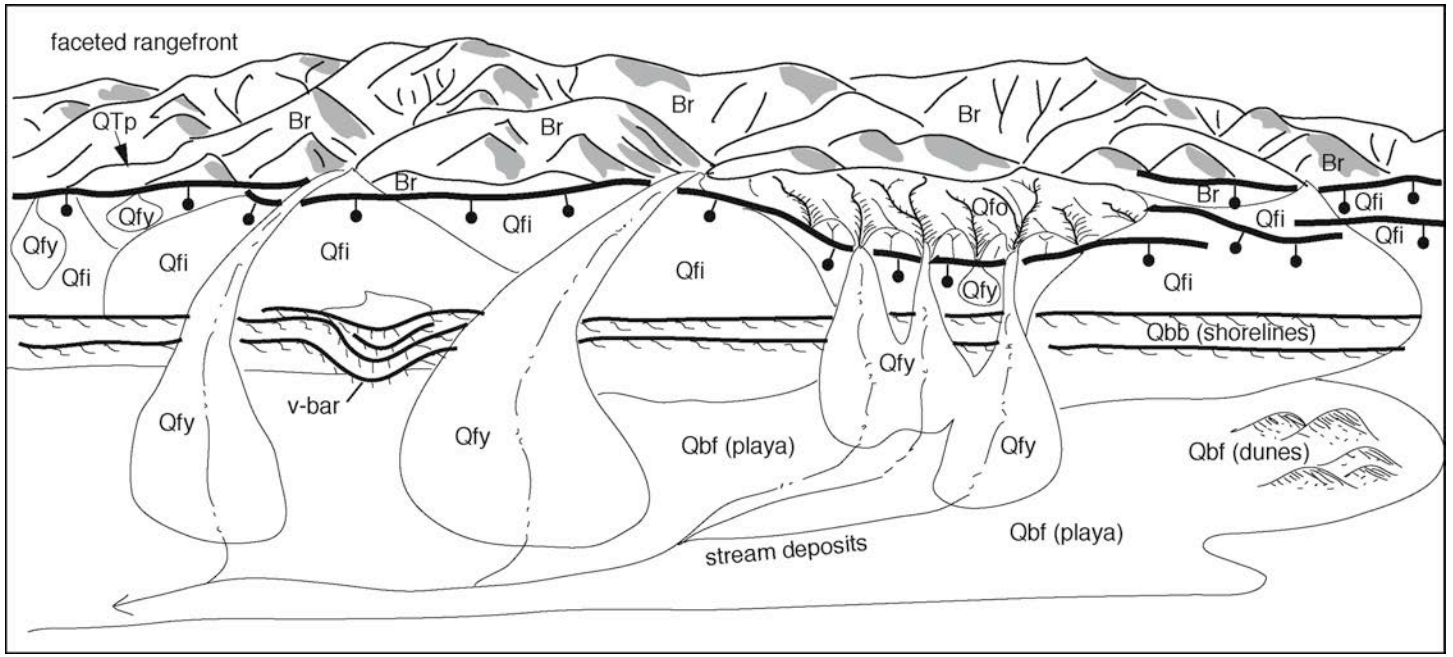


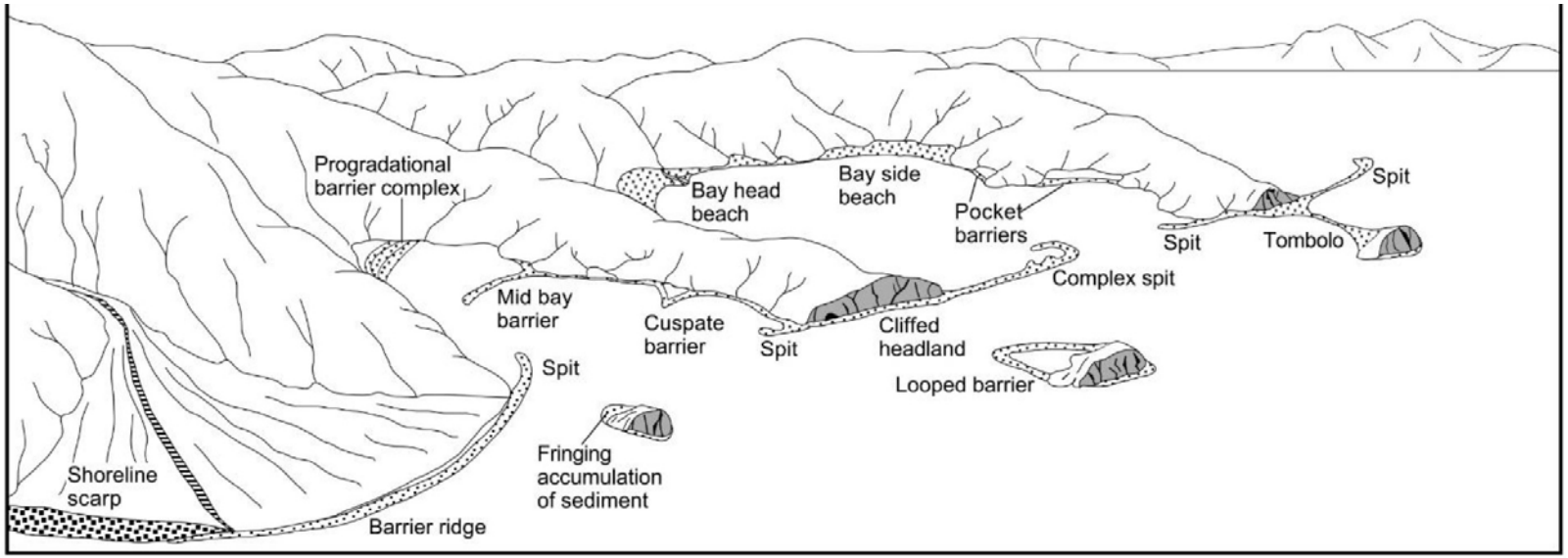
Burbank and Anderson, 2001



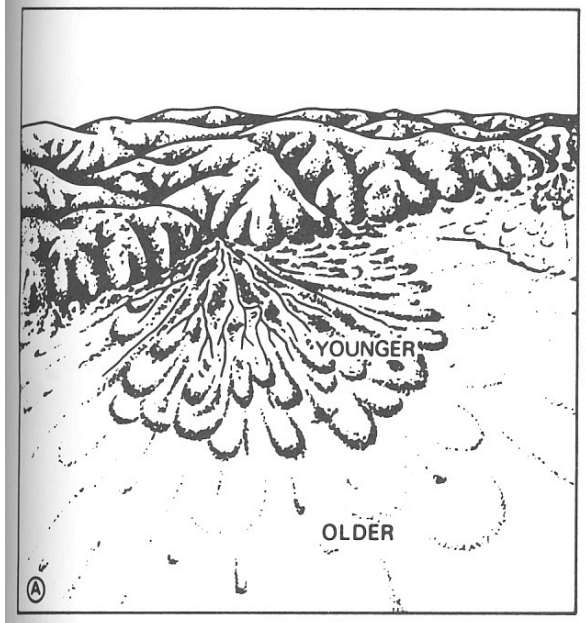
Geomorphic features along normal faults

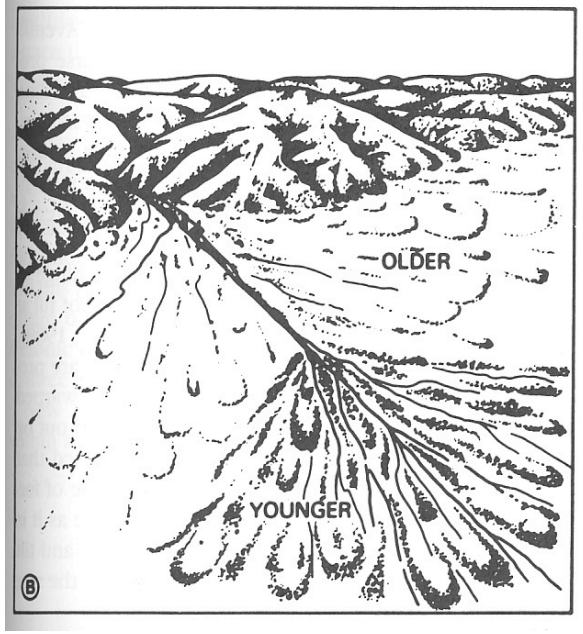
Alluvial fan and
Lacustrine stratigraphy





Variable rates of deformation

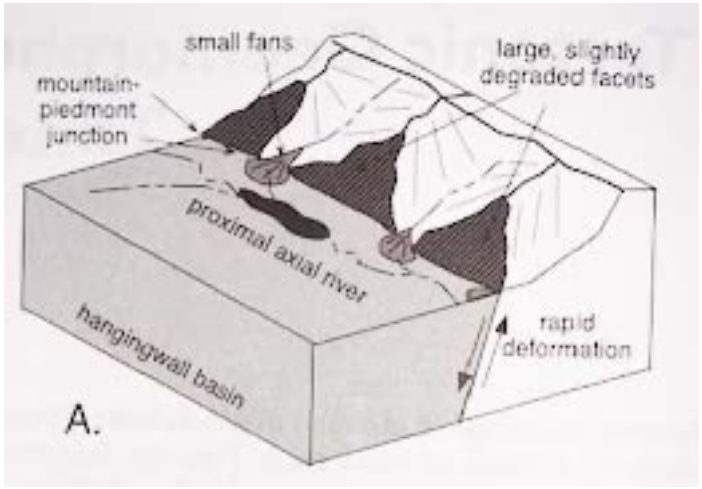




Bull, 1964

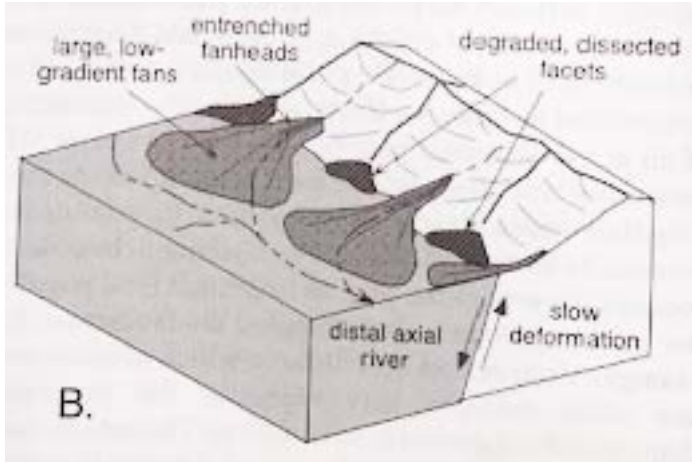
Relatively fast Uplift

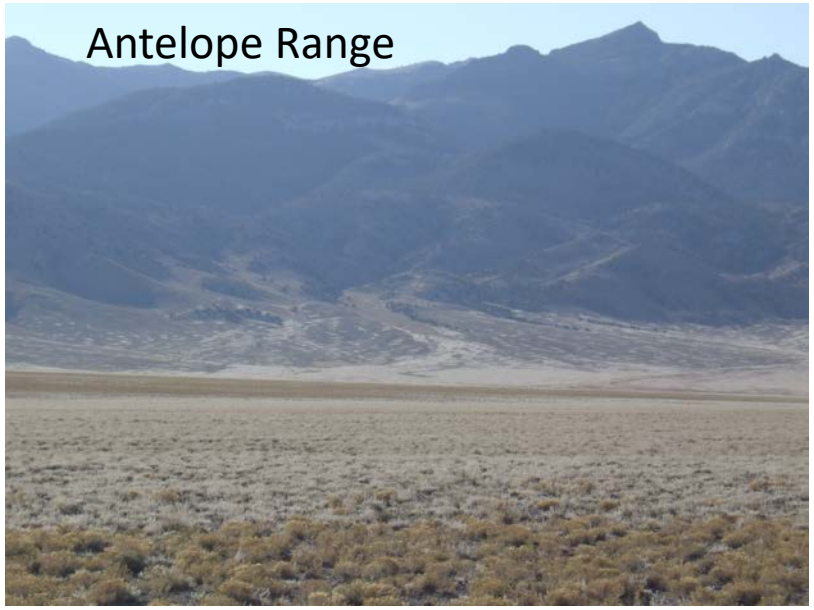
Steep young fans at mt. front, large Facets, proximal axial river, linear range front.



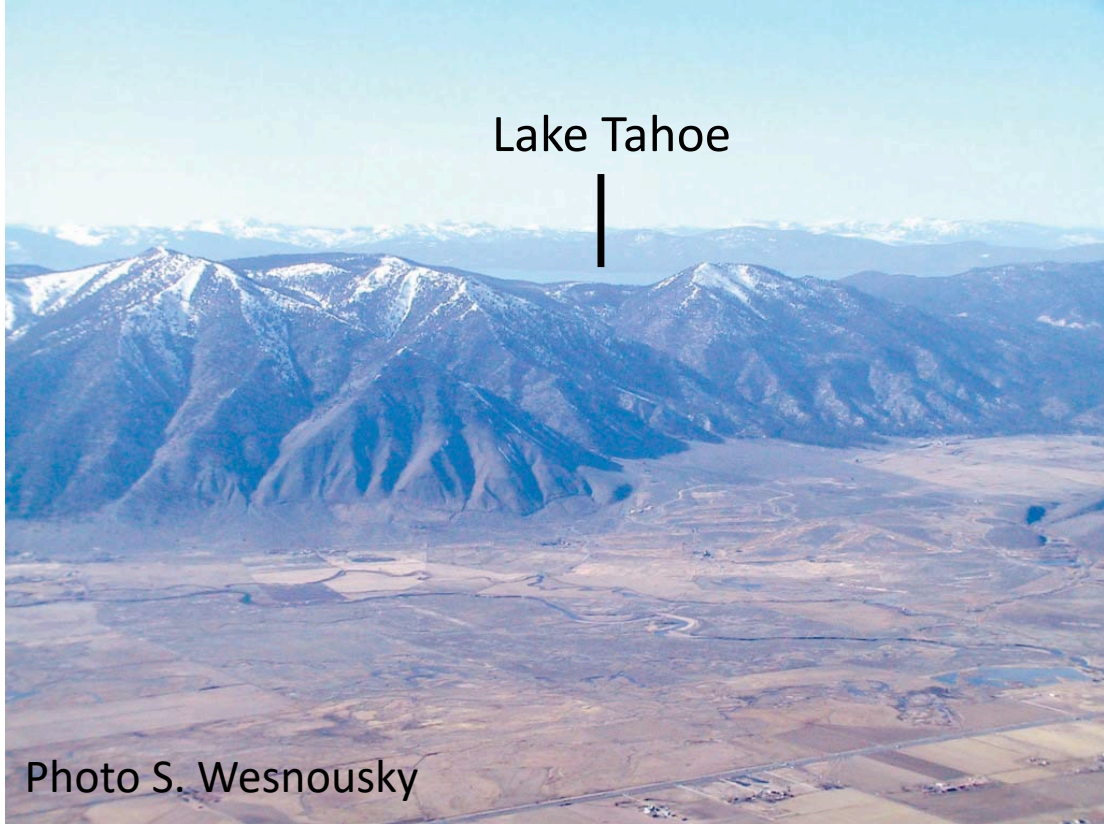
Relatively slow Uplift

Shallow young fans away from Mt front, small facets, distal axial river, sinuous range front.



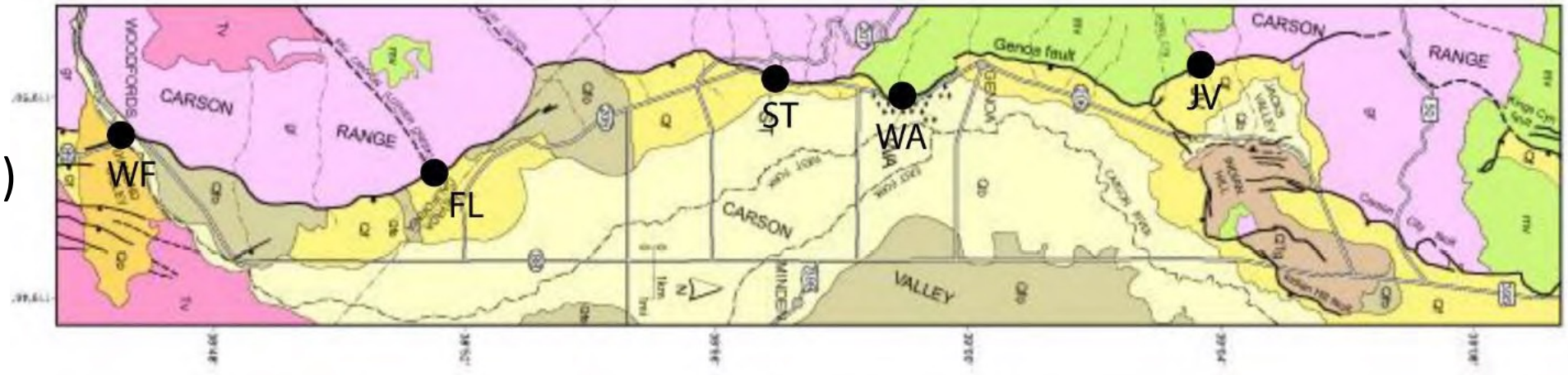


Genoa fault, Sierra Range front

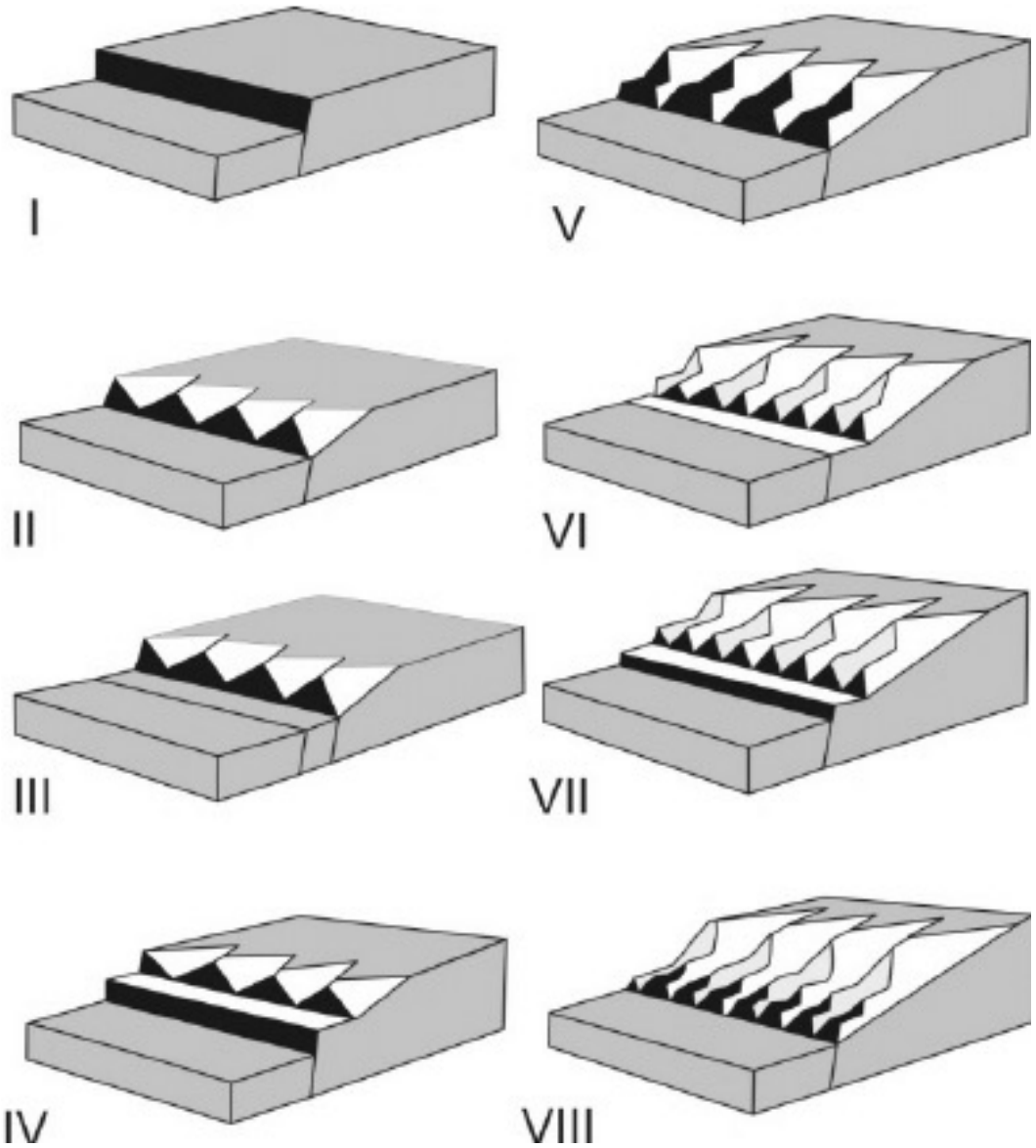


- Triangular facets
- Wineglass canyons
- Young scarp (~500 yr)

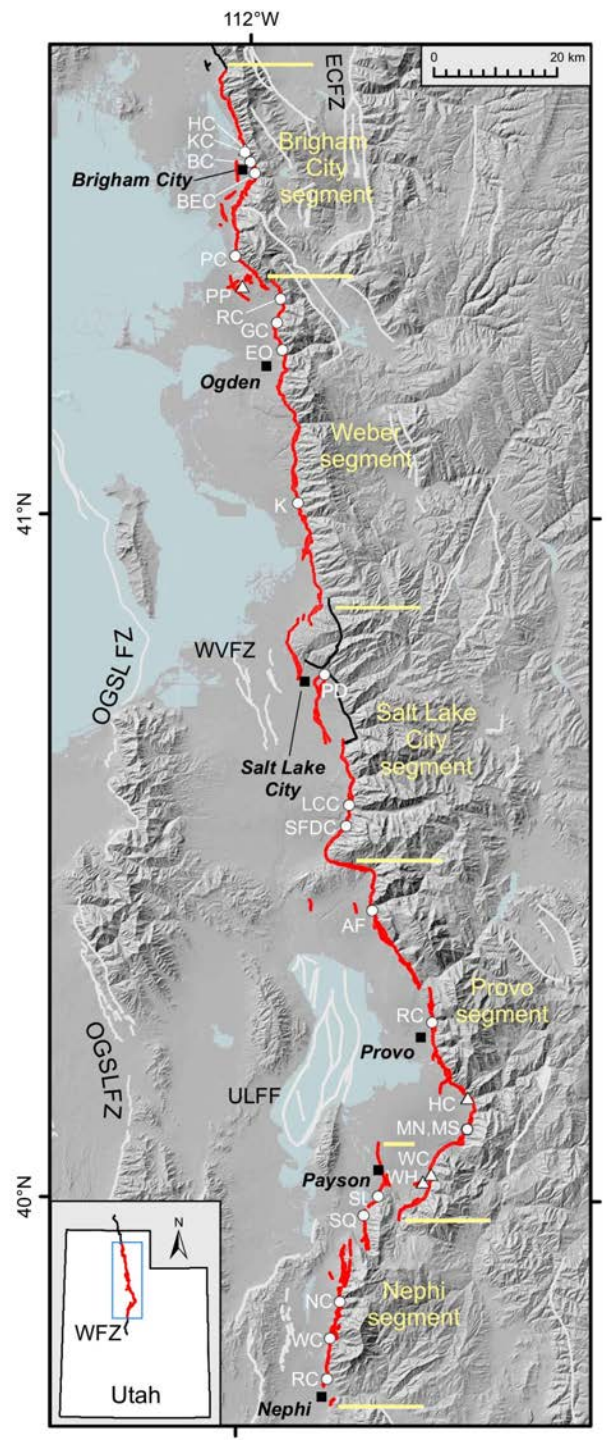
Ramelli et al., 1999

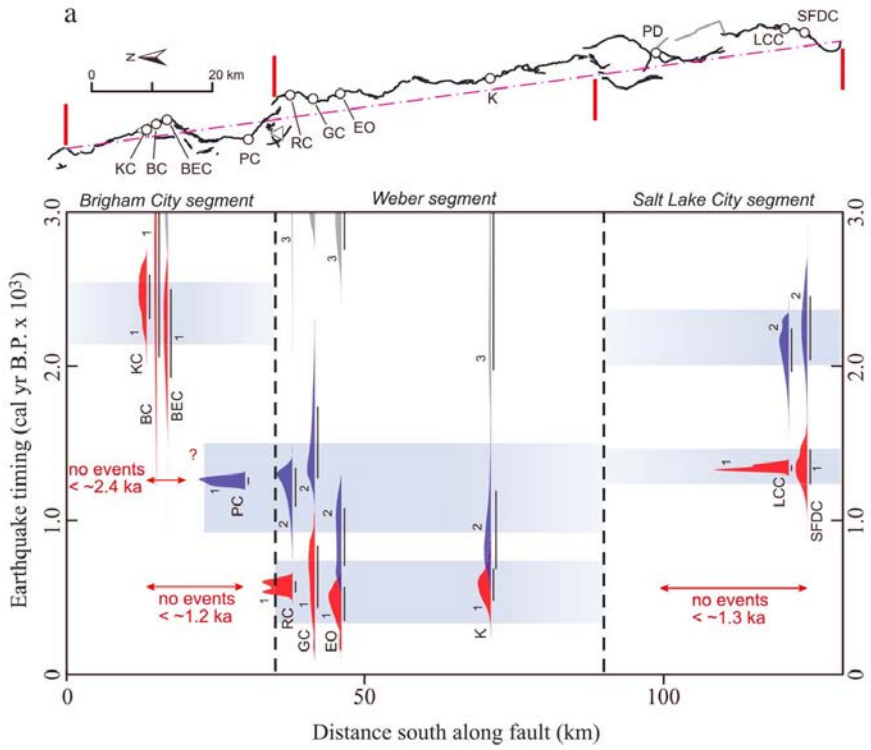


Development of triangular facets



Wasatch fault, Utah





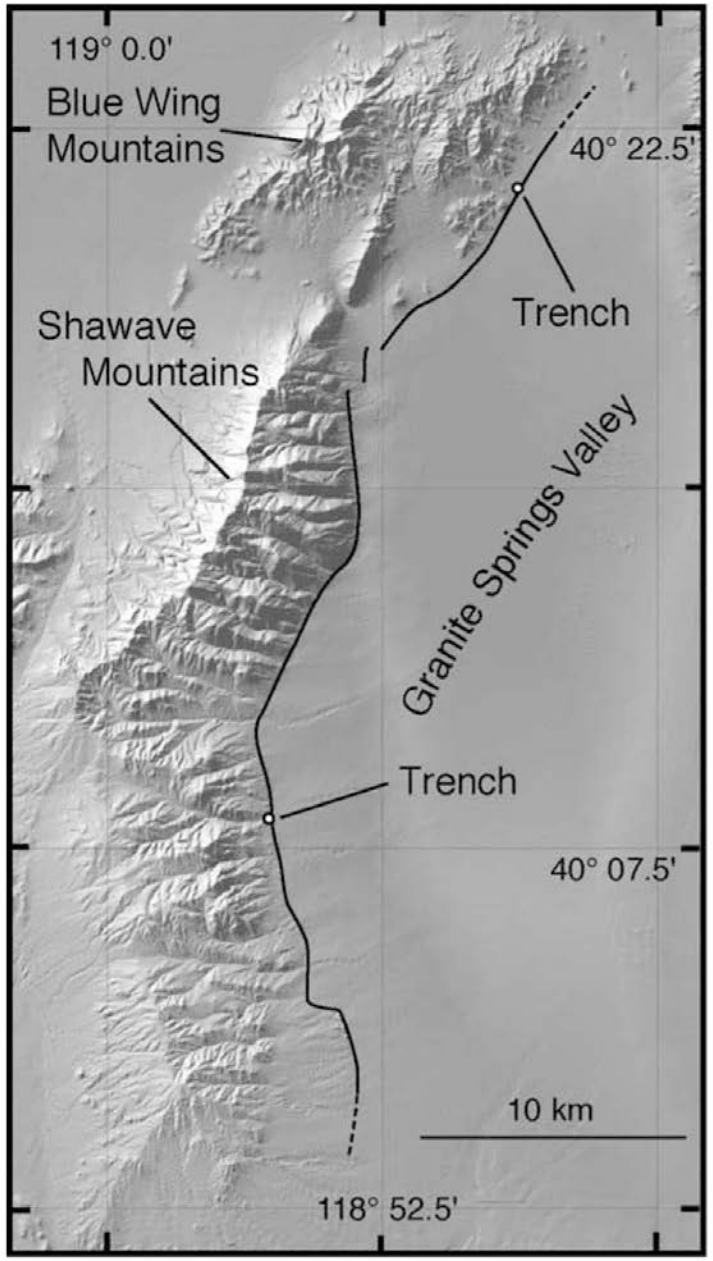
DuRoss et al., 2015

Cortez Range

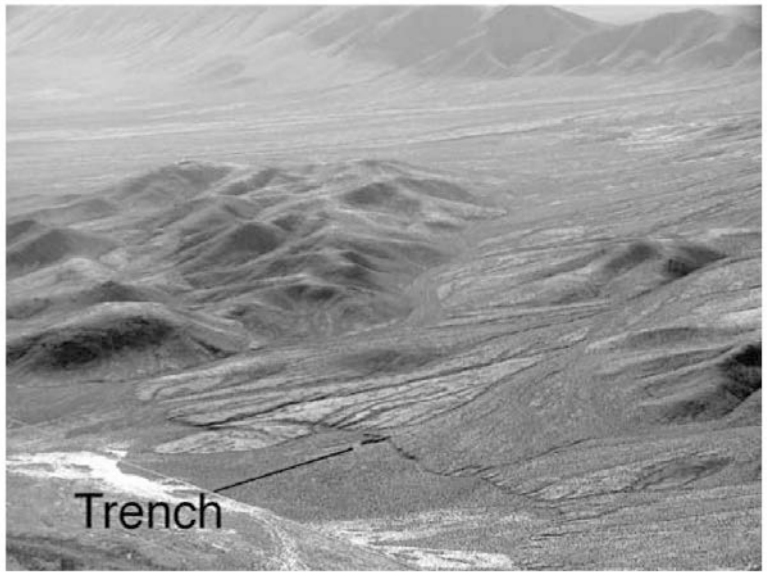
Basin facing scarps

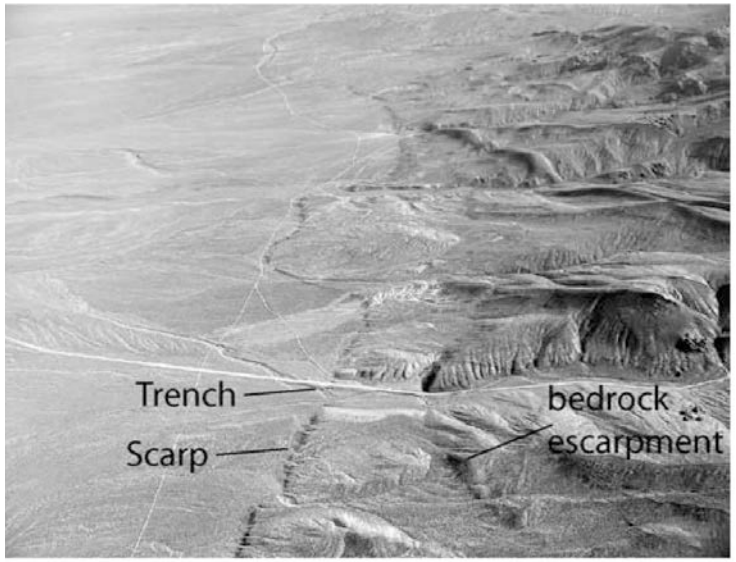
Simpson Park Mountains

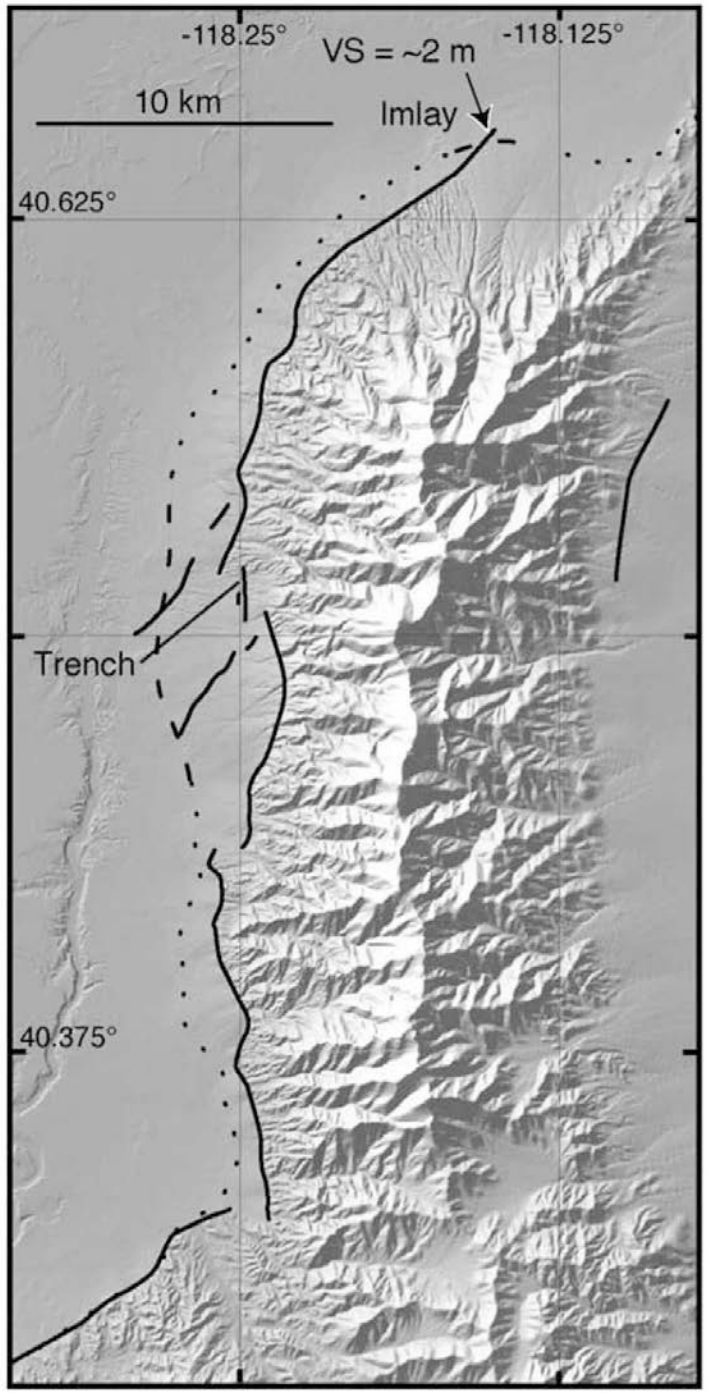
Schell Creek Range



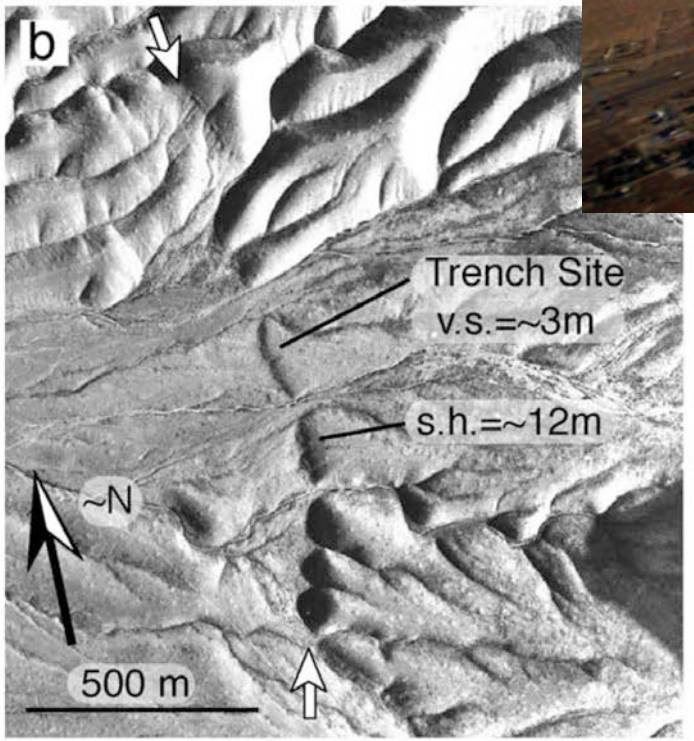
Wesnousky et al., 2005







Humboldt Range



2 events 4600 and 1900 years ago
Must be careful separating shorelines and fault scarps.

Wesnousky et al., 2005

Abbreviations for geomorphic features for use in mapping faults

strike-sip faults

Table 1. Geomorphic Symbol Codes used in Map Compilation

Geomorphic Feature	Symbol
Scarp (northeast facing)	s (NE)
Scarp (southwest facing)	s (SW)
Pond	p
Swampy depression	ds
Dry linear depression or swale	d
Saddle	sa
Spring	sp
Linear valley	lv
Linear drainage	ld
Swale	sw
Linear break in slope	bs
Bench	b
Tectonic ridge	r
Stream knickpoint	kp
Vegetation lineament	v
Drainage divide	dd
Offset stream channel	os
Beheaded or abandoned stream channel	bs
Deflected stream	ds
Pirated channel	pc

normal faults

Geomorphic feature	Symbol
triangular facet	tf
graben	g
scarp	s
Over-steepened rangefront	or
wineglass canyon	wc
beveled scarp	bs
Distributed fracturing	df

Other data

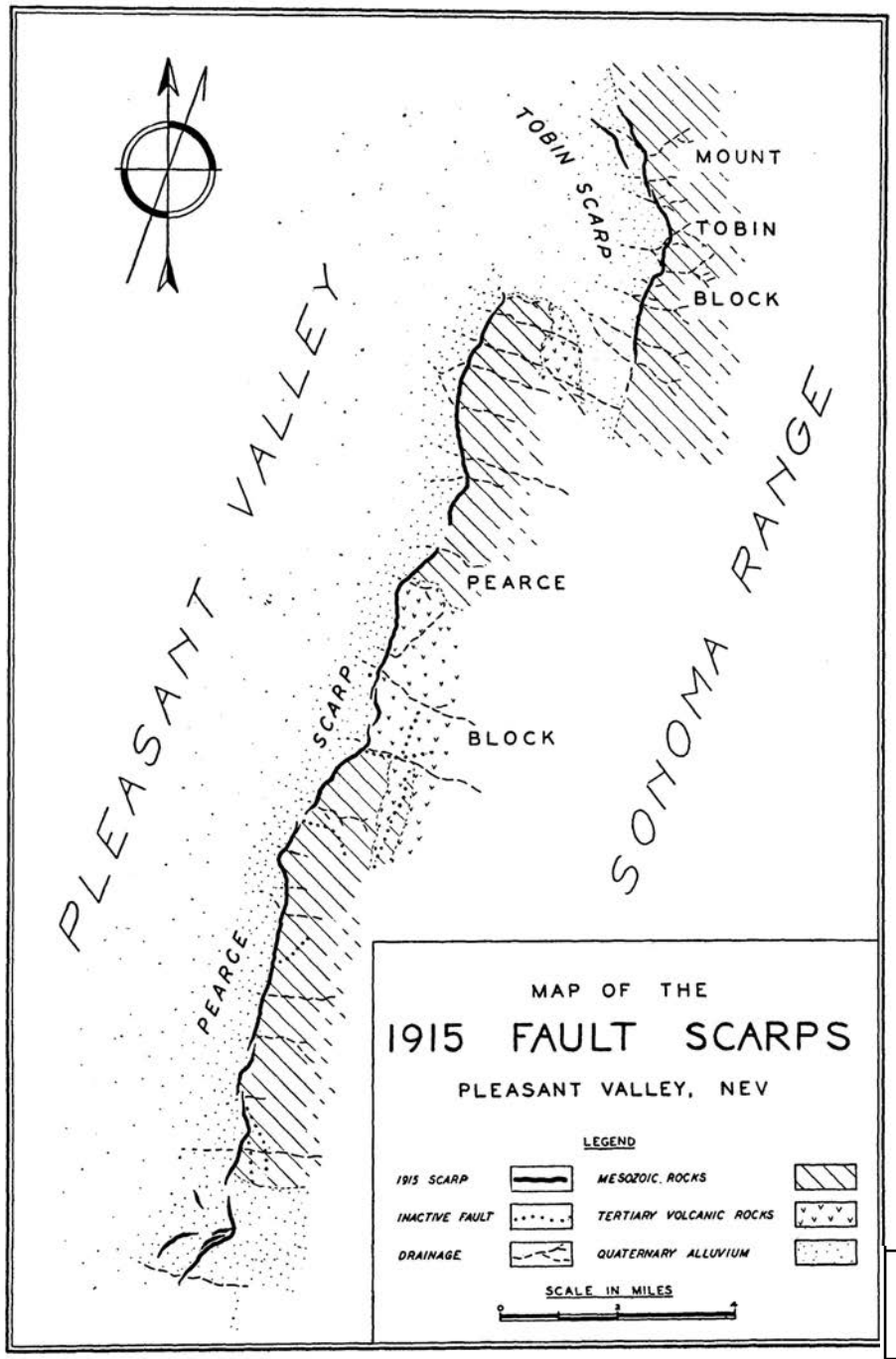
Vertical separation (v.s.)
Scarp height (s.h.)

can be measured in the field or using profile tools in ArcGIS or QGIS

Feature	Rank	Description	Justification as fault indicator
Triangular facet (NTF)	4	A broad base and a upward pointing apex	Often formed by erosion of the fault plane along range fronts
Beheaded Drainages (NBD)	3	Up- and down-stream channels are separated.	Fault-offset beheads down-stream channel
Offset or cut Alluvial Fan Complex (NAFC)	4	Series of fan-shaped alluvium deposits that are offset or cut by a fault	Faults can cut across and offset alluvial fans of different ages
Quaternary Scarp (NQSP)	3	A linear cliff-like slope or face that breaks a quaternary unit.	Produced by normal faulting or lateral offset of sloping surfaces
Bedrock Scarp (NBSP)	3	A linear cliff-like slope or face that breaks a bedrock unit.	Produced by normal faulting or lateral offset of sloping surfaces
Horst and grabens (NHG)	3	Topography consisting of alternating raised and lowered fault blocks. Large-scale feature.	Features are created by normal faulting and rifting caused by crustal extension
Single Offset or cut Alluvial fan (NAF)	3	A single fan-shaped alluvium deposit that is offset or cut by a fault	Faults can cut across and offset a single alluvial fan unit
Unit Offset (NOF)	3	Offset of bedrock or geomorphic units	Faulting is often responsible for offset
Over-steepened range front (NORF)	3	Dramatic change in slope near mountain base	Likely due to faulting when present along large topographic features
Depression/Sag Pond (NDSP)	2	Low elevation between strike-slip or normal faults, sometimes filled with water	Produced by extensional bends or normal faults.
Surface Unit Offset (NSUO)	2	The original deposition order is obscured	Faulting offsets units
Fissures (NFS)	1	Subvertical, downward-tapering zones bounded by sharp fractures, and filled with younger sediments. Infrequently preserved well enough to see in satellite imagery or DEM, DTM, DSM.	Form as tension cracks that opened coseismically
Spring (NSPR)	1	Upwelling of subsurface water	Caused by faulting that disrupts the groundwater and bedrock
Sackung (NSG)	1	Deep-seated gravitational spreading of mountain ridges and slopes considered a ‘half-landslide’	Spreading is due to normal faulting that is located high on mountain slopes

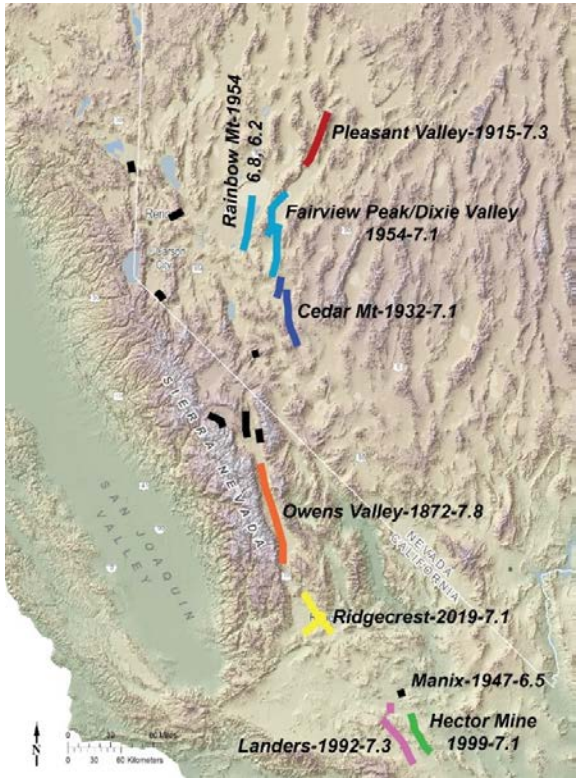
GIR nomenclature for normal faults

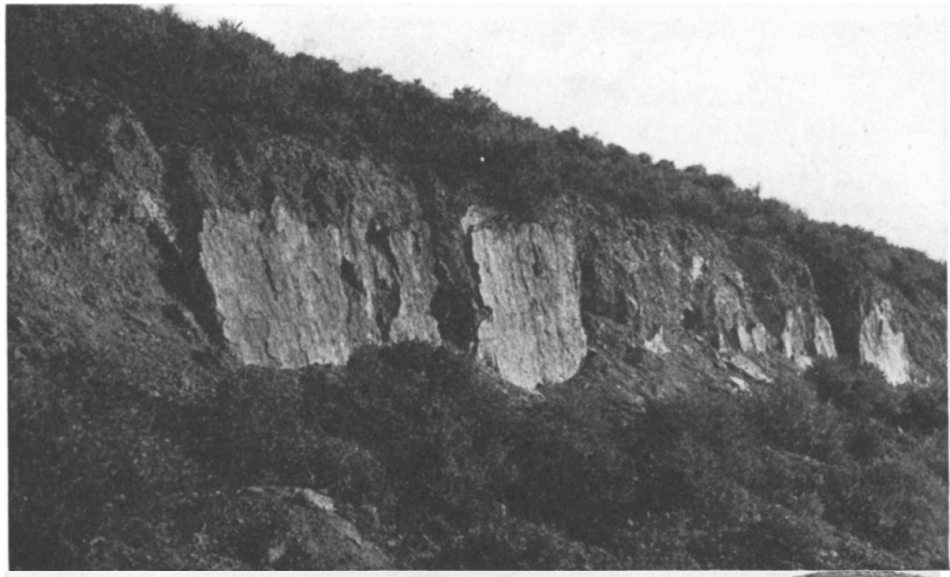
Historical surface rupture examples

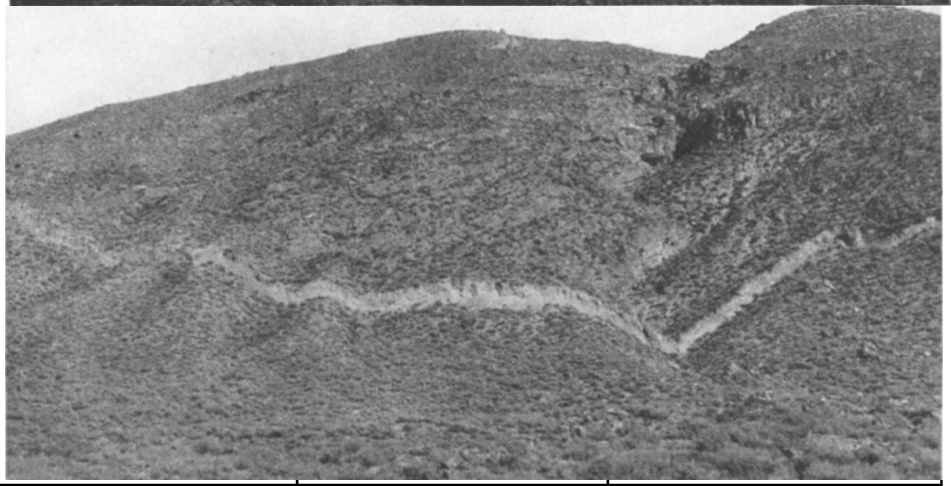


Page, 1935 FIG. 3.—Map of the 1915 fault scarps

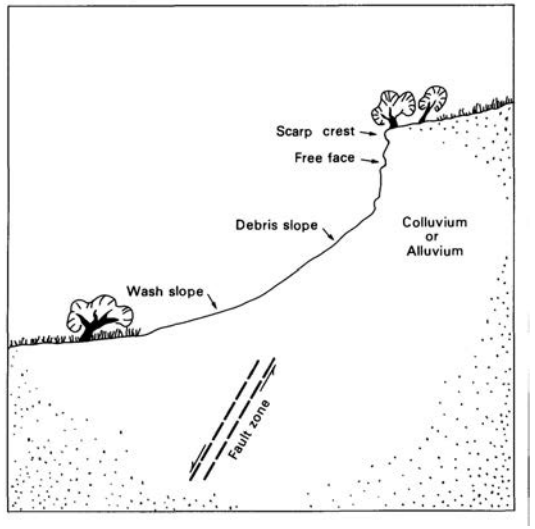
1915 Pleasant Valley earthquake

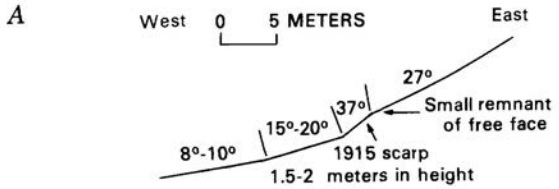


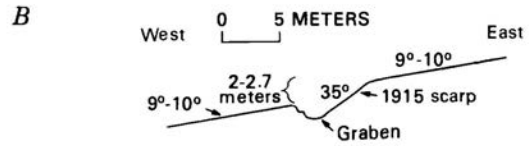


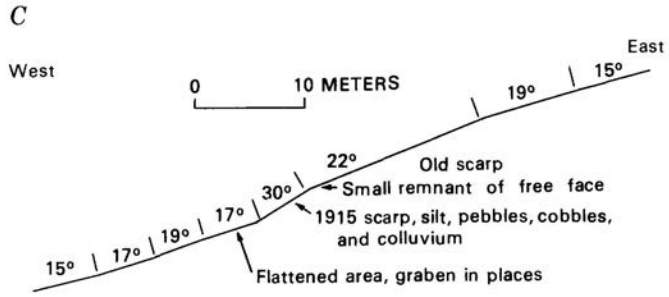


1915, M_s 7.6	Pleasant Valley, Nevada	5.8 m displ.	59 Km length	Wallace (1984)









Wallace, 1984