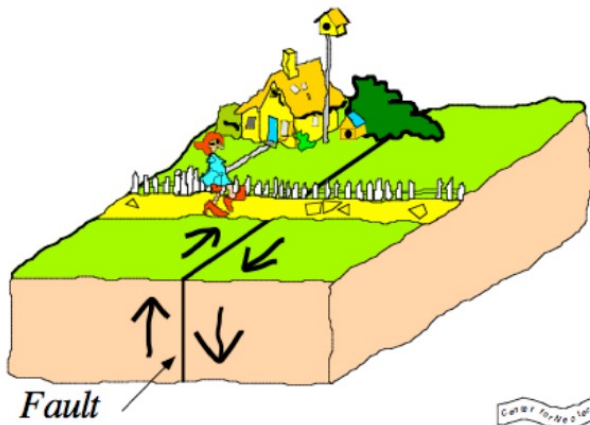Seismicity and Earthquakes of Nevada and western U.S.
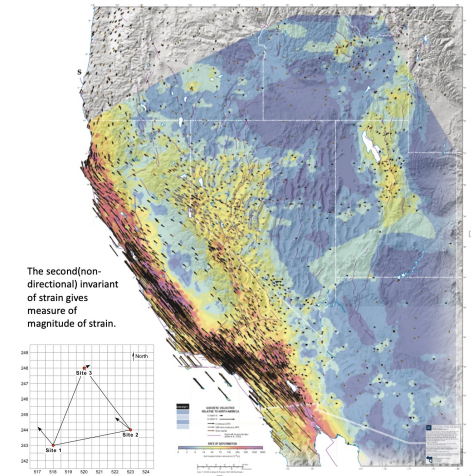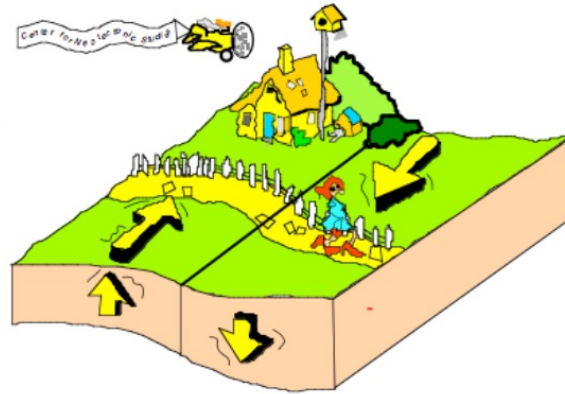
The 'contemporary' release of accumulated strain registered by Geodesy.
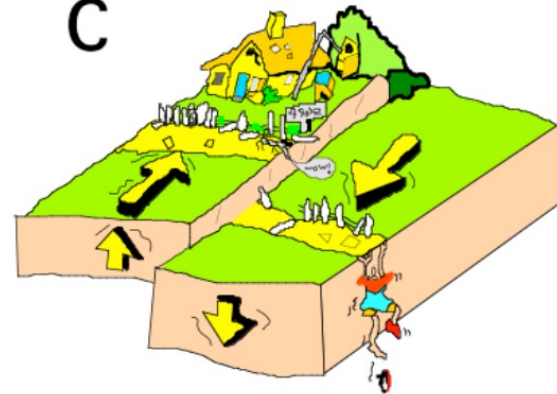
A

Fault

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….

B

The second(non-directional) invariant of strain gives measure of magnitude of strain.
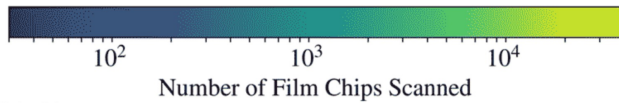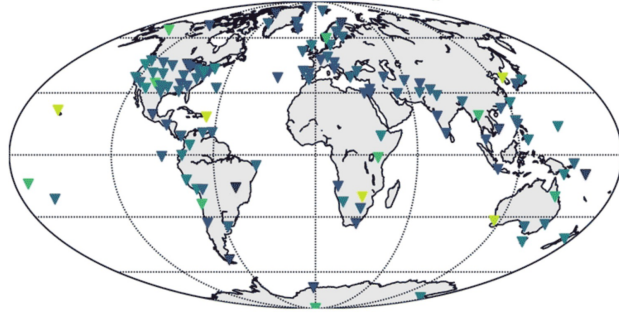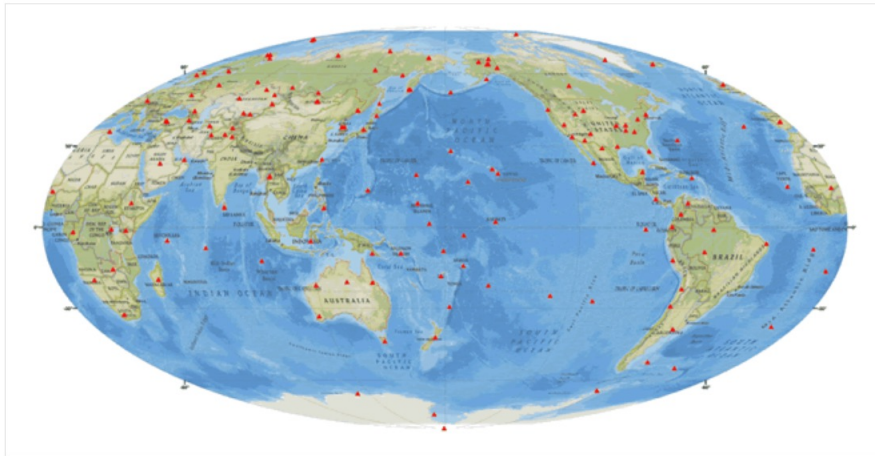
Center for Neotectonic Studies

C

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.

WWSSN Station Map

Number of Film Chips Scanned

GSN – Global Seismographic Network

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...

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.

- **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)

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
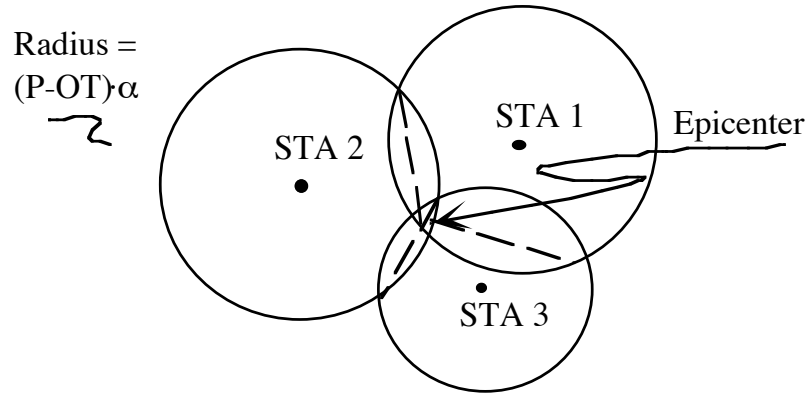
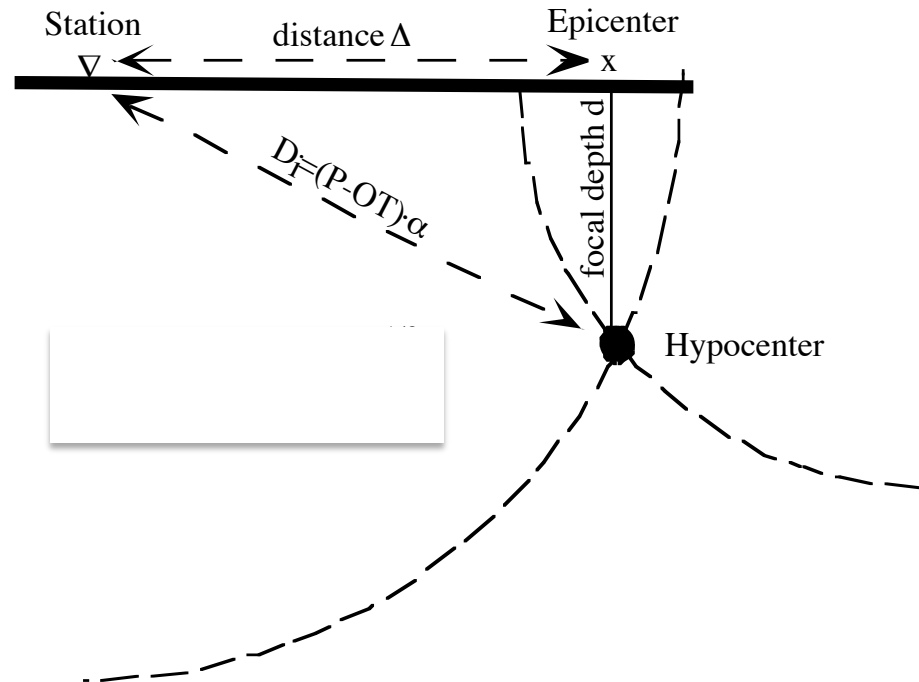Important point is that the accuracy of

EPICENTER
And
FOCAL DEPTH

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

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

Map View to illustrate epicenter determination

Radius = (P-OT)·α

STA 1

STA 2

Epicenter

STA 3

Cross Section to illustrate focal depth determination

Station

distance Δ

Epicenter

x

$D = (P-OT)\cdot\alpha$

focal depth d

Hypocenter

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....
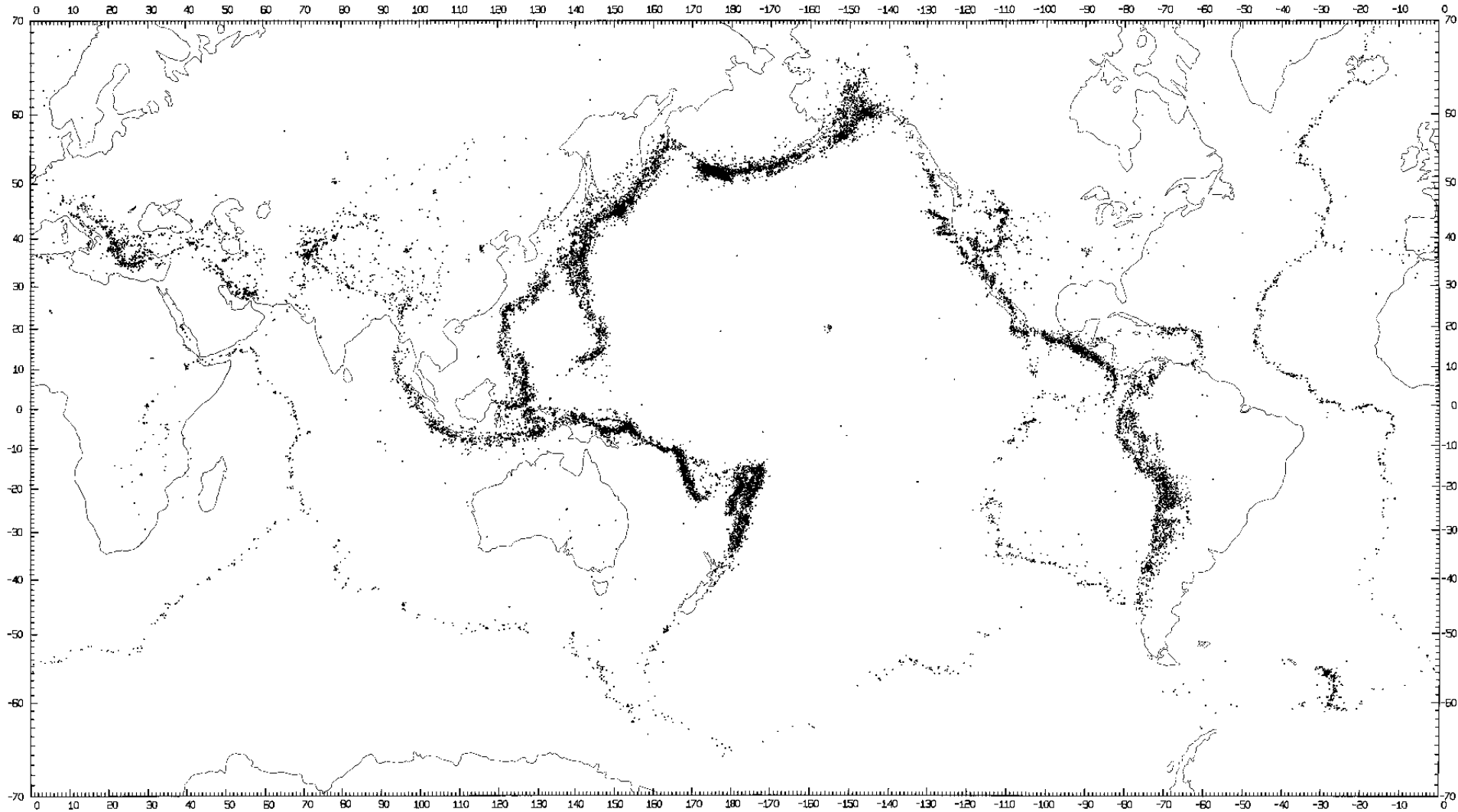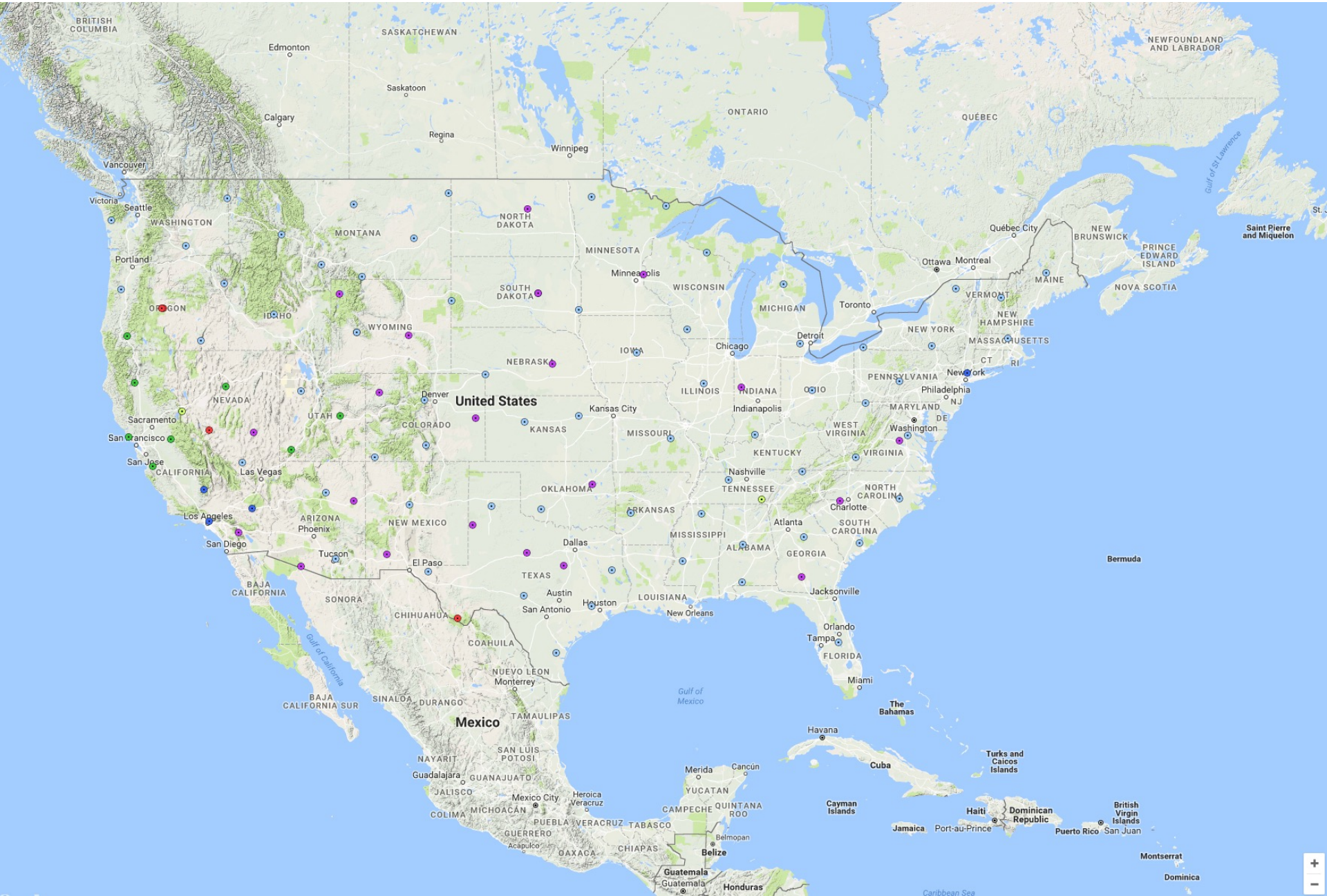

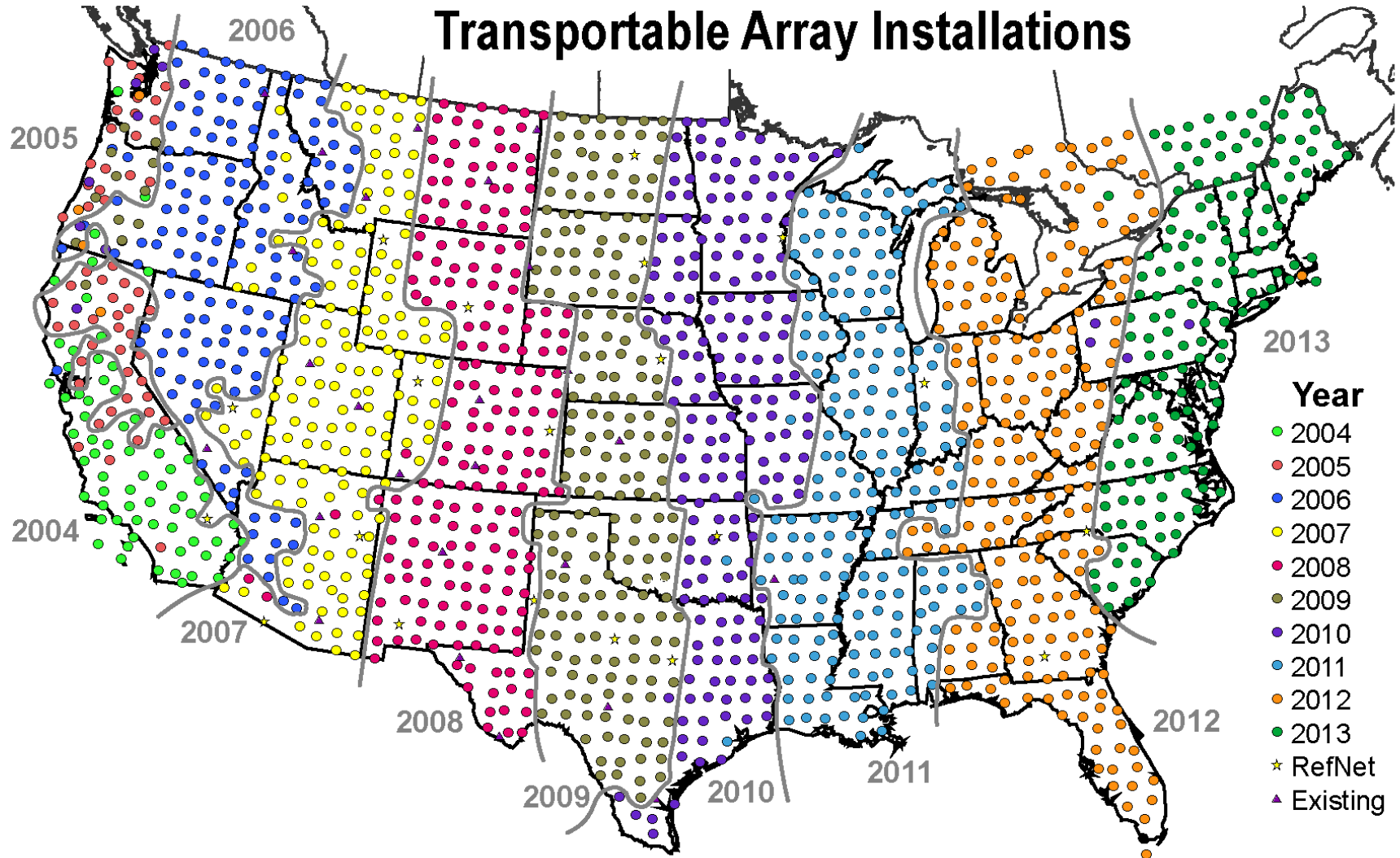SEISMICITY OF THE EARTH, 1961-1967, ESSA, CGS EPICENTERS

DEPTHS 000-700 KM.

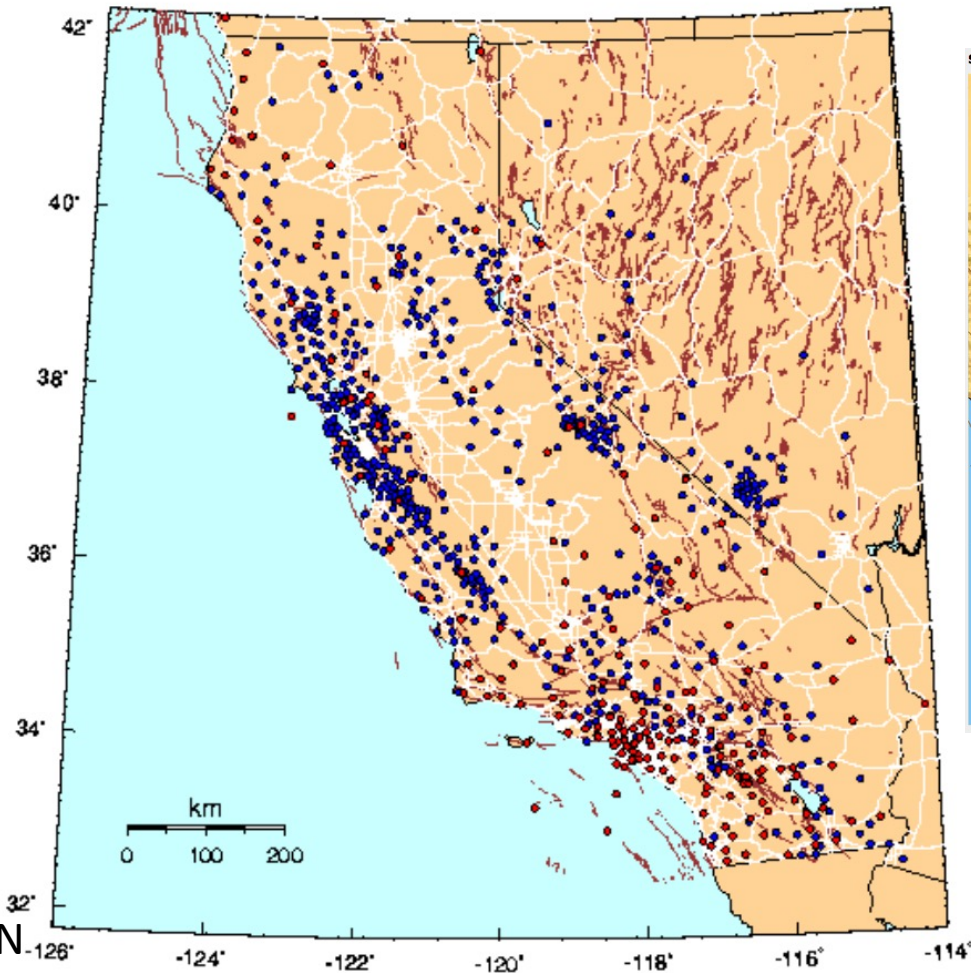US Array (reference stations) – A continental-scale network (part of ANSS)
One of 3 components of 'EARTHSCOPE' project funded by NSF – This dates to ~2006...

US Array (Transportable stations)

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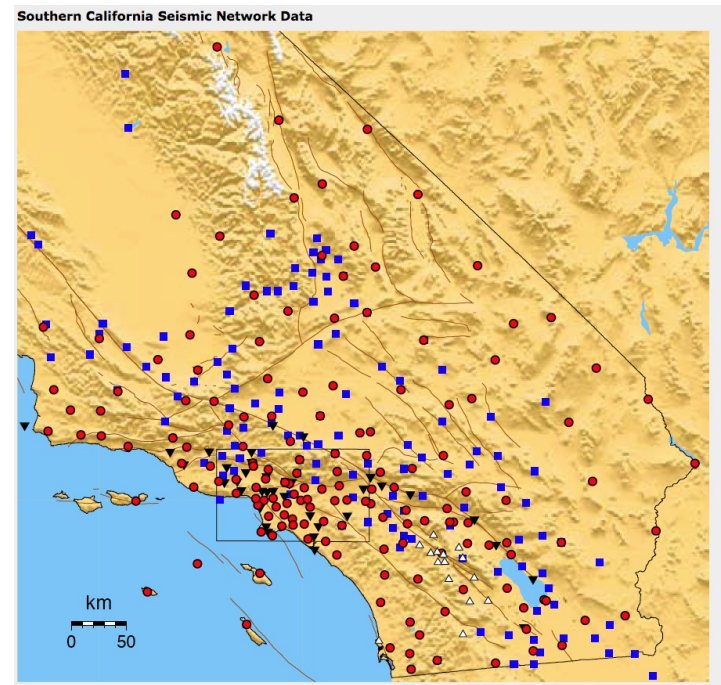

Transportable Array Installations

CISN
California Integrated
Seismic Network
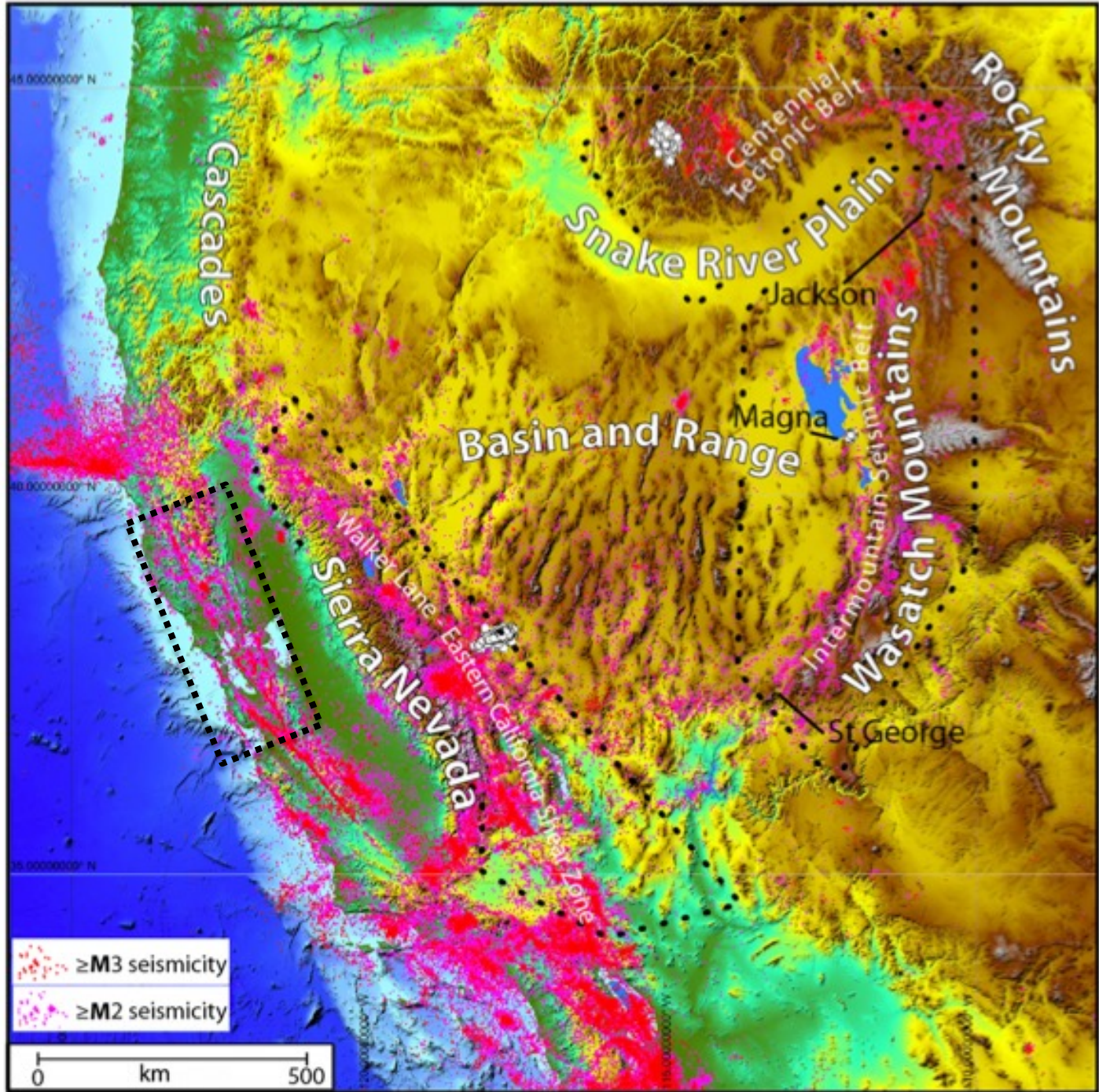

Southern California Seismic Network Data

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.

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)
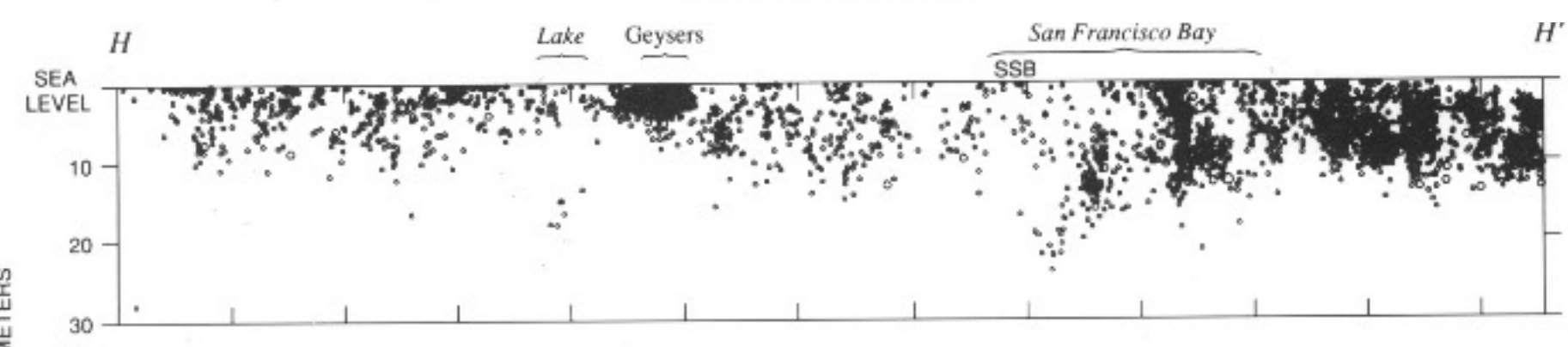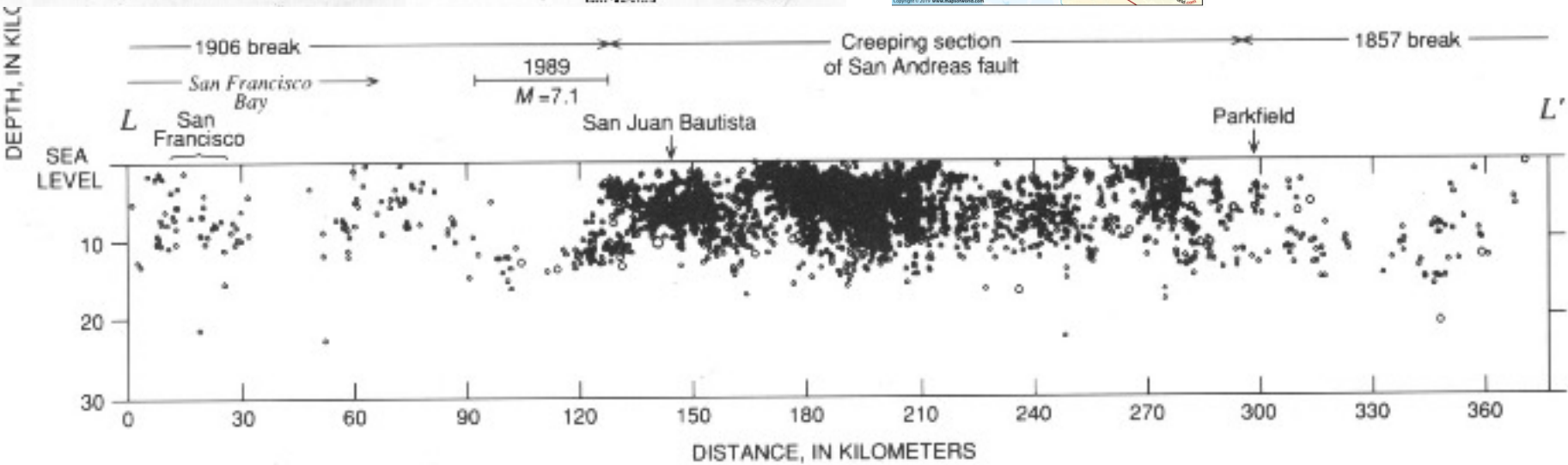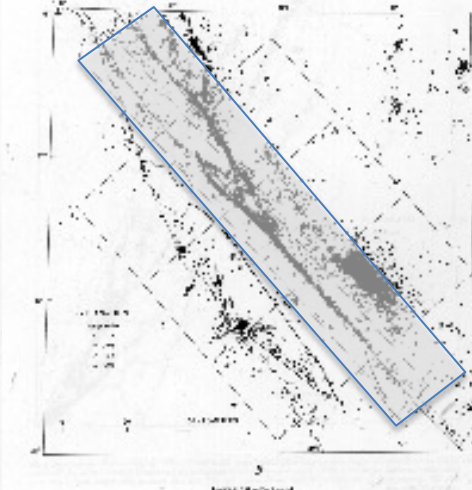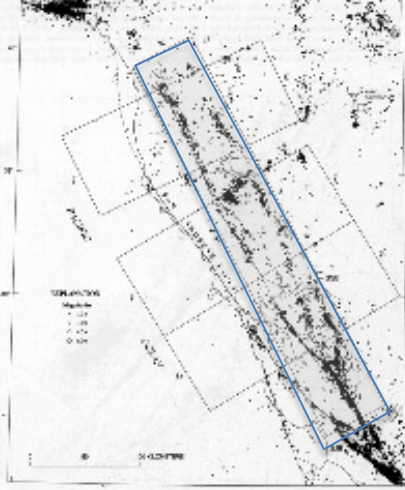- 708 instrumented structures (lifelines, dams, buildings)
- 38 borehole installations

UNR Seismo Lab 'Nevada Seismic Network'

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

Cascades

Snake River Plain

Centennial Tectonic Belt

Rocky Mountains

Jackson

Magna

Intermountain Seismic Belt

Basin and Range

Wasatch Mountains

St George

Walker Lane - Eastern California Shear Zone

Sierra Nevada
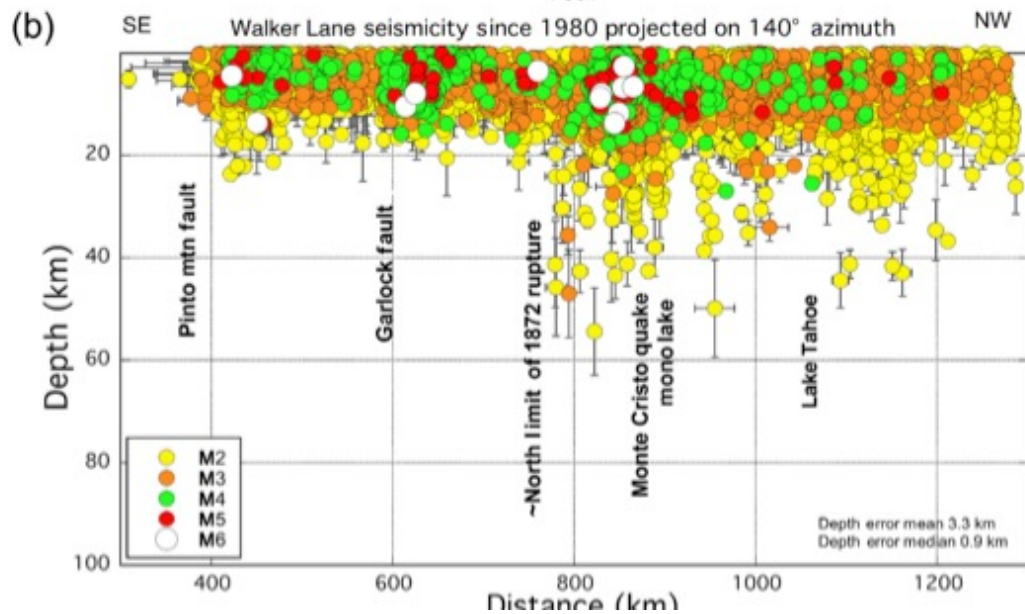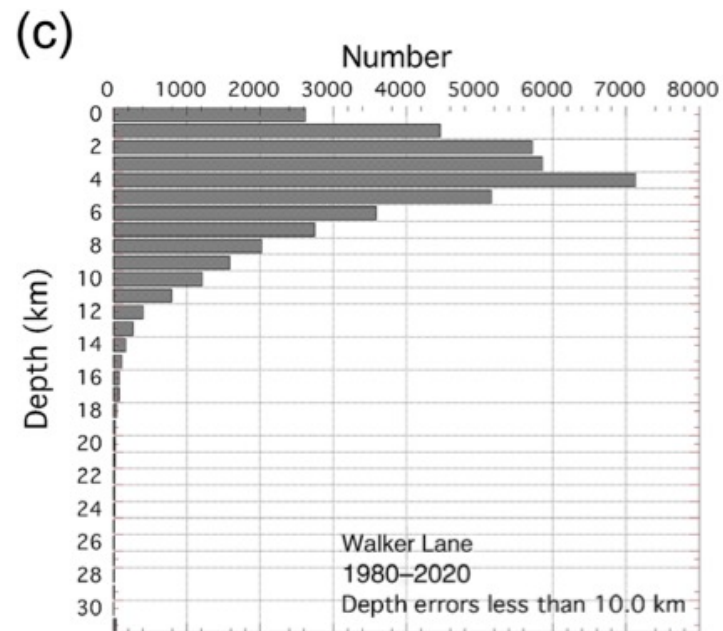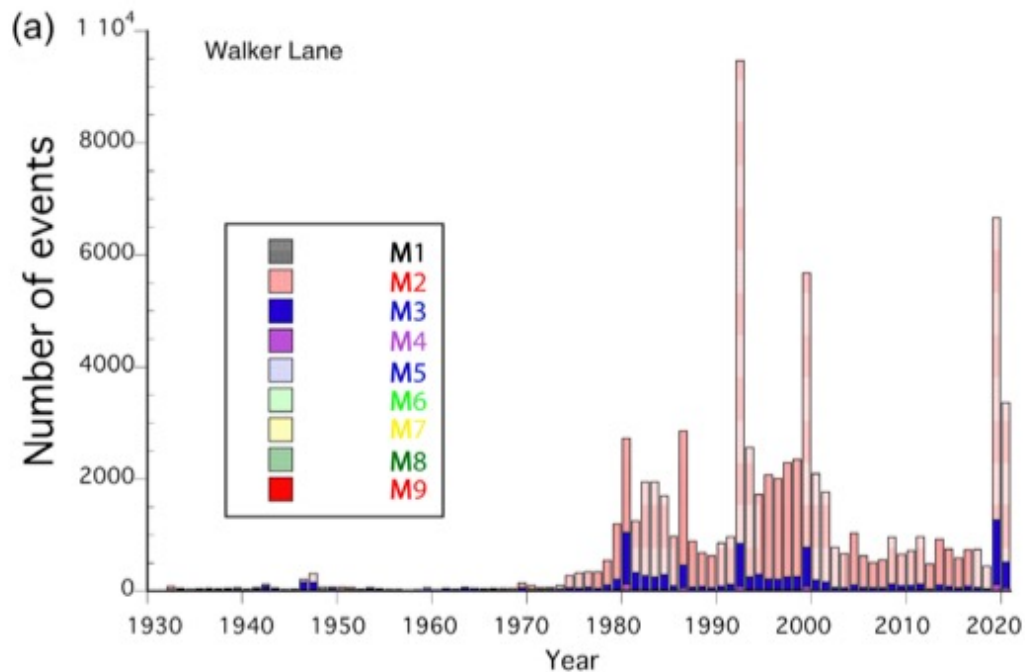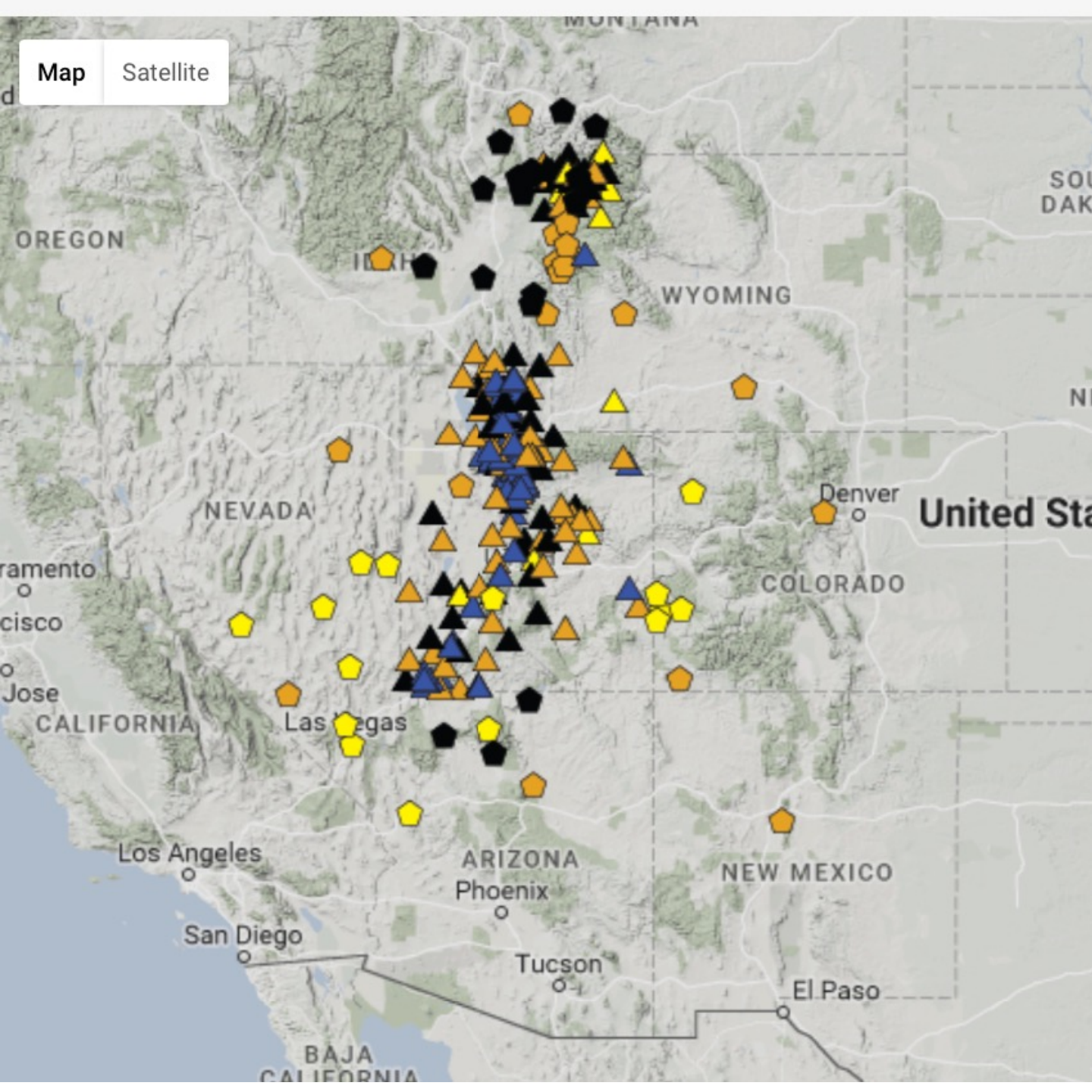
45.0000000° N

40.0000000° N

35.0000000° N

≥M3 seismicity

≥M2 seismicity

km

0   500
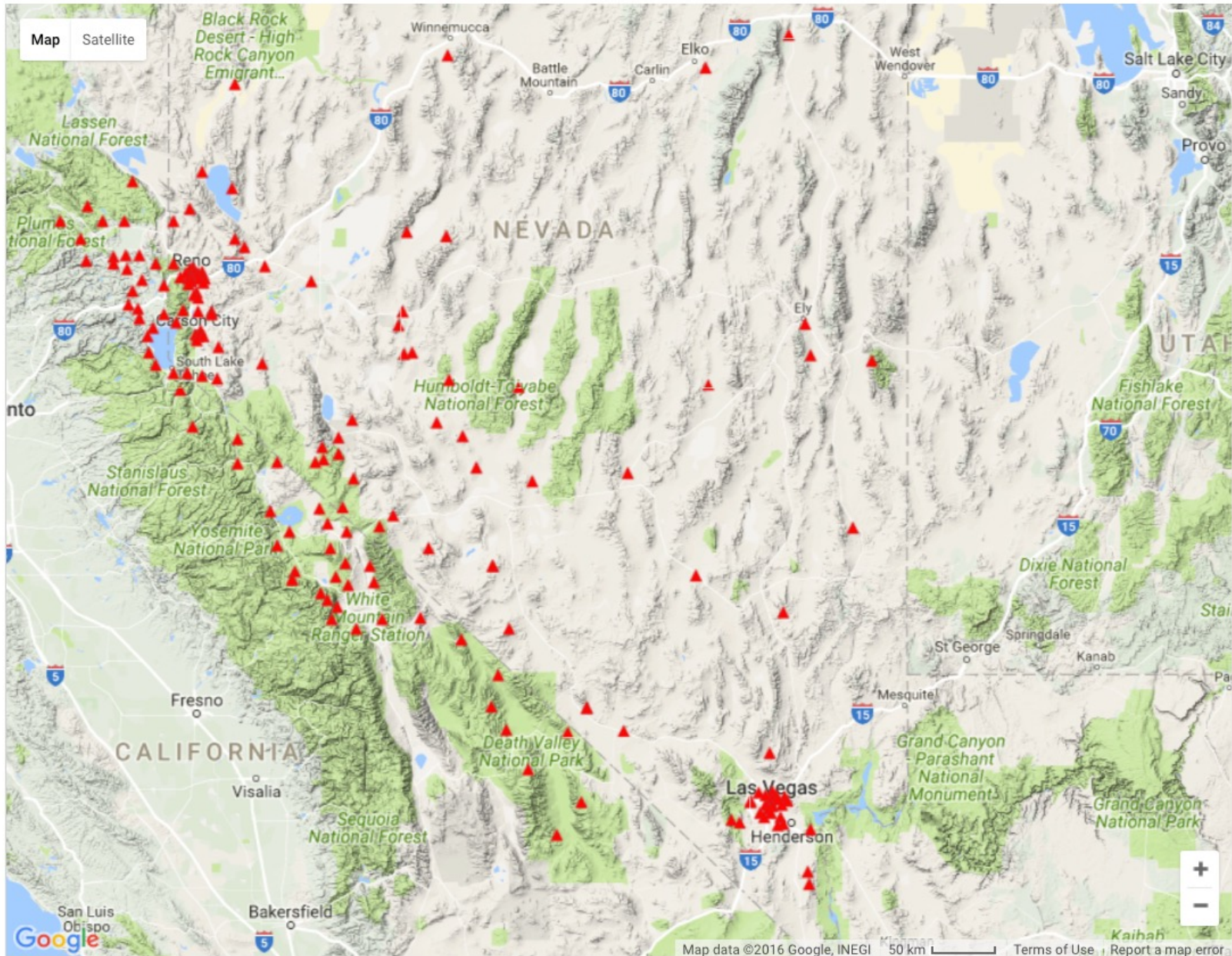
Most earthquakes limited to depths <15-20 km
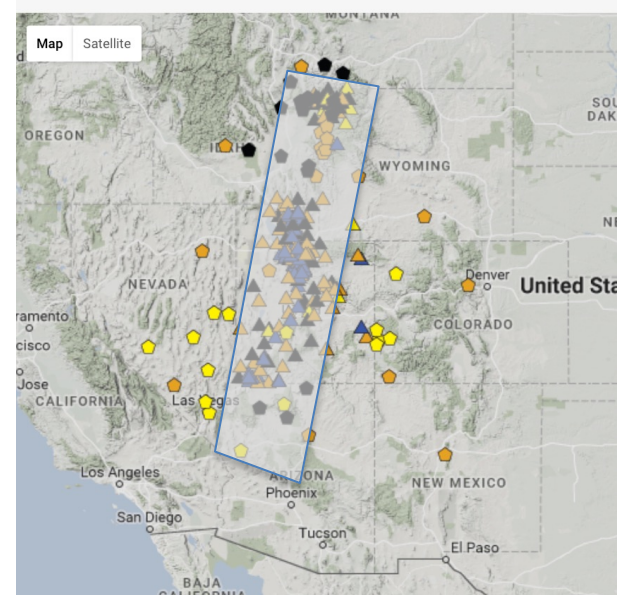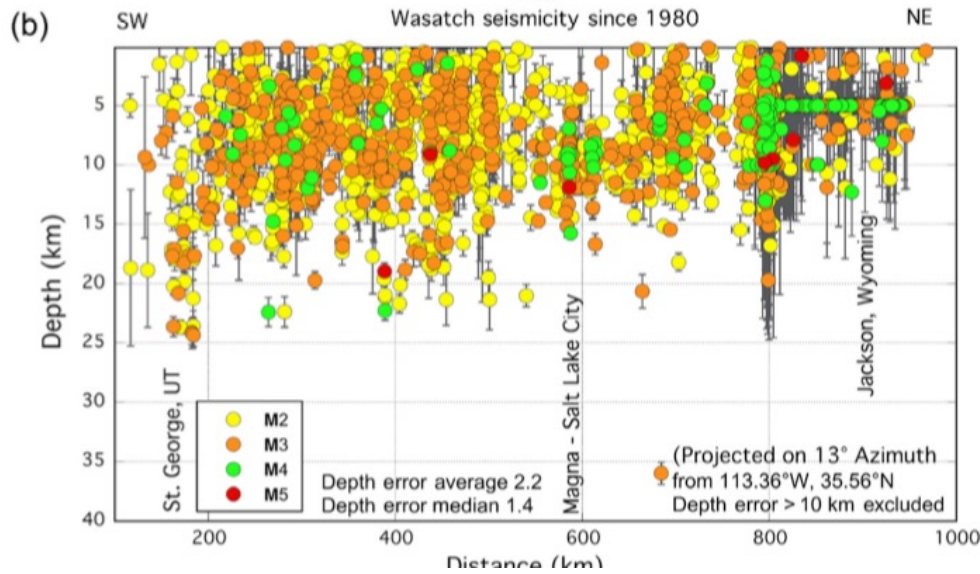
(a) Walker Lane

(b) Walker Lane seismicity since 1980 projected on 140° azimuth
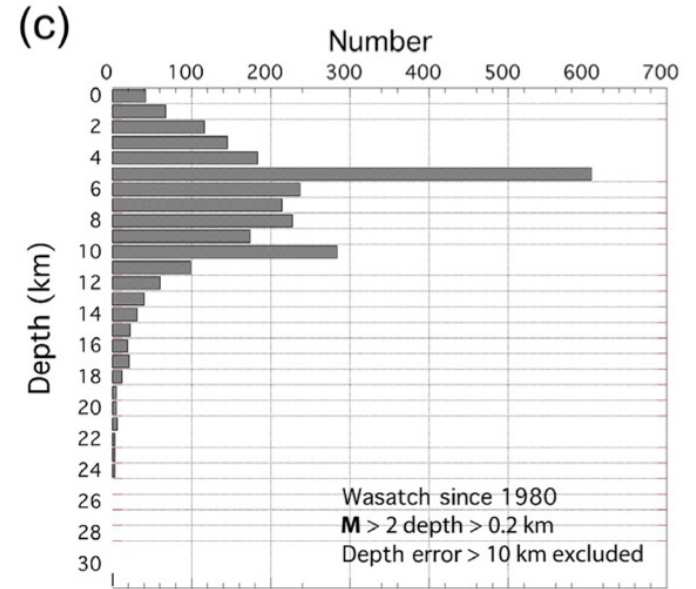
(c) Walker Lane
1980–2020
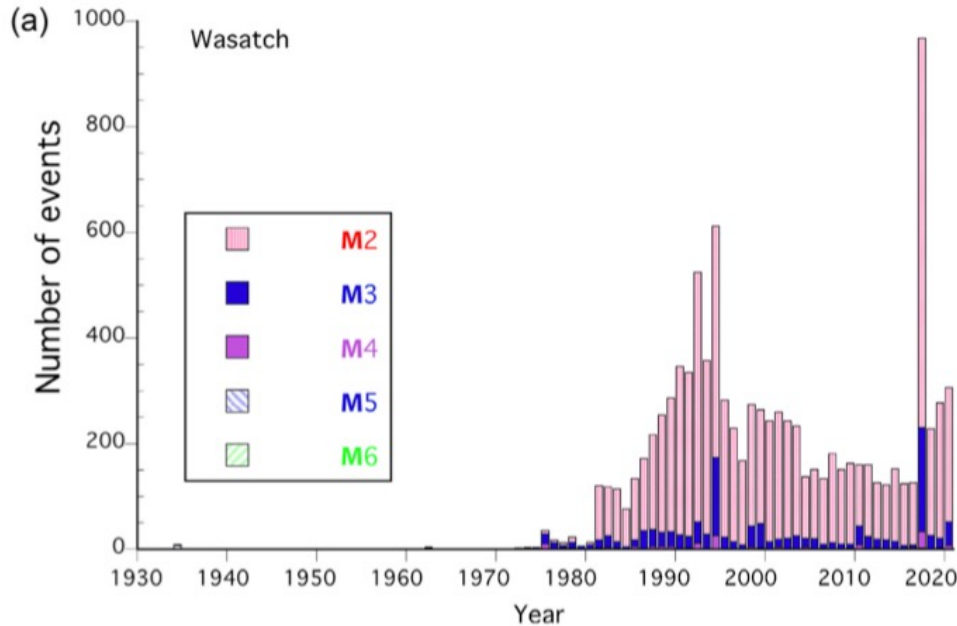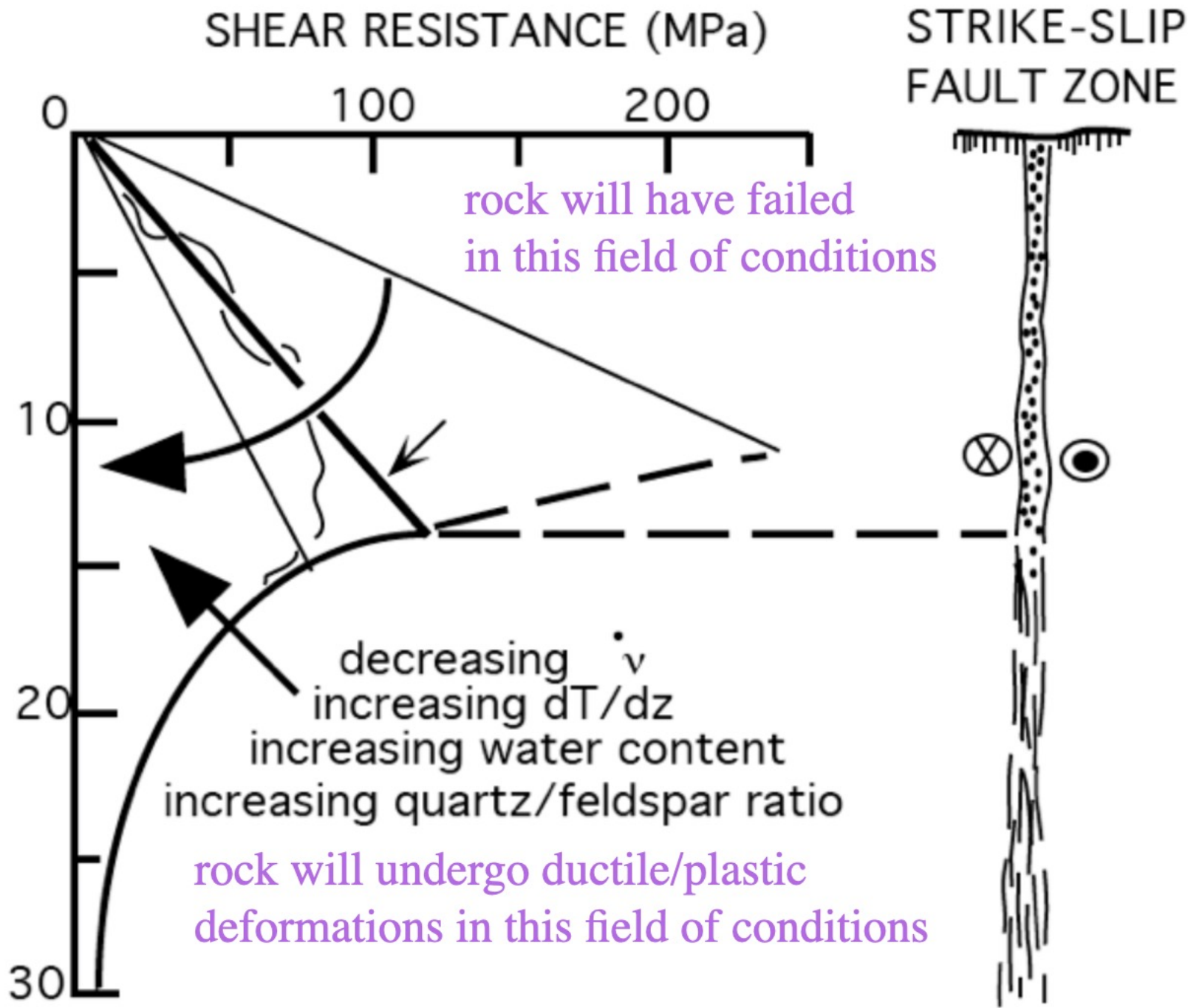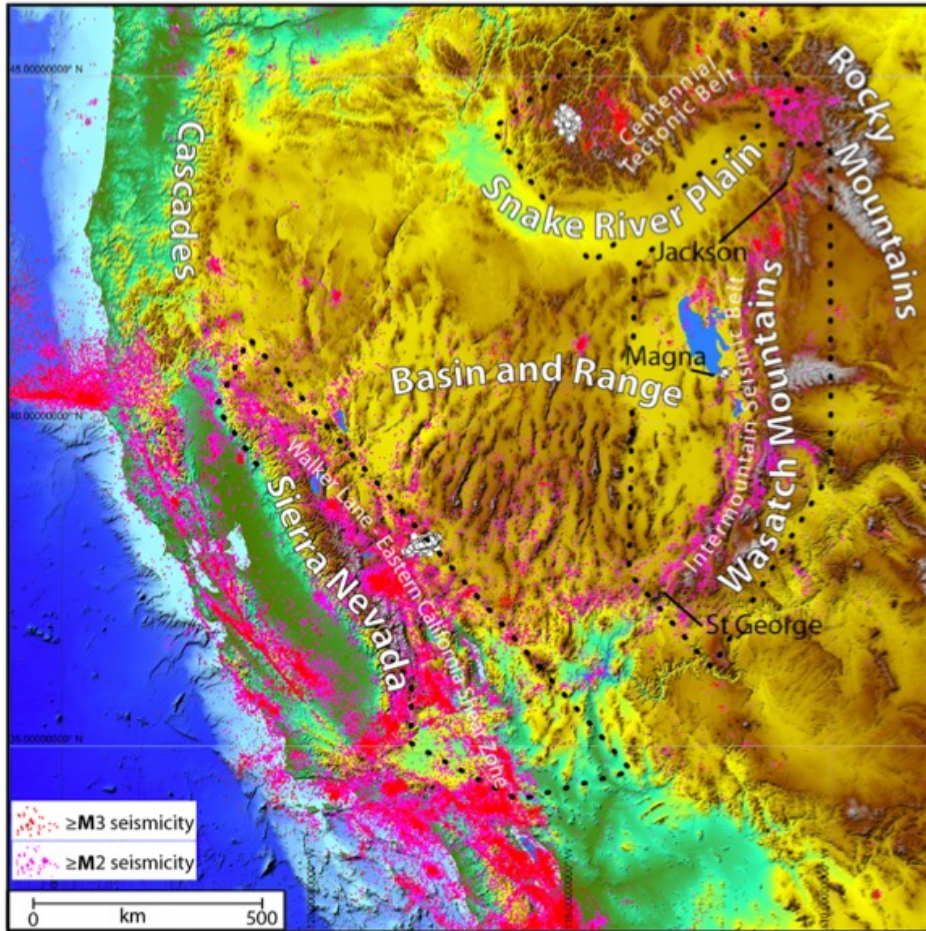Depth errors less than 10.0 km
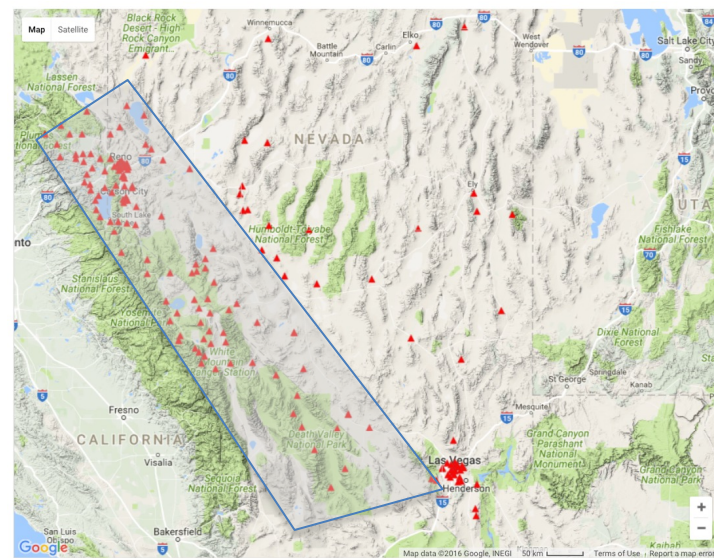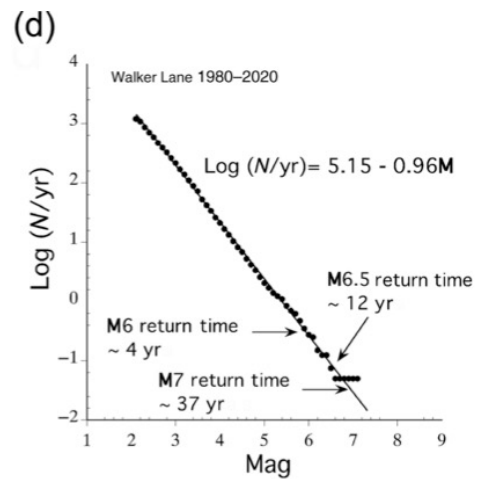
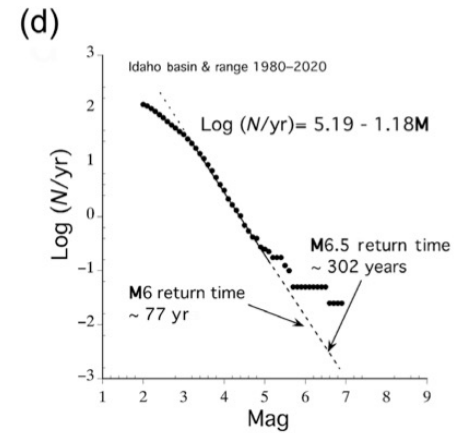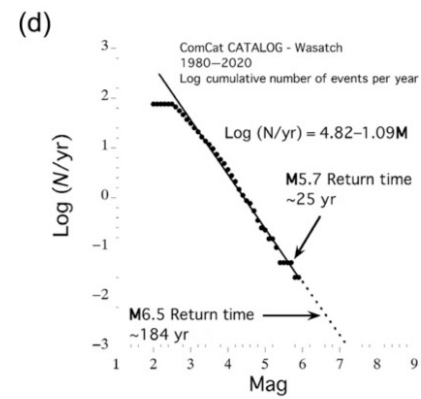Orange – broadband
Yellow - broadband
Black – short period
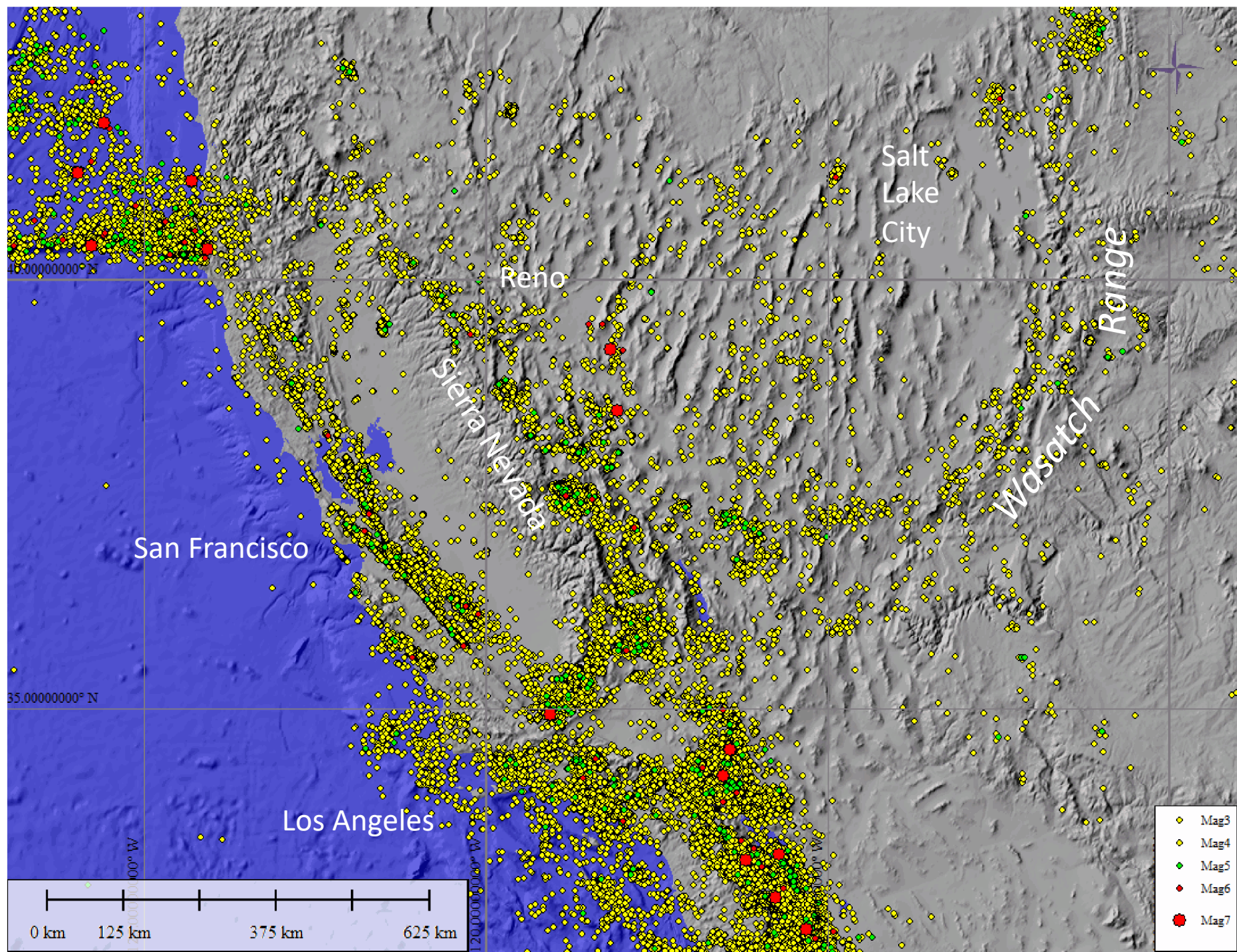Blue – strong ground motion

University of Utah
Seismograph
Stations.

(a) Wasatch
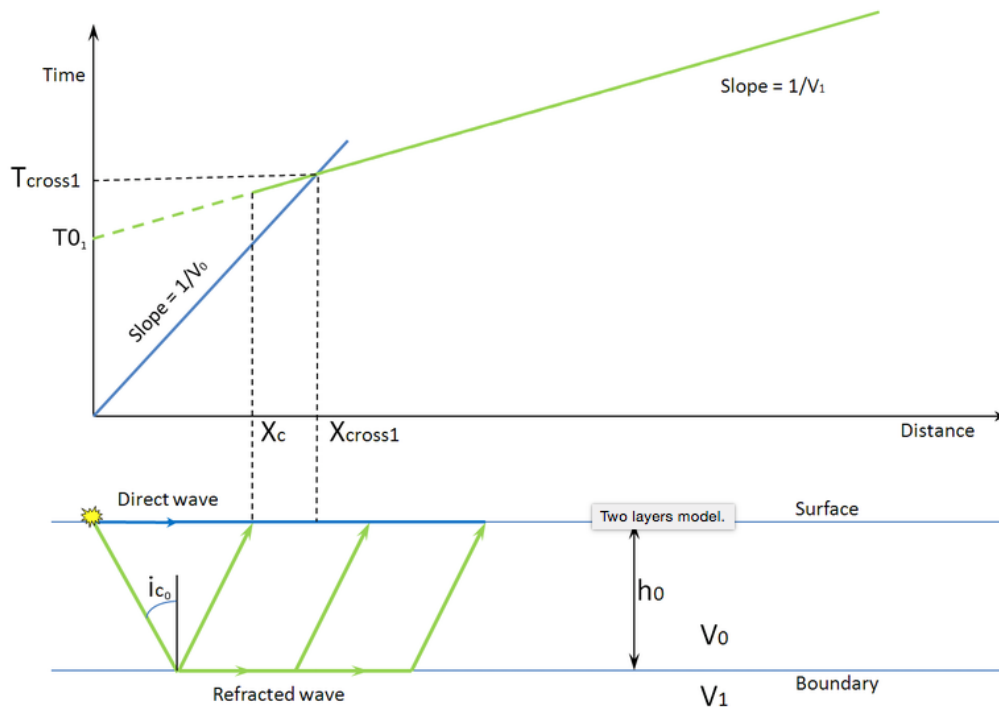
Legend: M2, M3, M4, M5, M6

(b) Wasatch seismicity since 1980

SW — NE

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)

(c) Number

Wasatch since 1980
M > 2 depth > 0.2 km
Depth error > 10 km excluded

SHEAR RESISTANCE (MPa)

STRIKE-SLIP FAULT ZONE

0   100   200

rock will have failed
in this field of conditions

10

20

decreasing $\dot{v}$
increasing dT/dz
increasing water content
increasing quartz/feldspar ratio

rock will undergo ductile/plastic
deformations in this field of conditions

30

How often?

Salt Lake City

Reno

Sierra Nevada

Wasatch Range

San Francisco

Los Angeles

40.00000000° N

35.00000000° N

| Mag3 |
| Mag4 |
| Mag5 |
| Mag6 |
| Mag7 |

0 km   125 km   375 km   625 km

Changing topics - Also arising from Seismological Studies – Information of thickness of CRUST

Three-Component Station

Free Surface

S wave

P wave

Velocity Contrast h

PpPhs   PsPhs   Pp Ps
            +
        PpShs

Direct P wave

Receiver Function

Ps   PpPhs
                PpShs
                  +
                PsPhs

PsShs

Time

Slope = 1/V₁

T_{cross1}

$T0_1$

Slope = 1/V₀

X_c X_{cross1}

Distance

Direct wave   Surface

ic_0 h_0

Two layers model.

V_0

Refracted wave V_1 Boundary
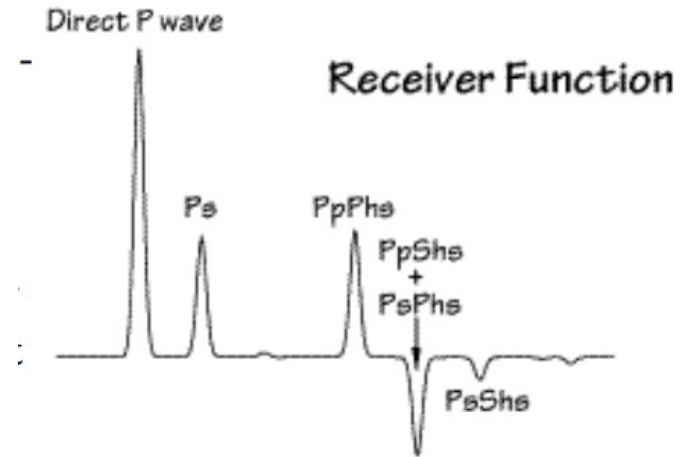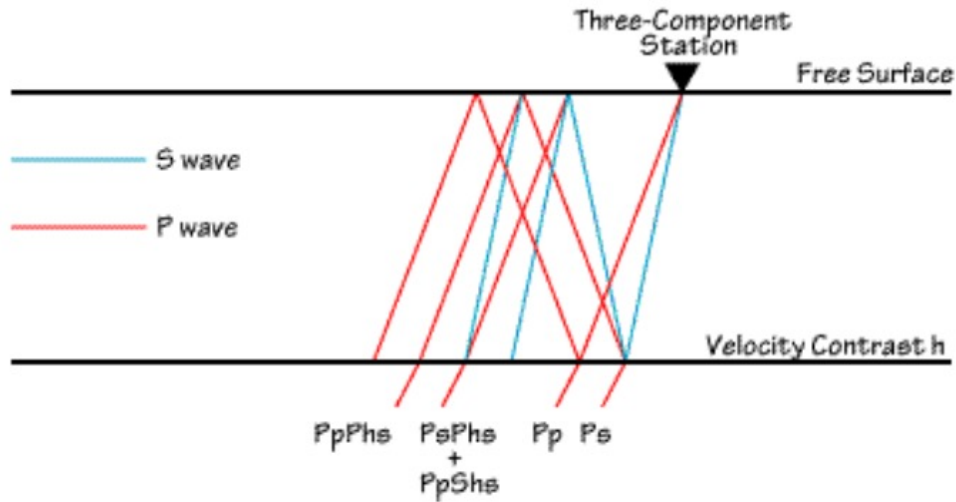
Both little and large earthquakes provide ability to look at velocity structure of the crust.

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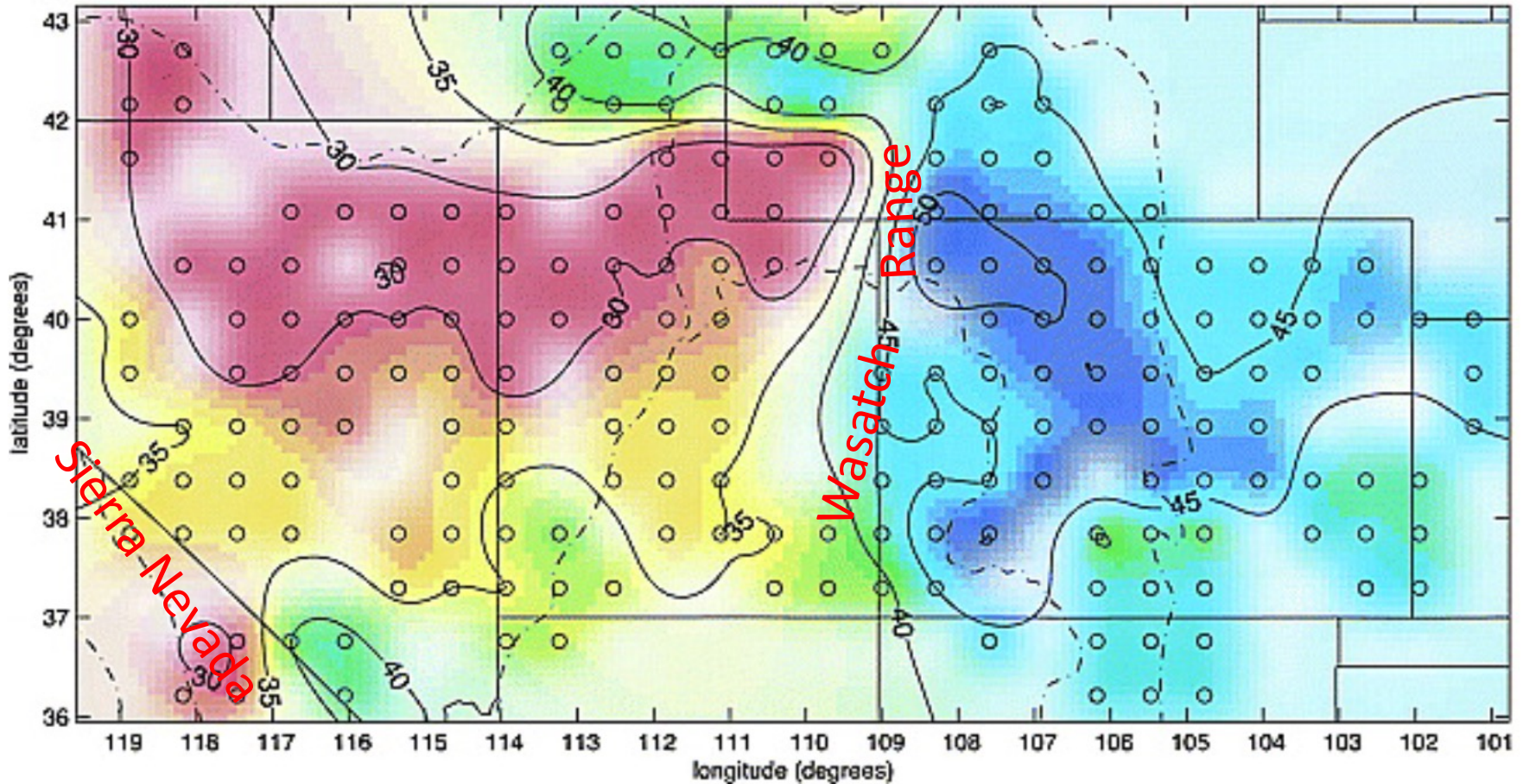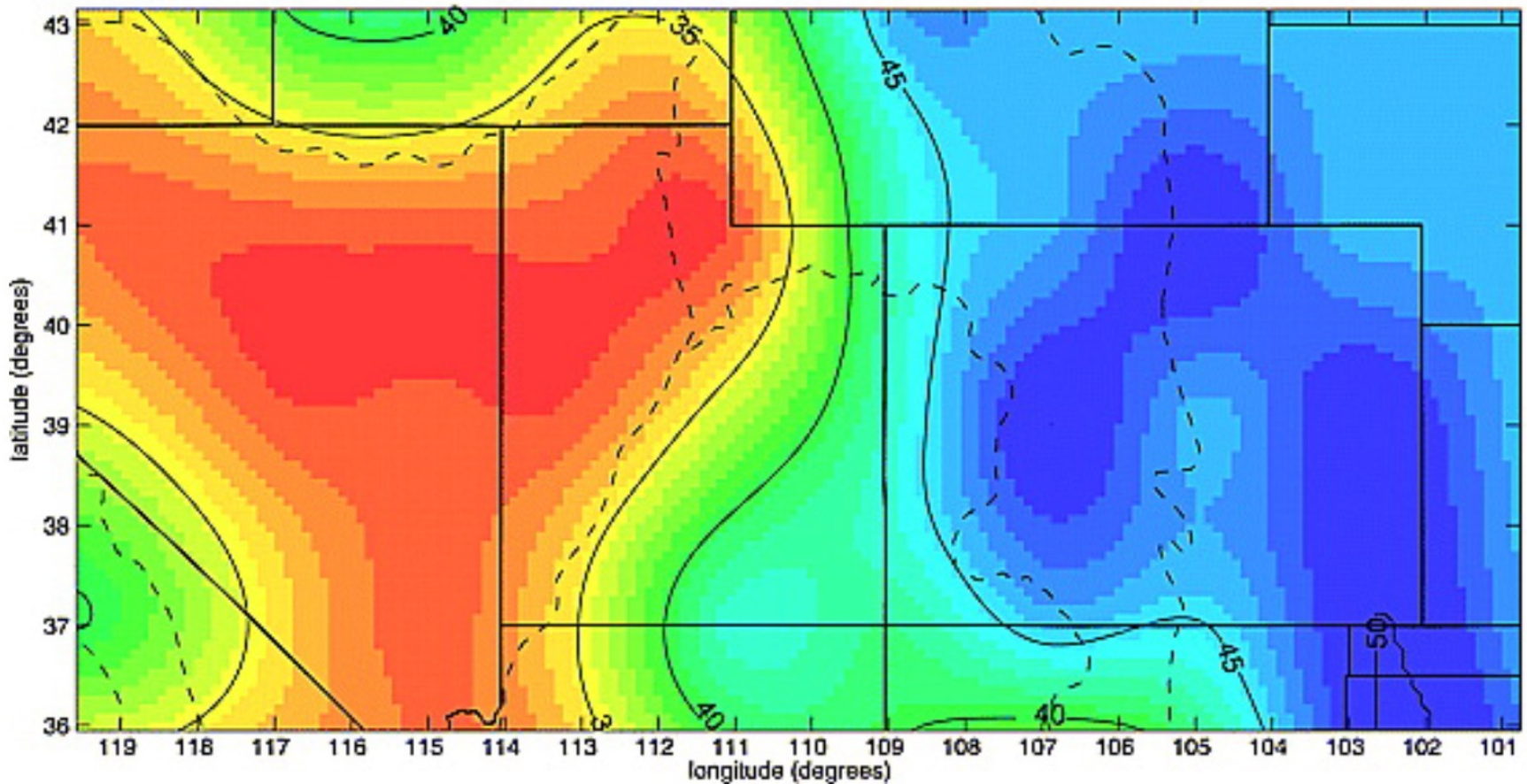
Older version of Previous with less resolution but displays broad scale features.

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

Geothermal Energy in the USA

GEOTHERMAL RESOURCE POTENTIAL
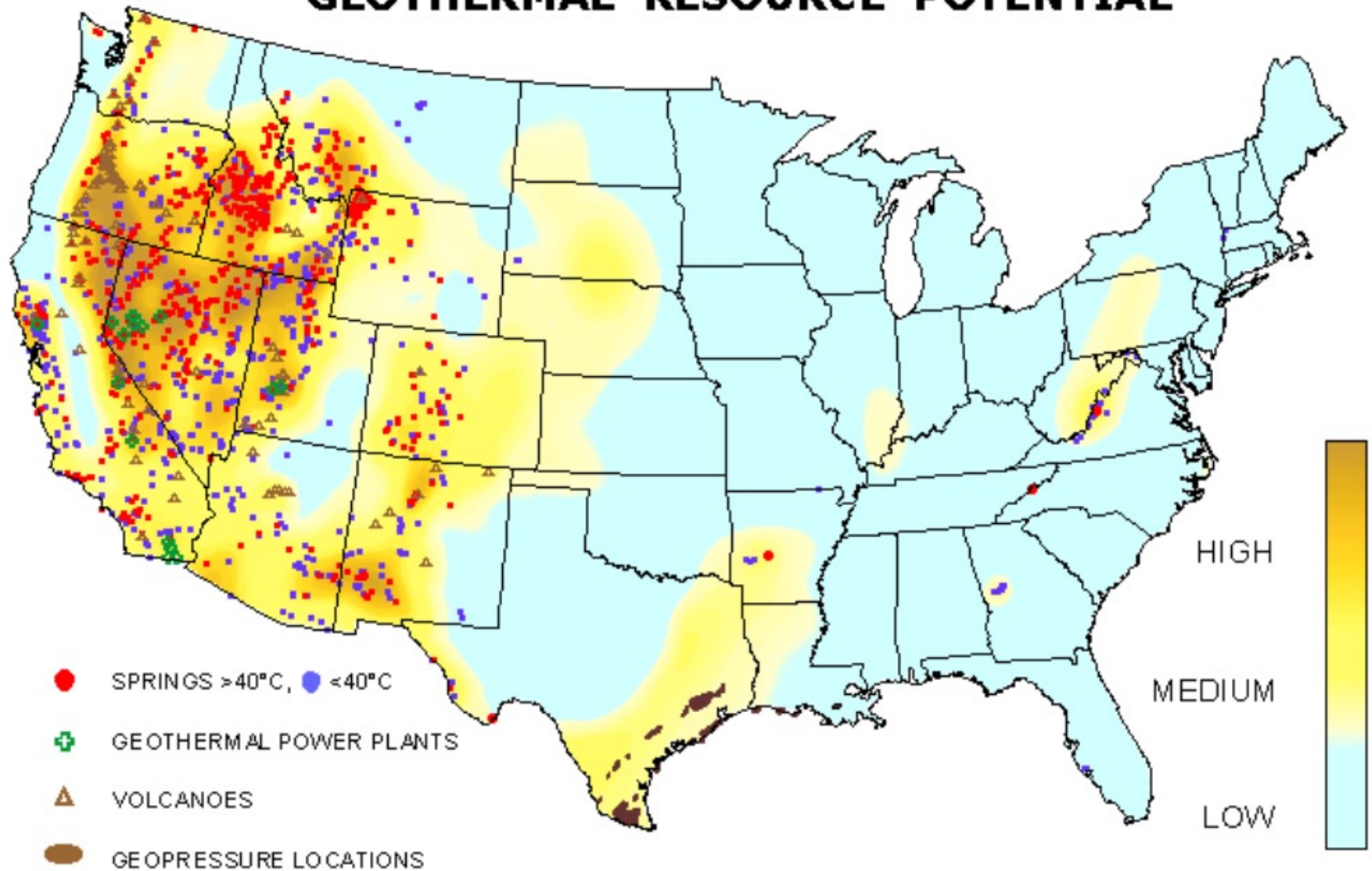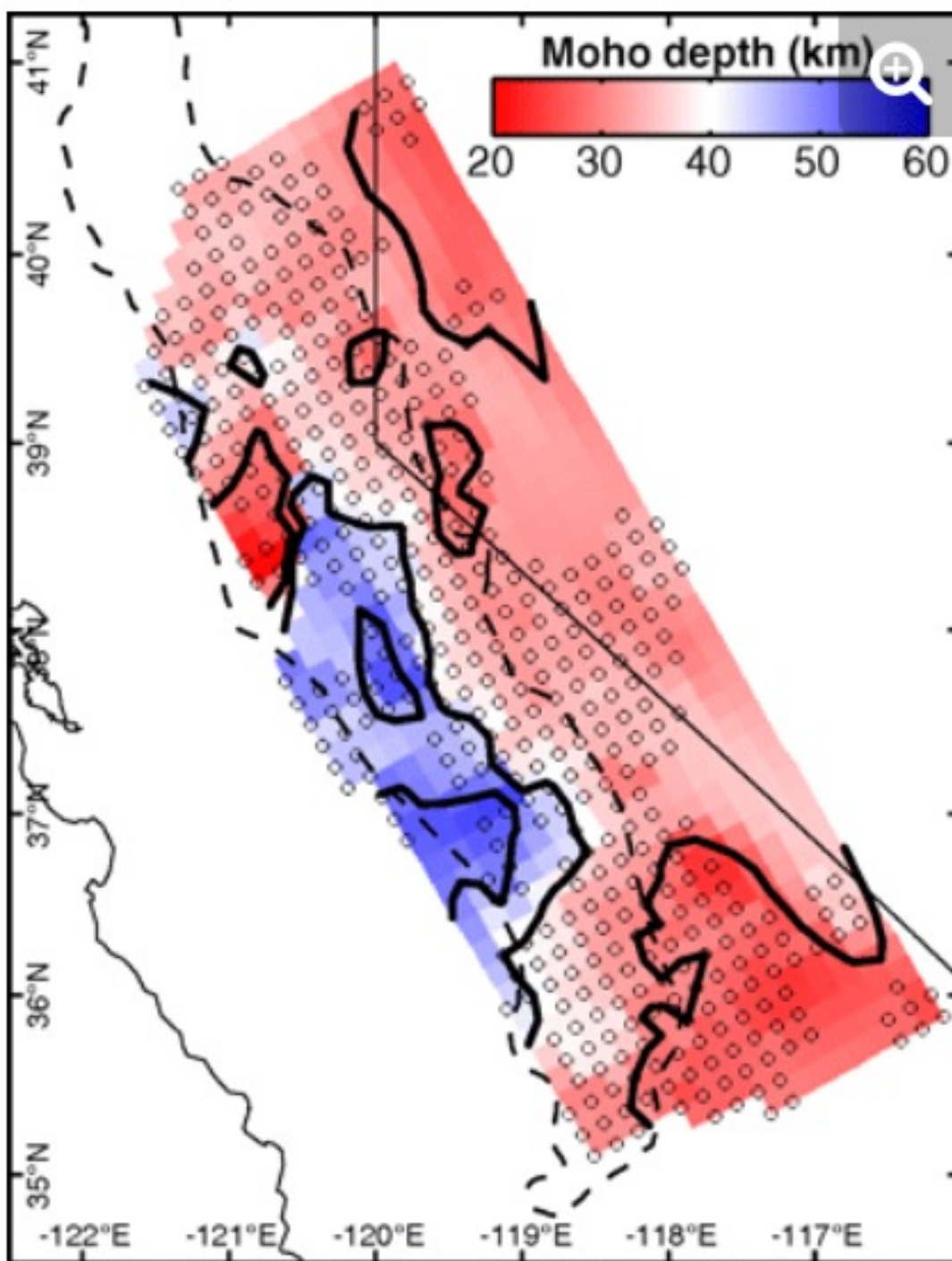
Beneath the Sierra Nevada

Absence of a root in southern
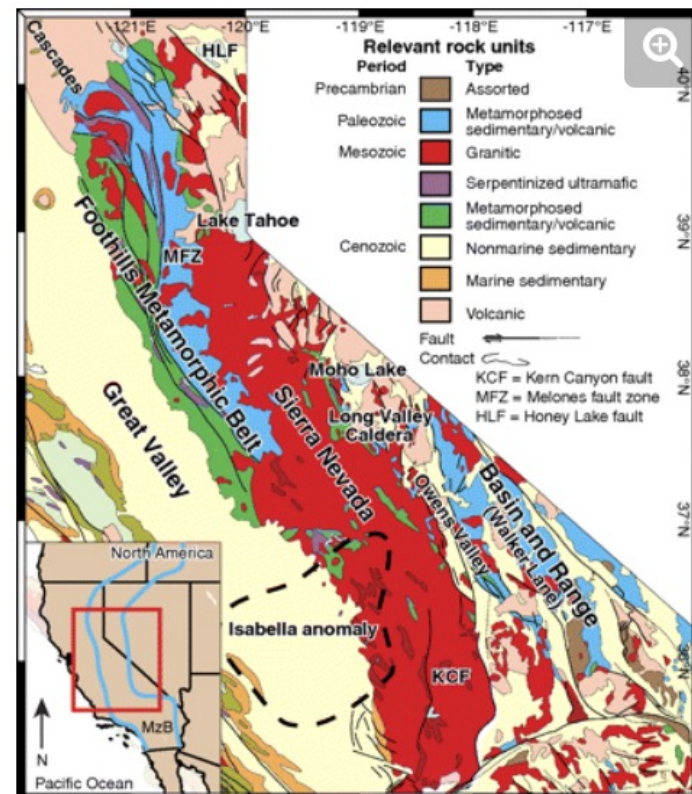
United States Elevation Map by www.FloodMap.net (beta)
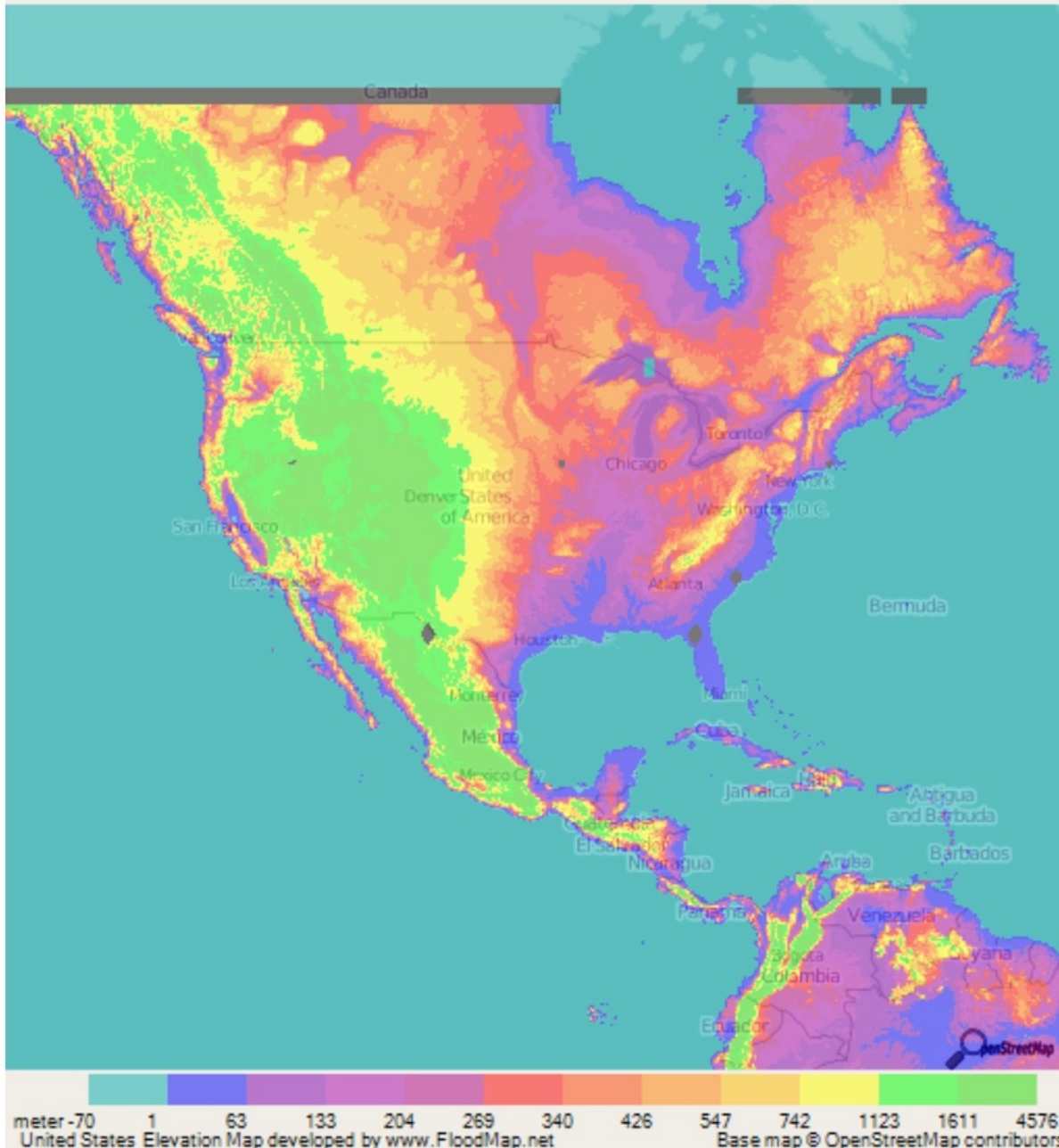
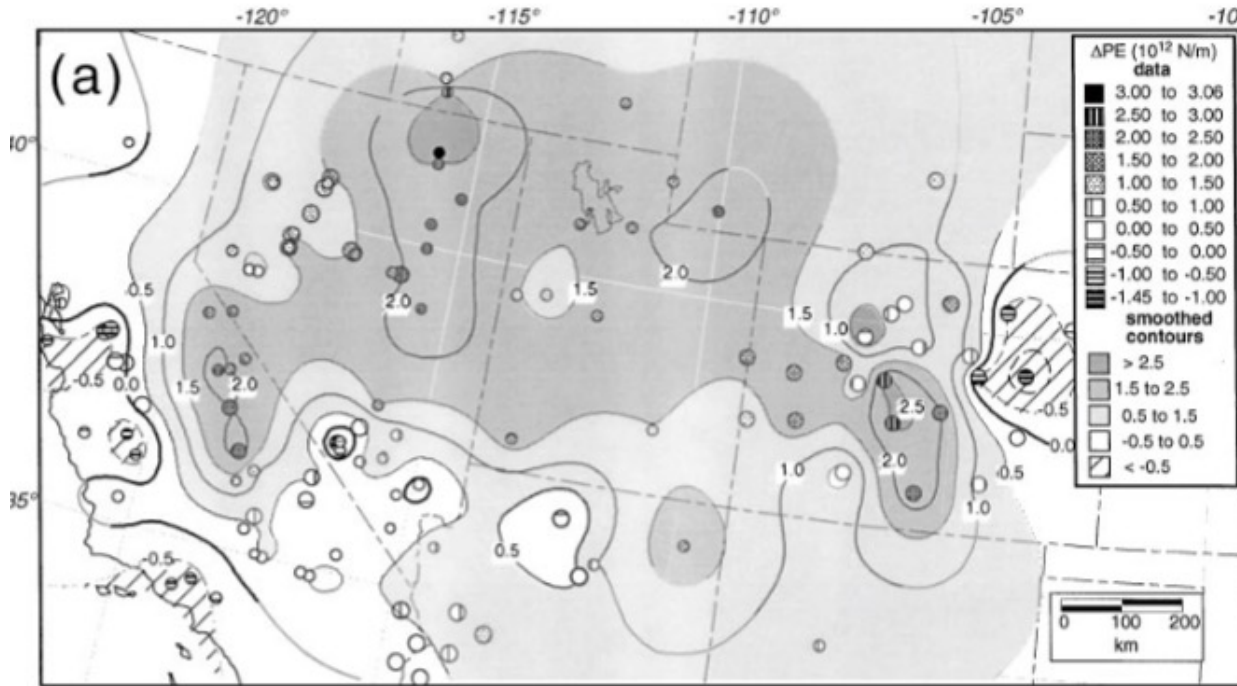While Crust is 'thin' in Basin and Range – Elevations are high

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-

High Elevation leads to increase in vertical stress in B&R- i.e. gravitational potential energy!- and normal faults…

Normal Fault

Reverse Fault

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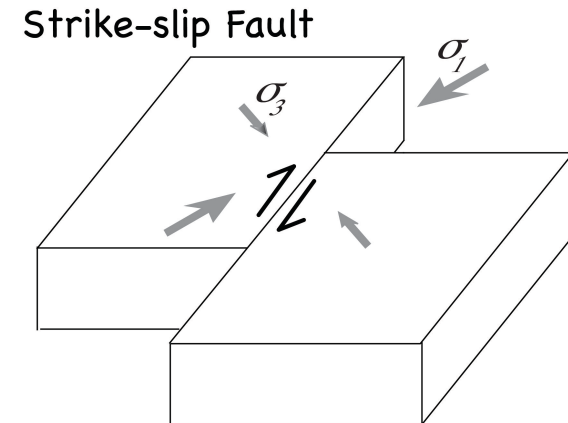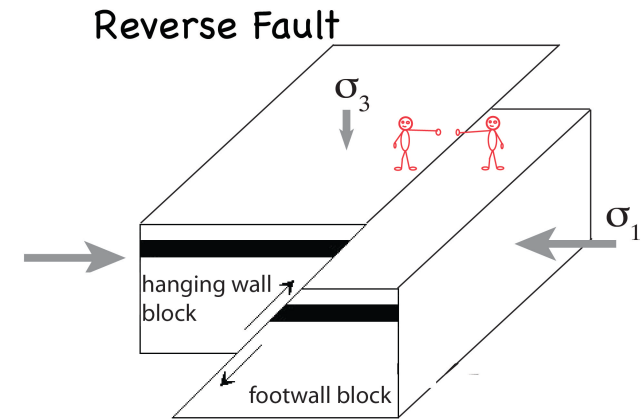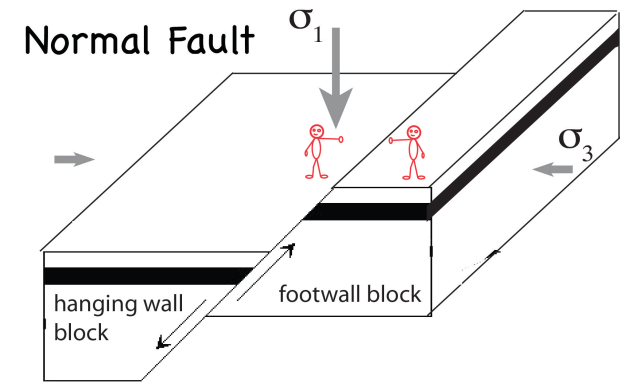
The high topography of the Basin and Range is not smooth – Between theWasatch and Sierra generally composed of northeast trending ranges and valleys

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...