Rapid response to the M6.5 Monte Cristo Mountains earthquake, the largest earthquake in Nevada in 65 years

Rich D. Koehler
Nevada Bureau of Mines and Geology
Geological Society of Nevada Zoom lecture
June 16, 2020

Support from:

nbmg

The Nevada Seismological Laboratory

California Department of Conservation

GEER

Nevada Geodetic Laboratory

USGS science for a changing world

N

Considerable media coverage

NevadaToday

The surface rupture of the Monte Cristo Range Earthquake is about 12 miles long.

Monte Cristo Earthquake fault still active with 6,500 aftershocks

University geoscience teams monitoring, finding, mapping damage and surface ruptures

Nevada Impact (https://www.unr.edu/nevada-today/news/nevada-impact) | June 01, 2020
Mike Wolterbeek (https://www.unr.edu/nevada-today/about/authors/mike-wolterbeek)

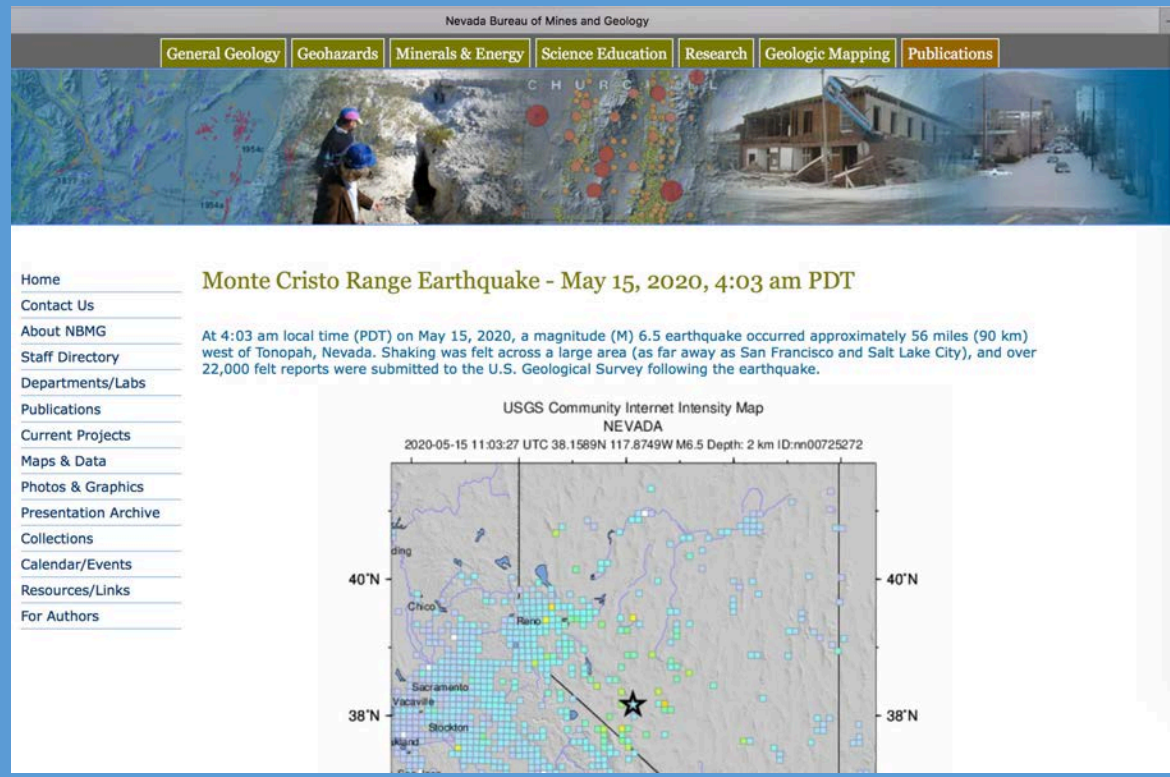
Seismologist: Nevada 'dodged a bullet' when Friday's 6.5 earthquake struck in a remote area

Sam Gross, Reno Gazette Journal Published 3:24 p.m. PT May 15, 2020

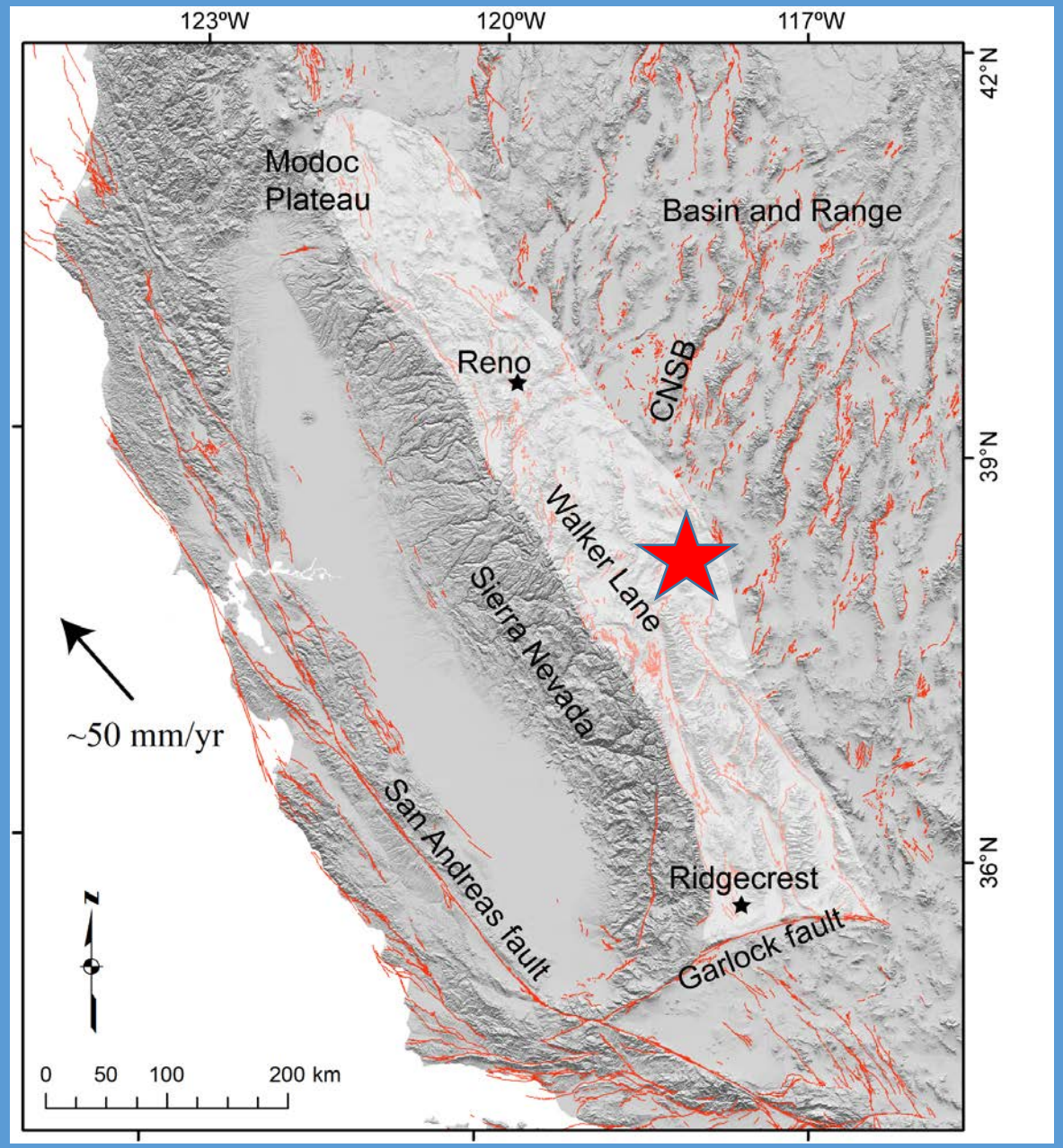
Magnitude 6.5 earthquake was Nevada's largest in 66 years; shaking reported in 3 states

Sam Gross, Reno Gazette Journal Published 3:21 p.m. PT May 15, 2020

Event page
NBMG website

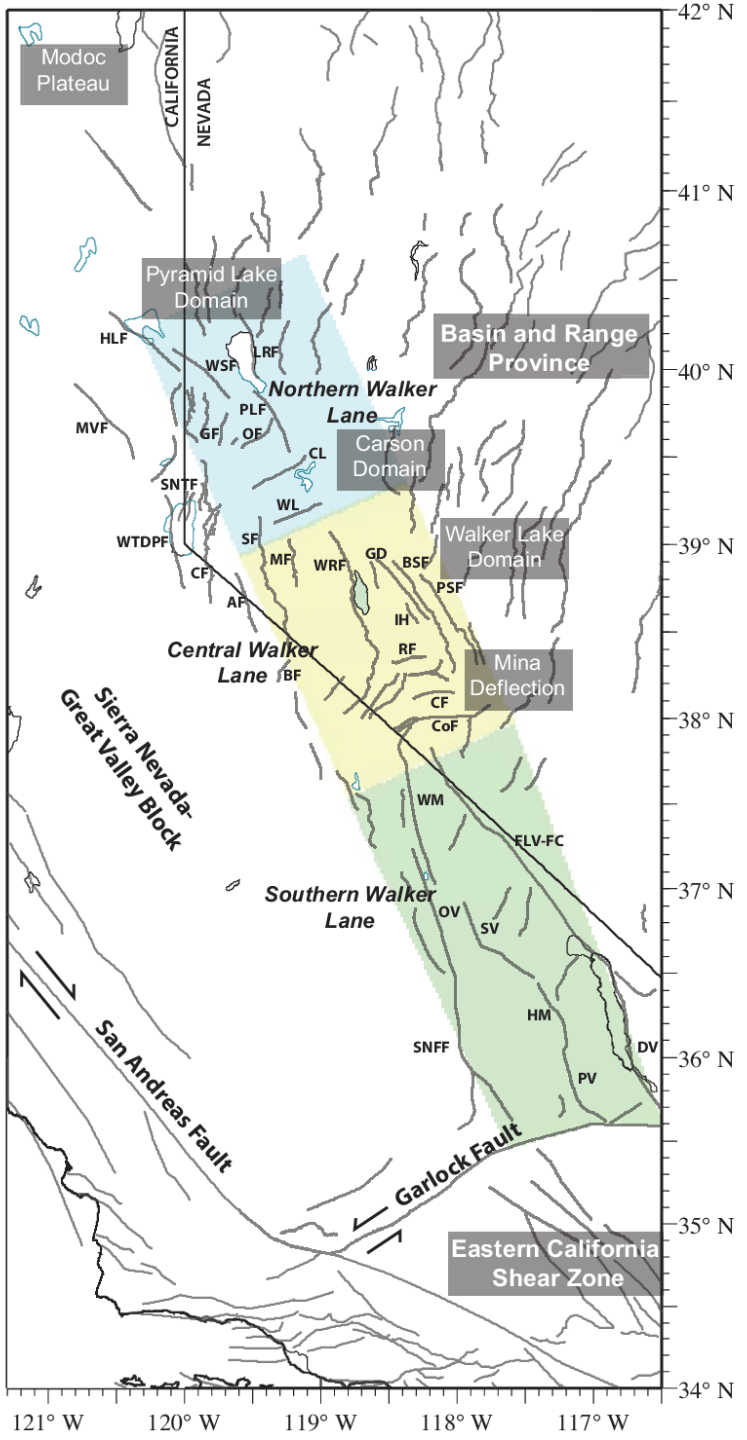


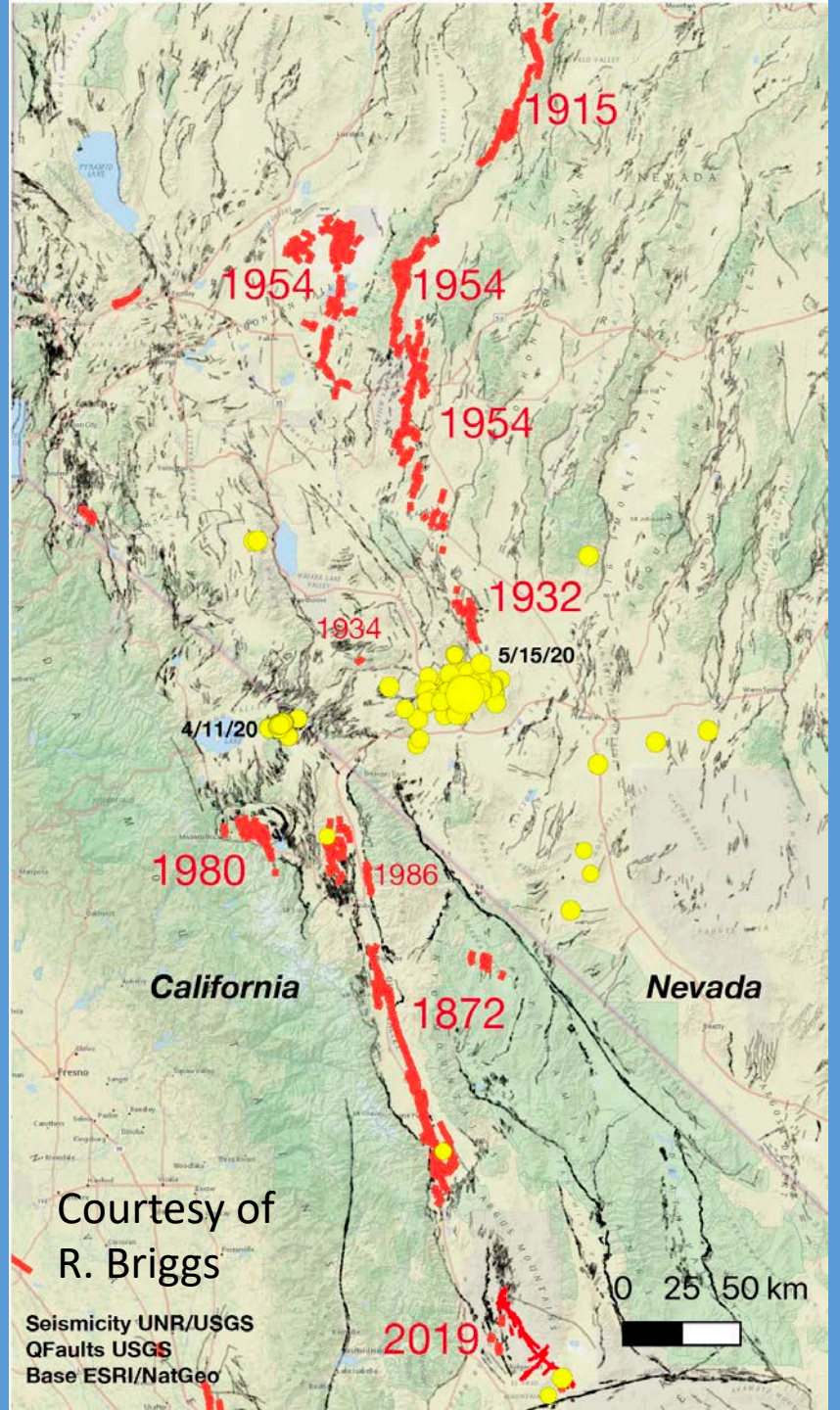
http://www.nbmg.unr.edu/Geohazards/Earthquakes/MonteCristoRangeEQ.html


123°W
120°W
117°W
42°N
39°N
36°N
Modoc Plateau
Basin and Range
Reno
CSMB
Walker Lane
Sierra Nevada
~50 mm/yr
San Andreas fault
Ridgecrest
Garlock fault
N
0 50 100 200 km

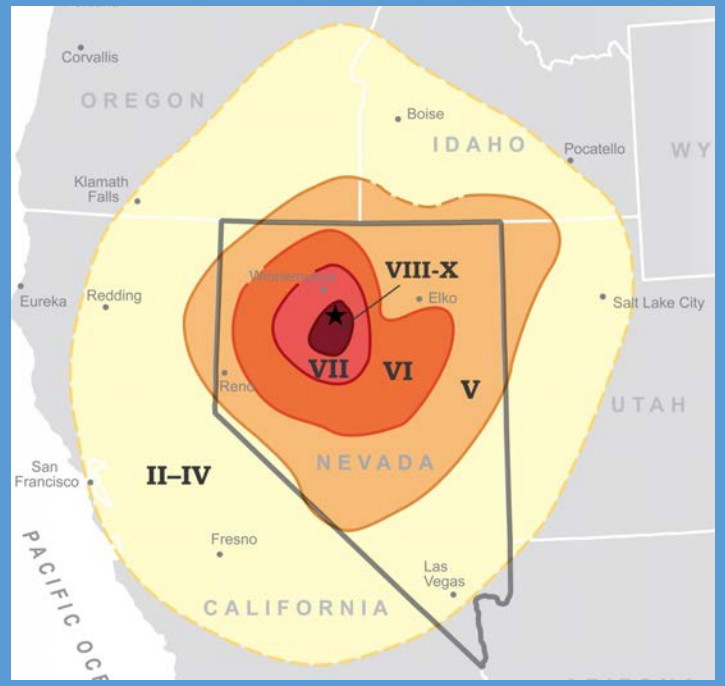

NEVADA TECTONICS
NORTH AMERICAN PLATE
Juan de Fuca Plate
Basin and Range Province
Sierra Nevada
Walker Lane Belt
Block
Colorado Plateau
PACIFIC PLATE
Arrows indicate movement relative to the "spike"


Mendocino Triple Junction
OB
Cascade arc
MP
NWL
San Andreas Fault
Sierra Nevada – Great Valley
Walker Lane
GD
CWL
M
OV
SWL
GF
BB
T
R
ECSZ
LM
MD
ST
125°
35°
120°
30°

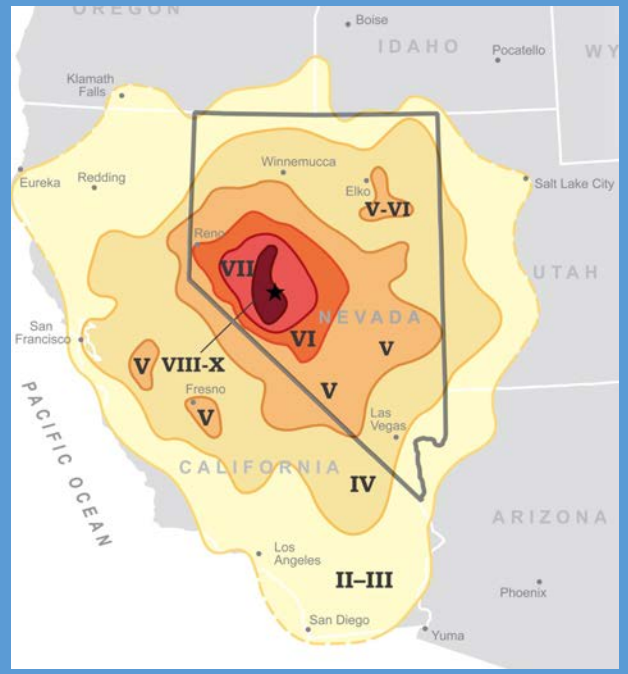

Modoc Plateau
CALIFORNIA
NEVADA
Pyramid Lake Domain
Basin and Range Province
Northern Walker Lane
Carson Domain
Walker Lake Domain
Central Walker Lane
Mina Deflection
Sierra Nevada Great Valley Block
Southern Walker Lane
San Andreas Fault
Garlock Fault
Eastern California Shear Zone
HLF
WSF
LRF
PLF
GF
OF
MVF
CL
SNTF
WL
WTDPF
SF
MF
WRF
GD
BSF
PSF
CF
AF
IH
RF
BF
CoF
WM
FLV-FC
OV
SV
HM
SNFF
DV
PV
42° N
41° N
40° N
39° N
38° N
37° N
36° N
35° N
34° N
121° W
120° W
119° W
118° W
117° W


1915
1954
1954
1954
1932
1934
5/15/20
4/11/20
1980
1986
1872
2019
California
Nevada
Courtesy of R. Briggs
Seismicity UNR/USGS
QFaults USGS
Base ESRI/NatGeo
0 25 50 km

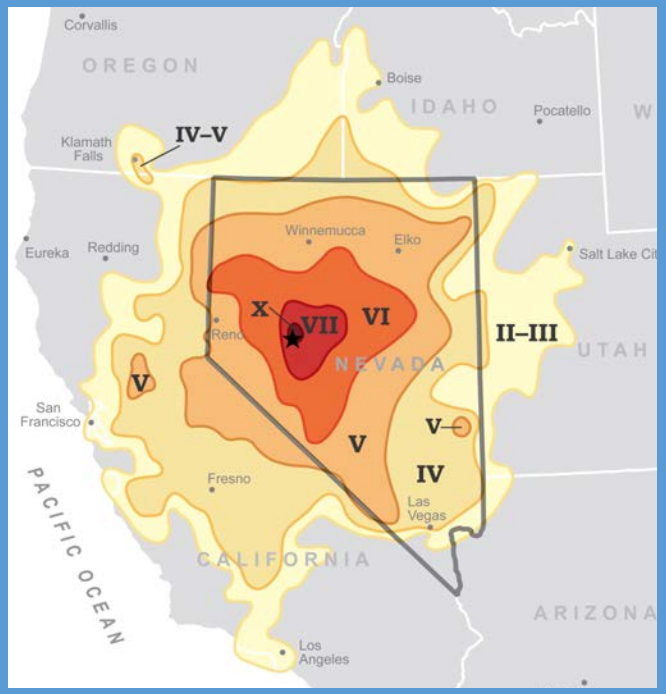
Historical earthquakes northeast of the Central Walker Lane



1915 M7.3 Pleasant Valley



1932 Cedar Mountain M7.1

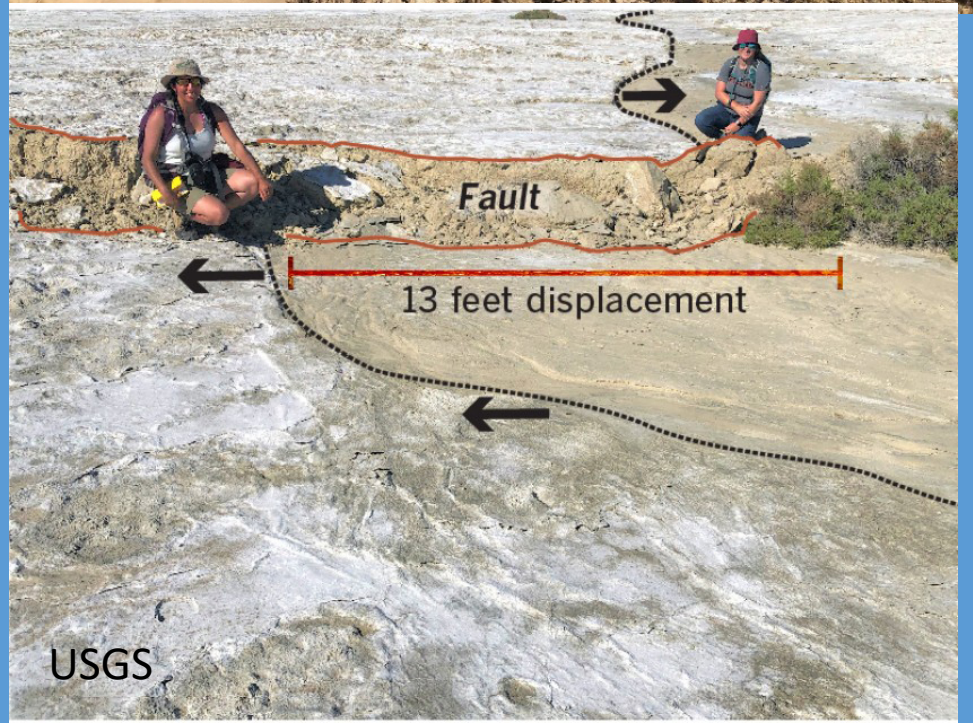


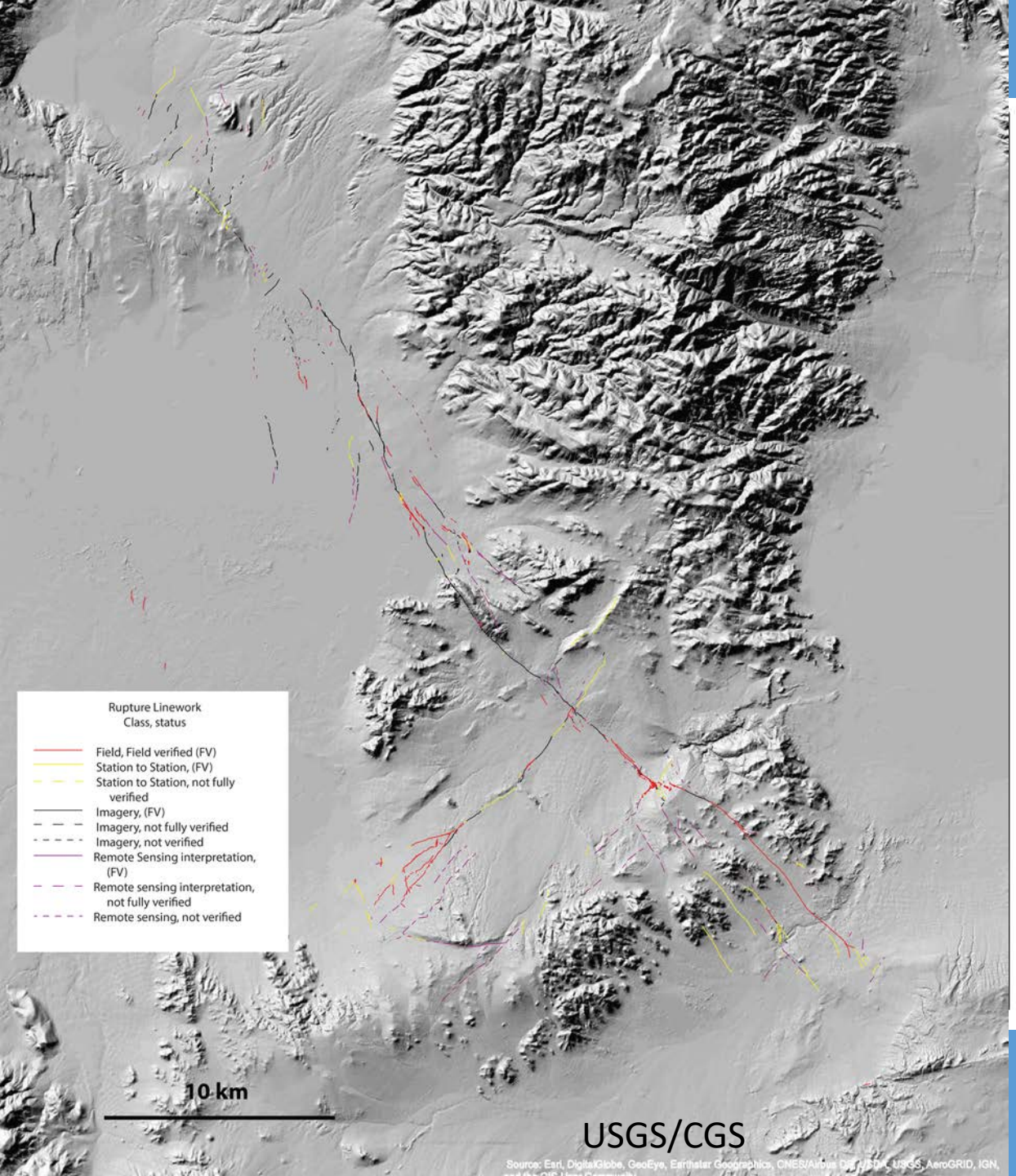
1954 Rainbow Mountain, Stillwater, Fairview Peak, Dixie Valley, M7.1 and 6.9

The 2019 Mw 6.4 and Mw 7.1 Ridgecrest, California earthquakes

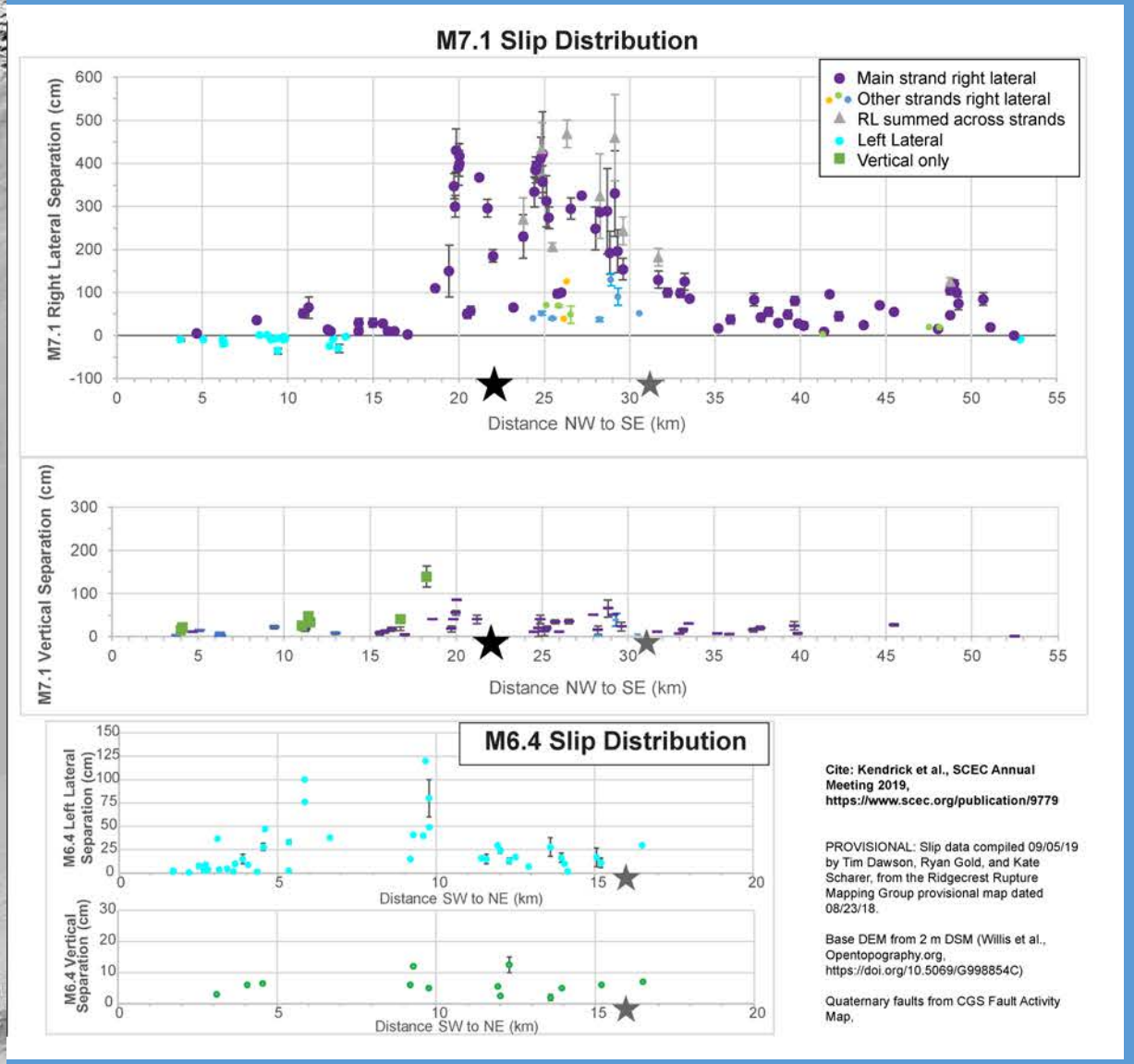
Photo: Colin Chupik

Drone imagery collection and mapping, Ridgecrest 2019





USGS/CGS

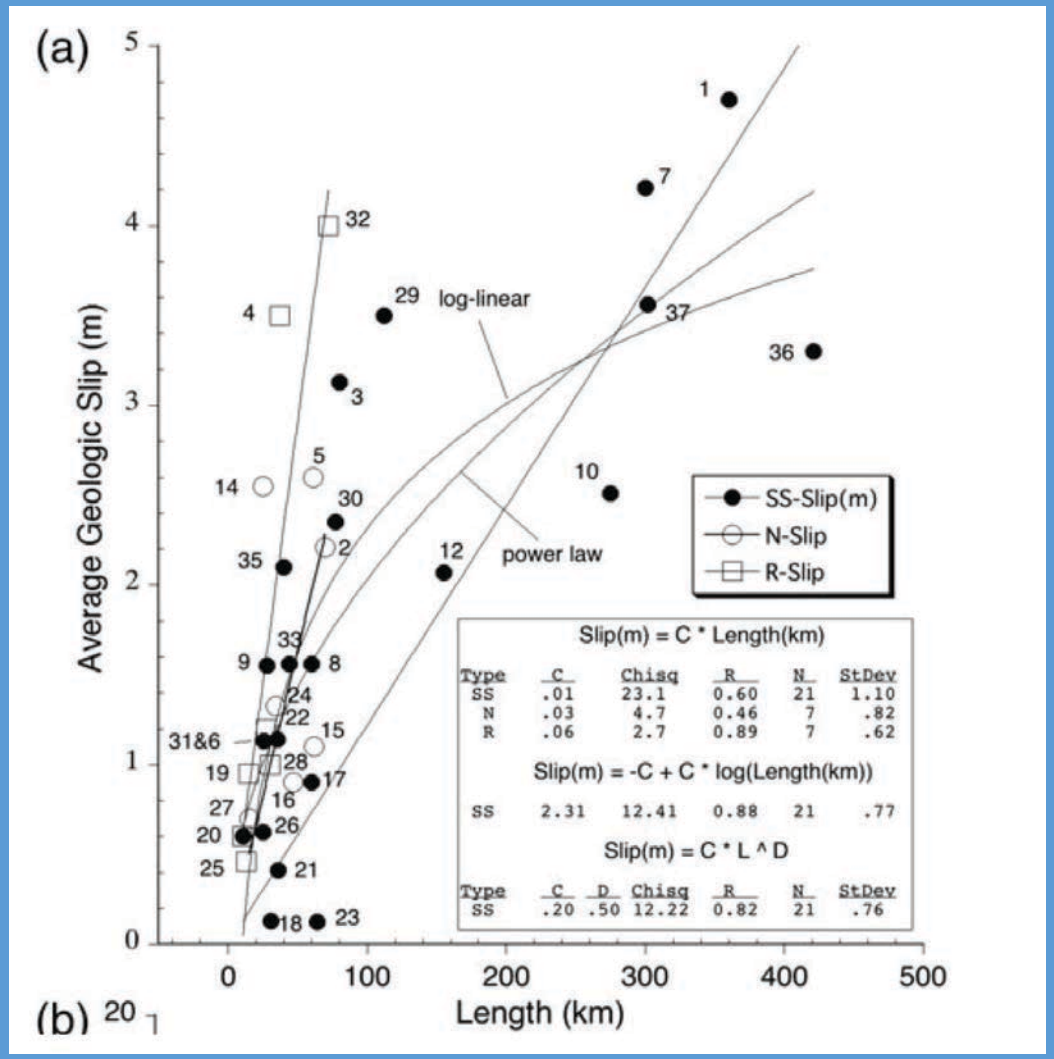


DuRoss et al., 2020

Why do earthquake reconnaissance?

- Geomorphic effects are ephemeral (erosion and repair activities). Fieldwork provides a record of this perishable data (offset, rupture length).
- Data contributes to a better understanding of earthquake processes and effects.
- Knowledge applicable to engineering geologic applications and earthquake mitigation.
- Coseismic slip distribution combined with fault slip rate (geologic and geodetic) provides insight into future earthquake occurrence and contributes to rupture forecast and probability models (seismic hazards assessment).
- Identification of sites for paleoseismic studies (slip rate, timing, and recurrence).
- Archived observations can inform new ideas, theories, and analytical techniques and calibrate remotely sensed information (InSAR, GPS, lidar, seismic).

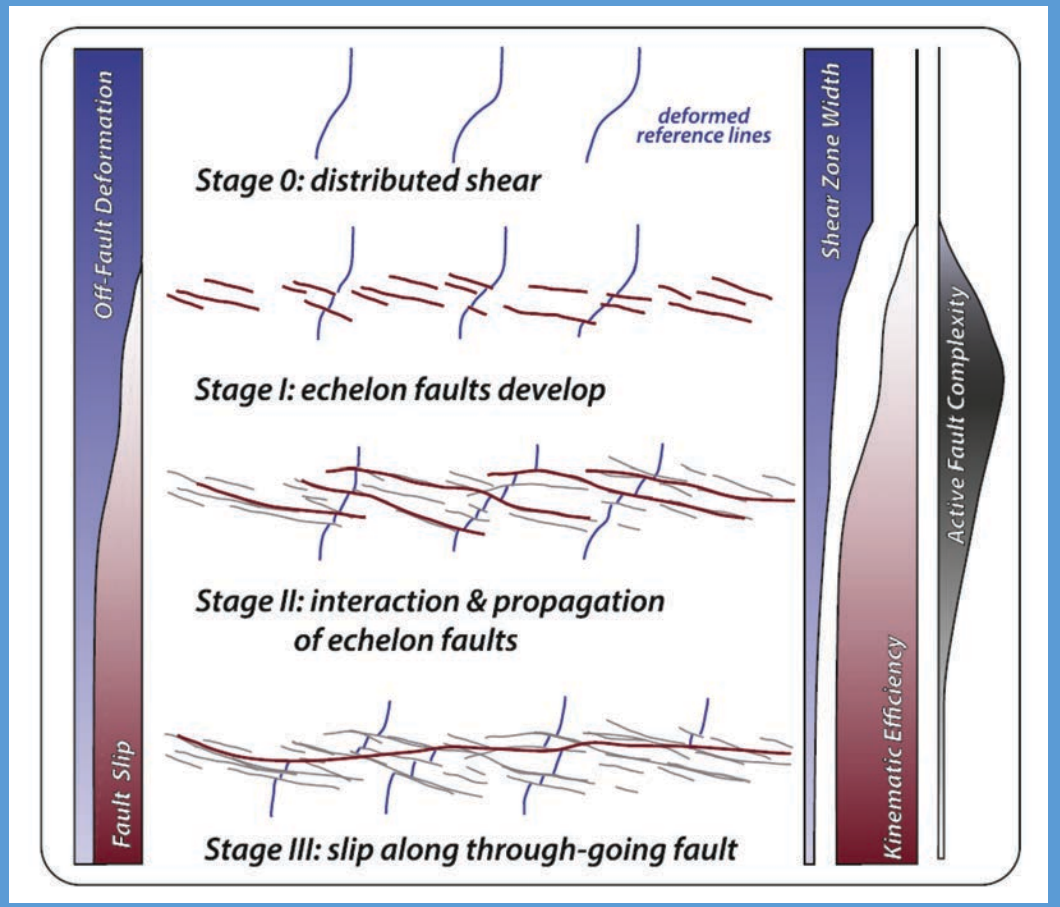
Average slip vs. rupture length



Wesnousky, 2008

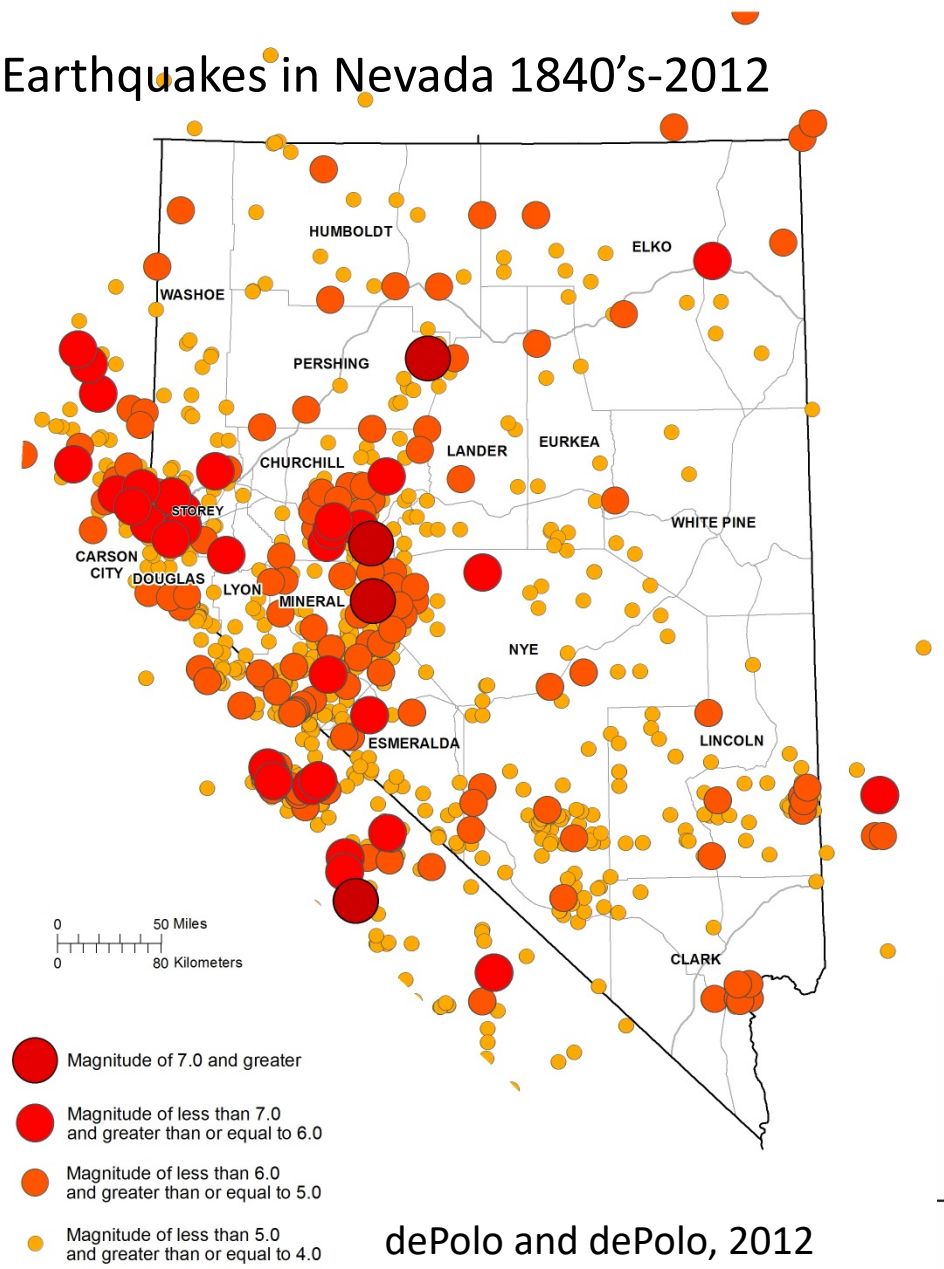
Rupture width and off fault deformation

- Important for fault displacement hazard analyses
- Immature faults up to 40% of slip off-fault



Hatem et al., 2017

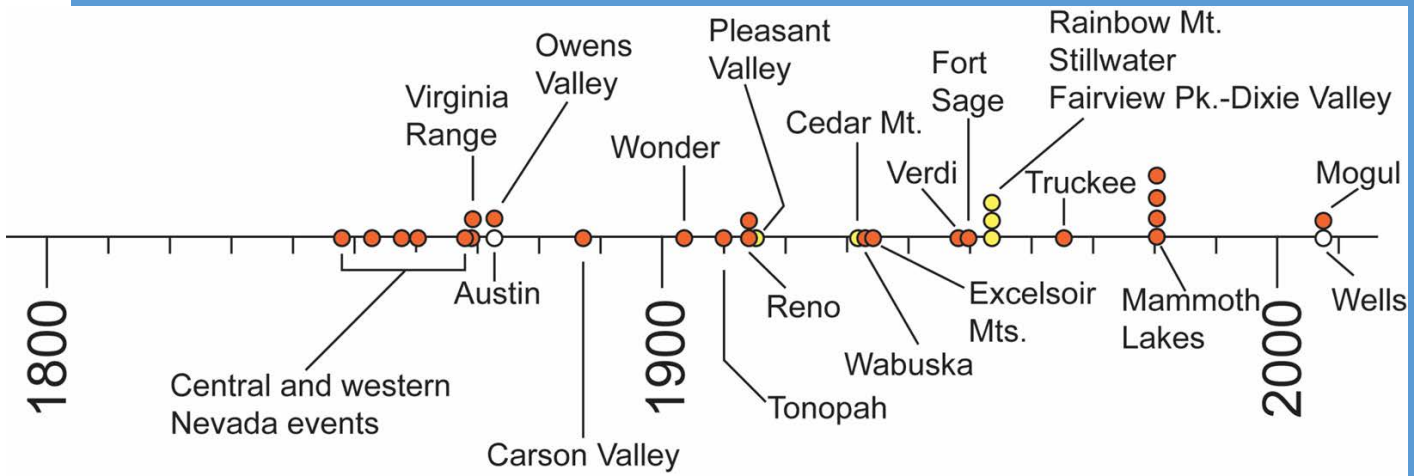
Earthquakes in Nevada 1840's-2012

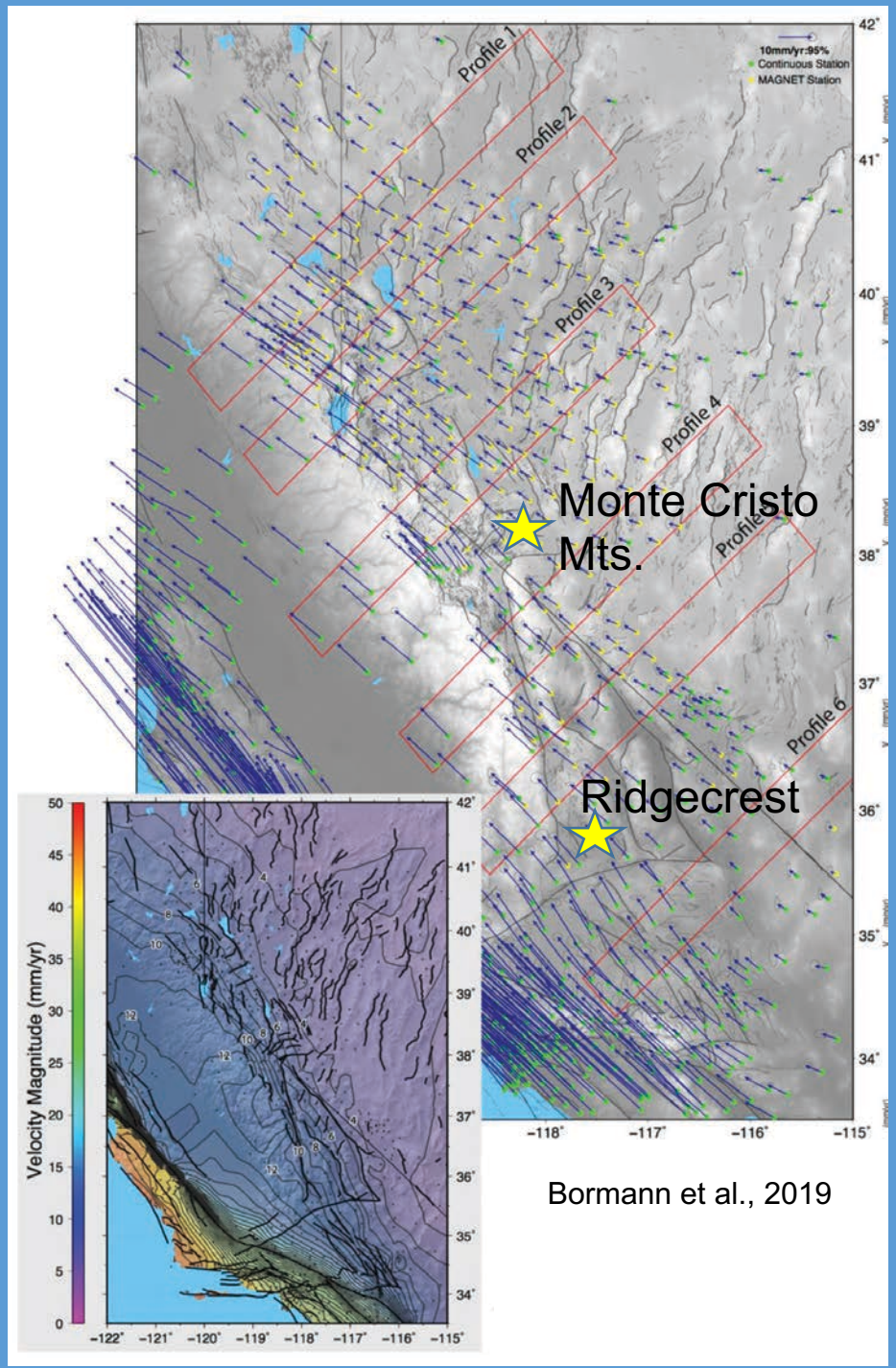


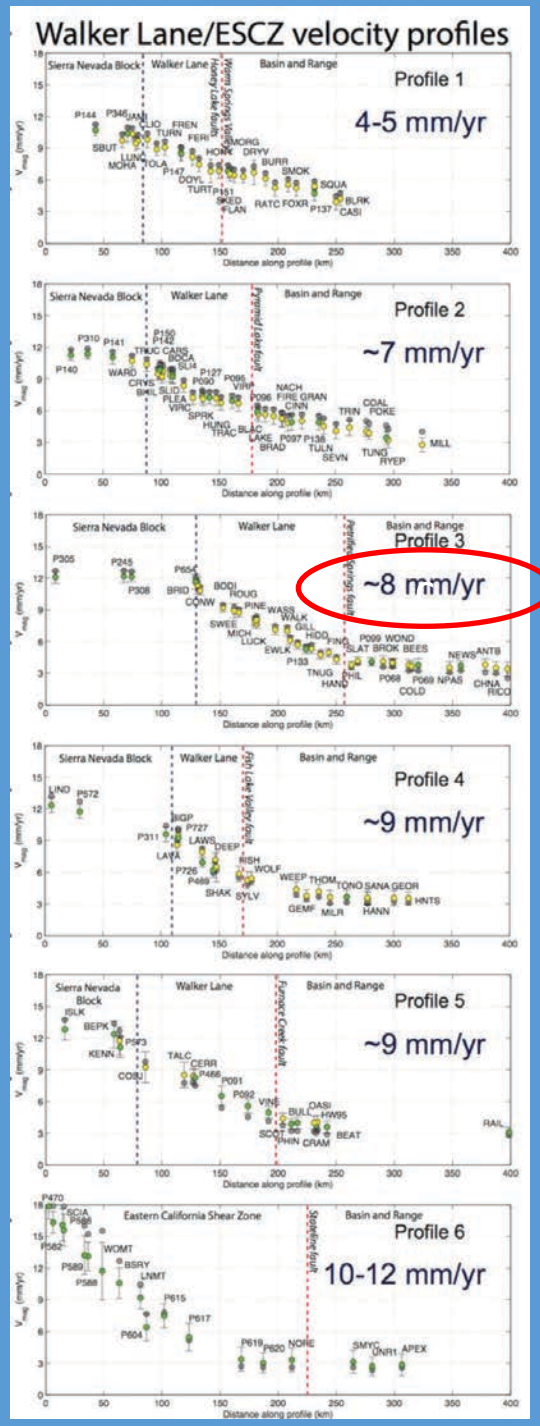
dePolo and dePolo, 2012

Major Earthquakes in Nevada

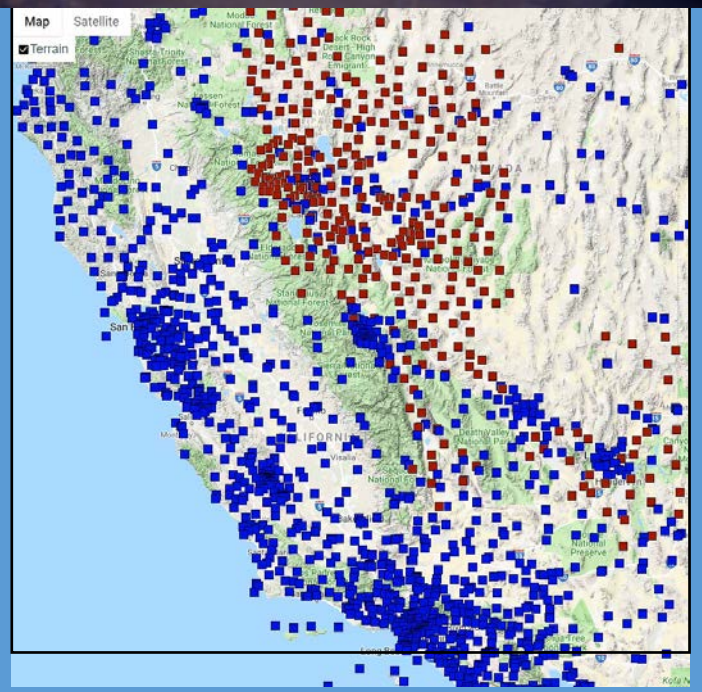
- over 35 historic M>6
- Largest M7.6
- Inter-event times: 4 min – 22+ yrs.







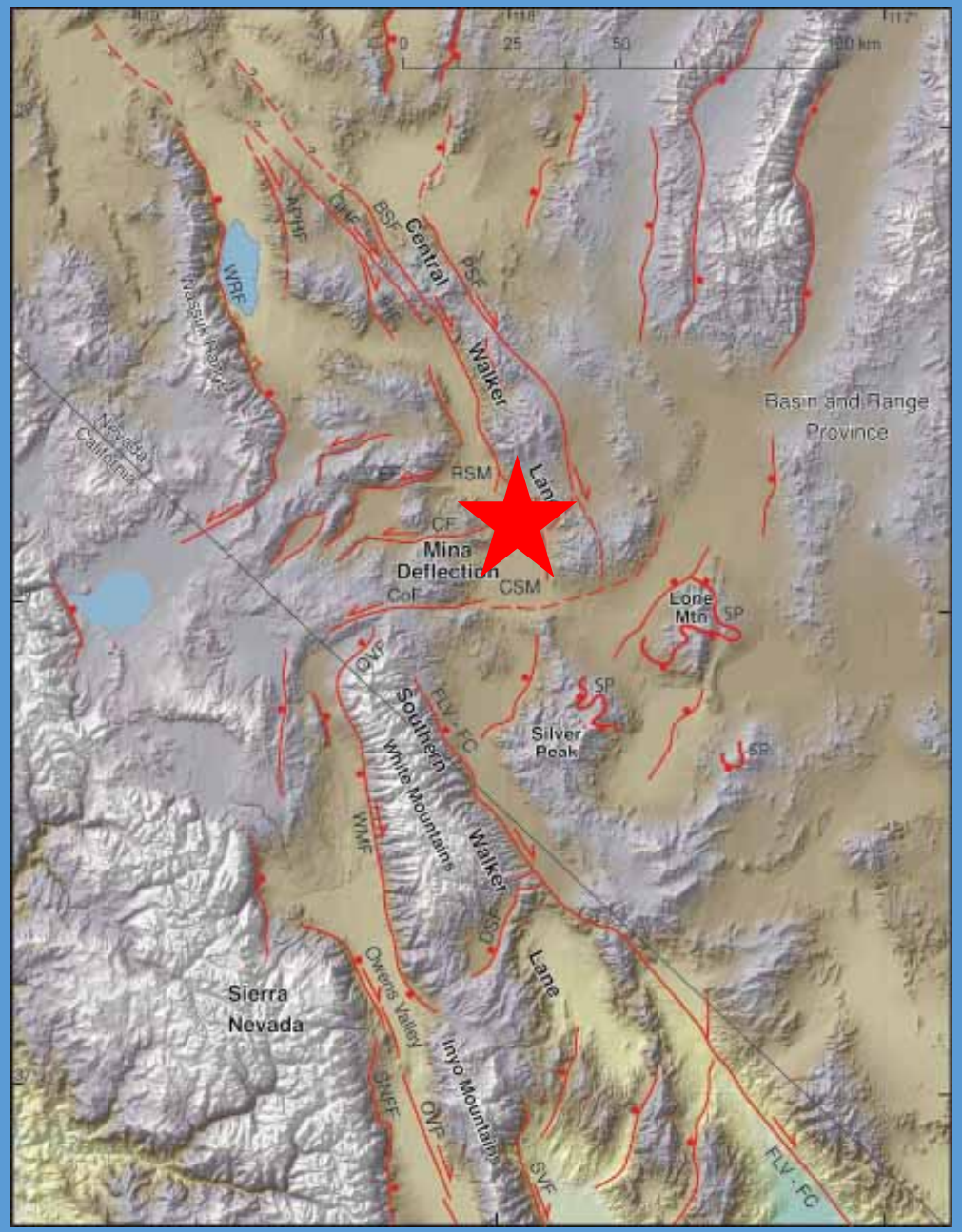
Nevada Geodetic Laboratory
MAGNET network



Central Walker Lane

Bedrock mapping suggests 48-60 km of dextral displacement in the last 10-15 Myr.

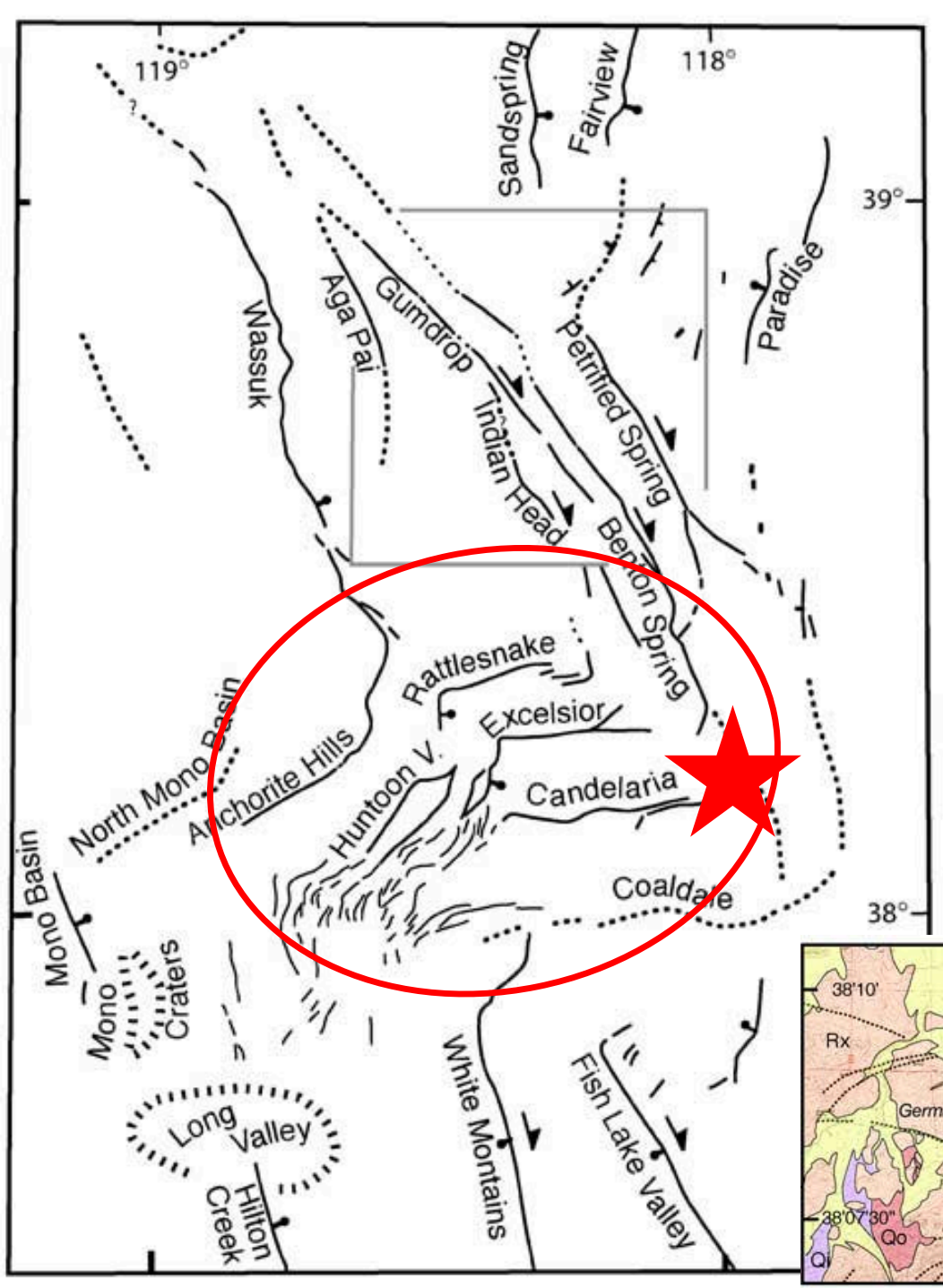
Active tectonic geomorphology

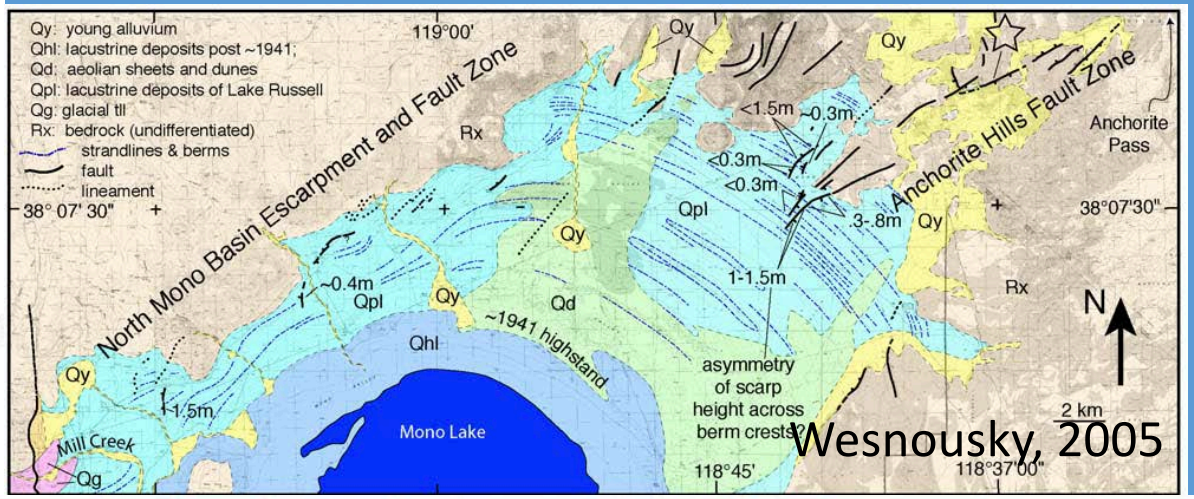


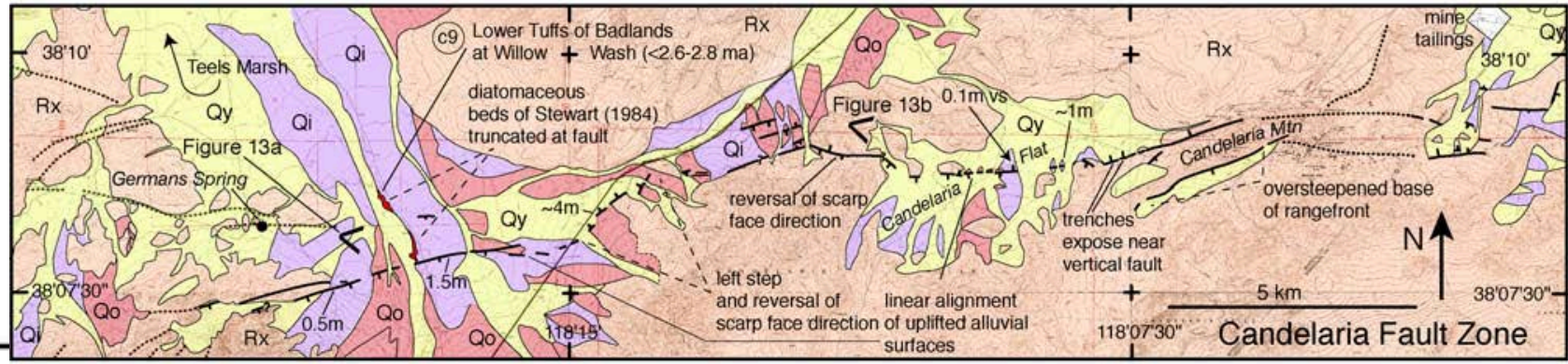
All faults in the Mina Deflection exhibit linear enclosed depressions, uphill and alternately facing scarps, and side hill benches consistent with left-lateral displacement.

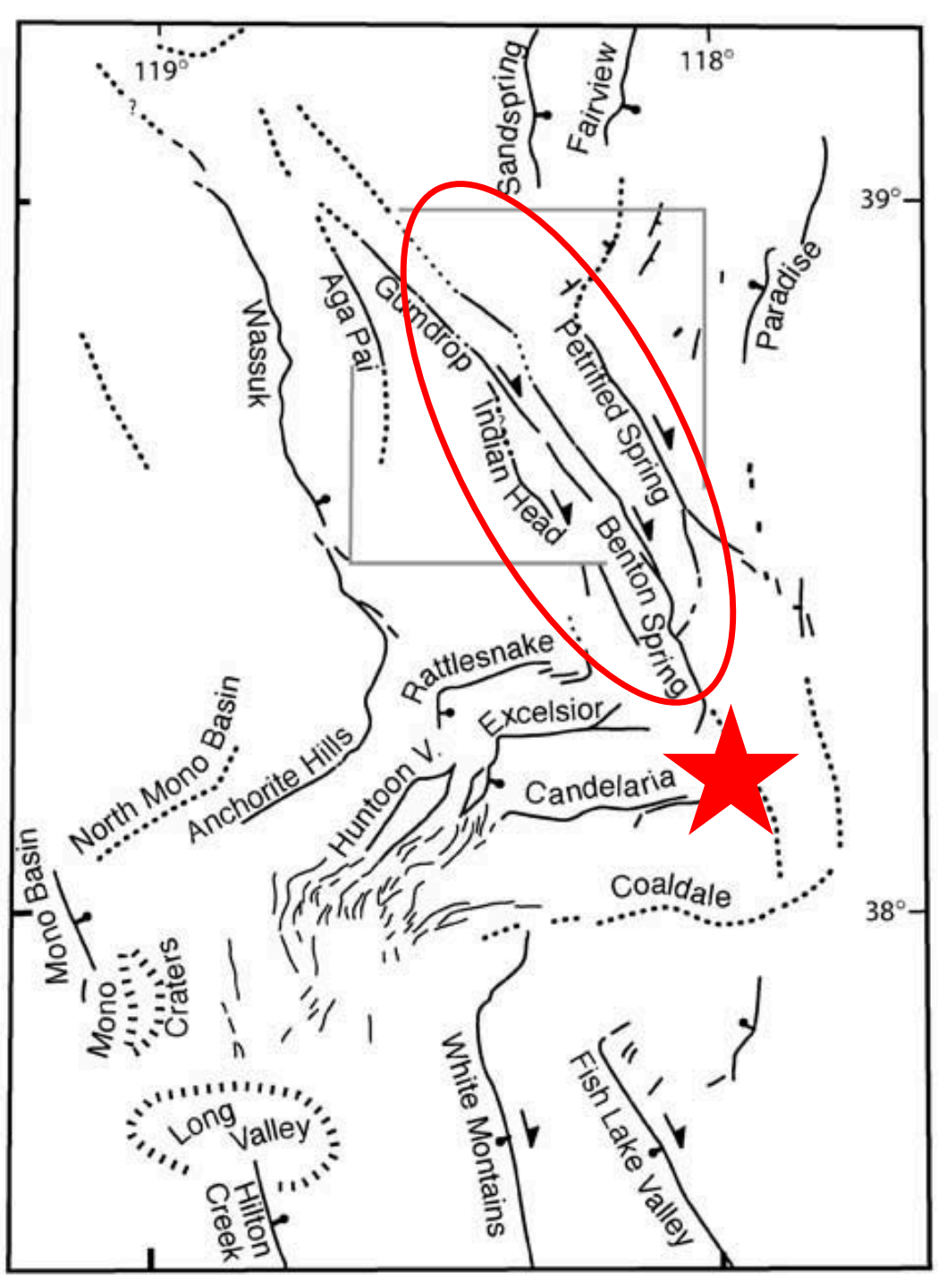
Excelsior fault: 0.01 mm/yr uplift rate.

Candelaria fault: 0.3 mm/yr

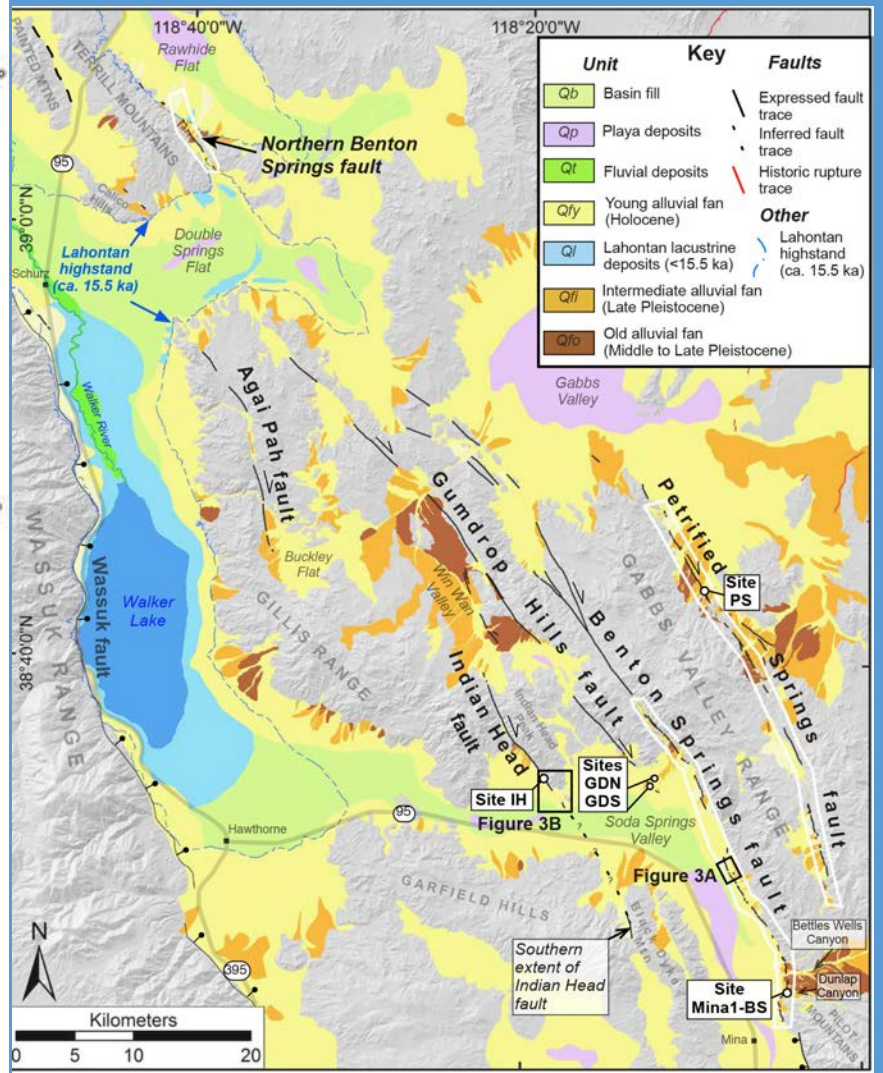


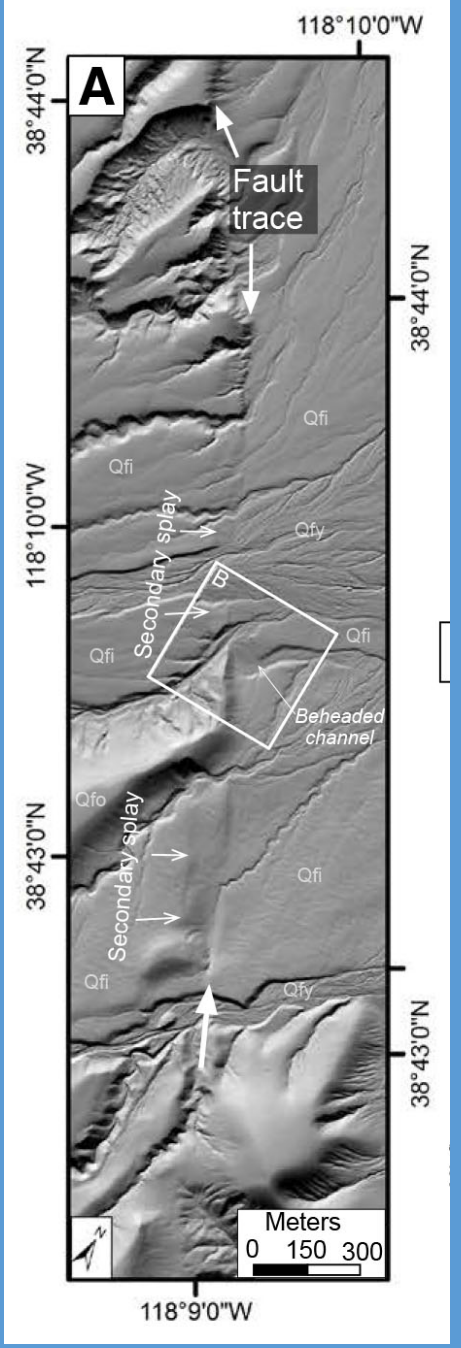






Benton Springs fault: 1.5 mm/yr
Petrified Springs fault: 0.7 mm/yr
Gumdrop Hills fault: 0.9 mm/yr
Indian Head fault: 0.8 mm/yr



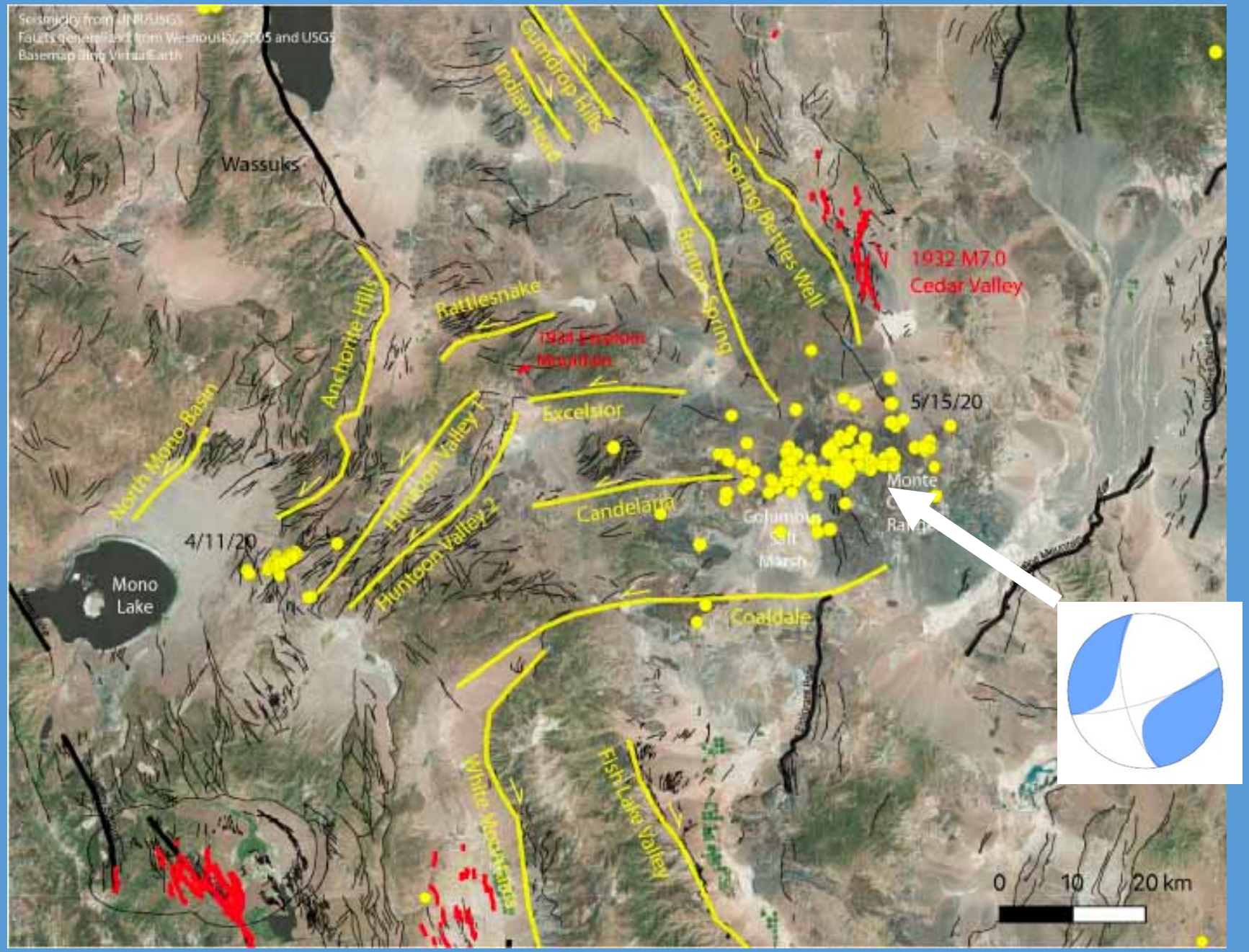


Angster, 2019

May 15, 2020
M6.5 Monte Cristo Mts. Earthquake

4 AM.

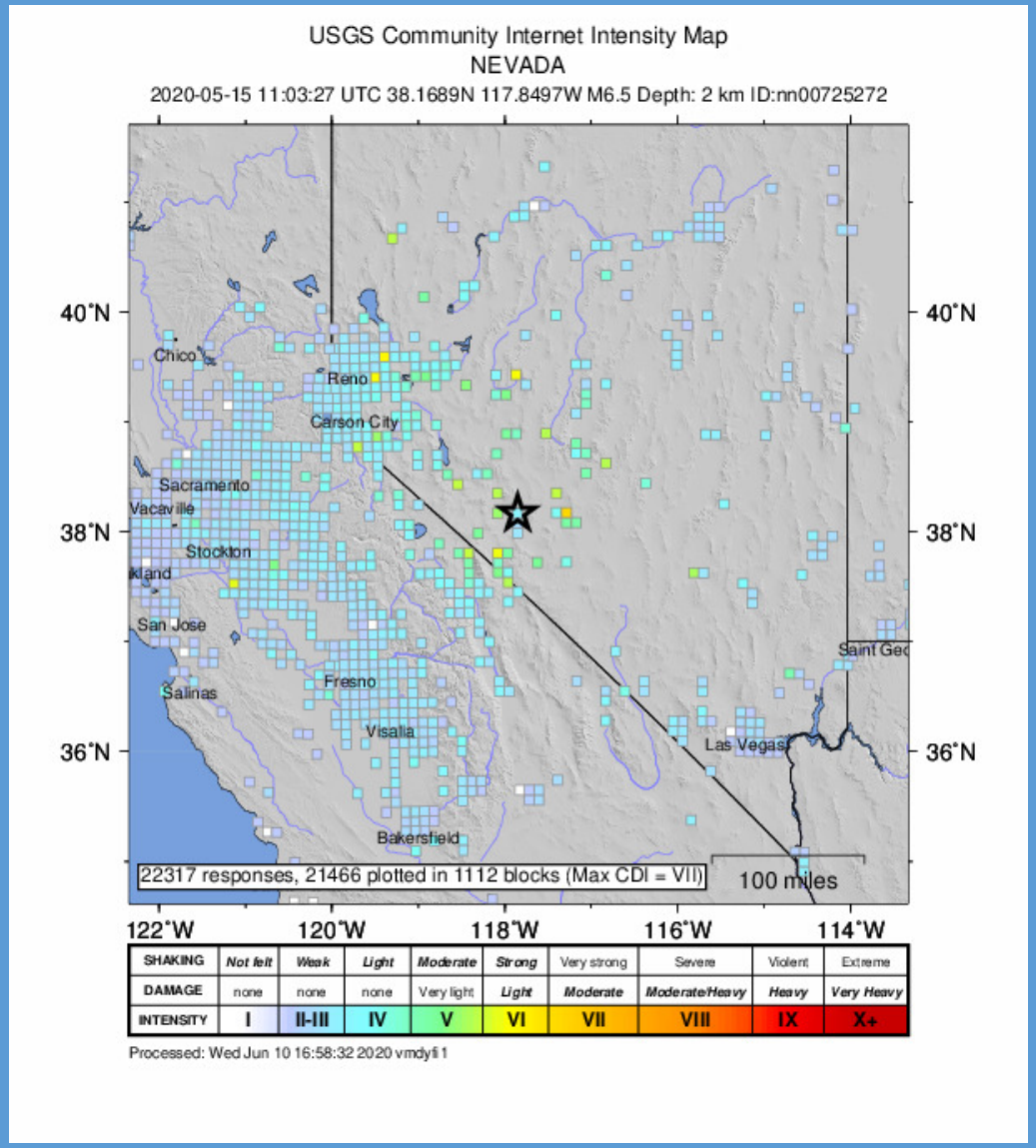
Rapid deployment.

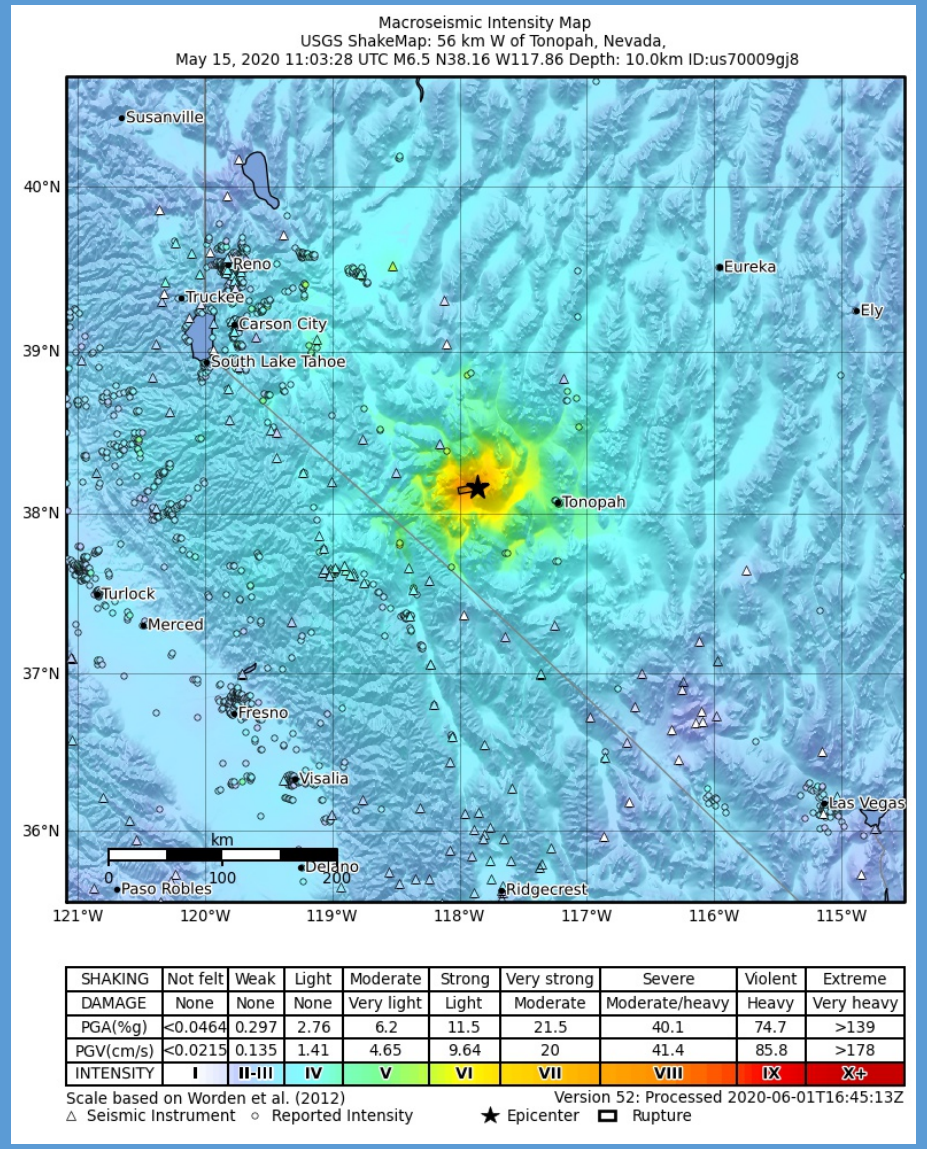


Early reports of highway damage (Hwy 95)

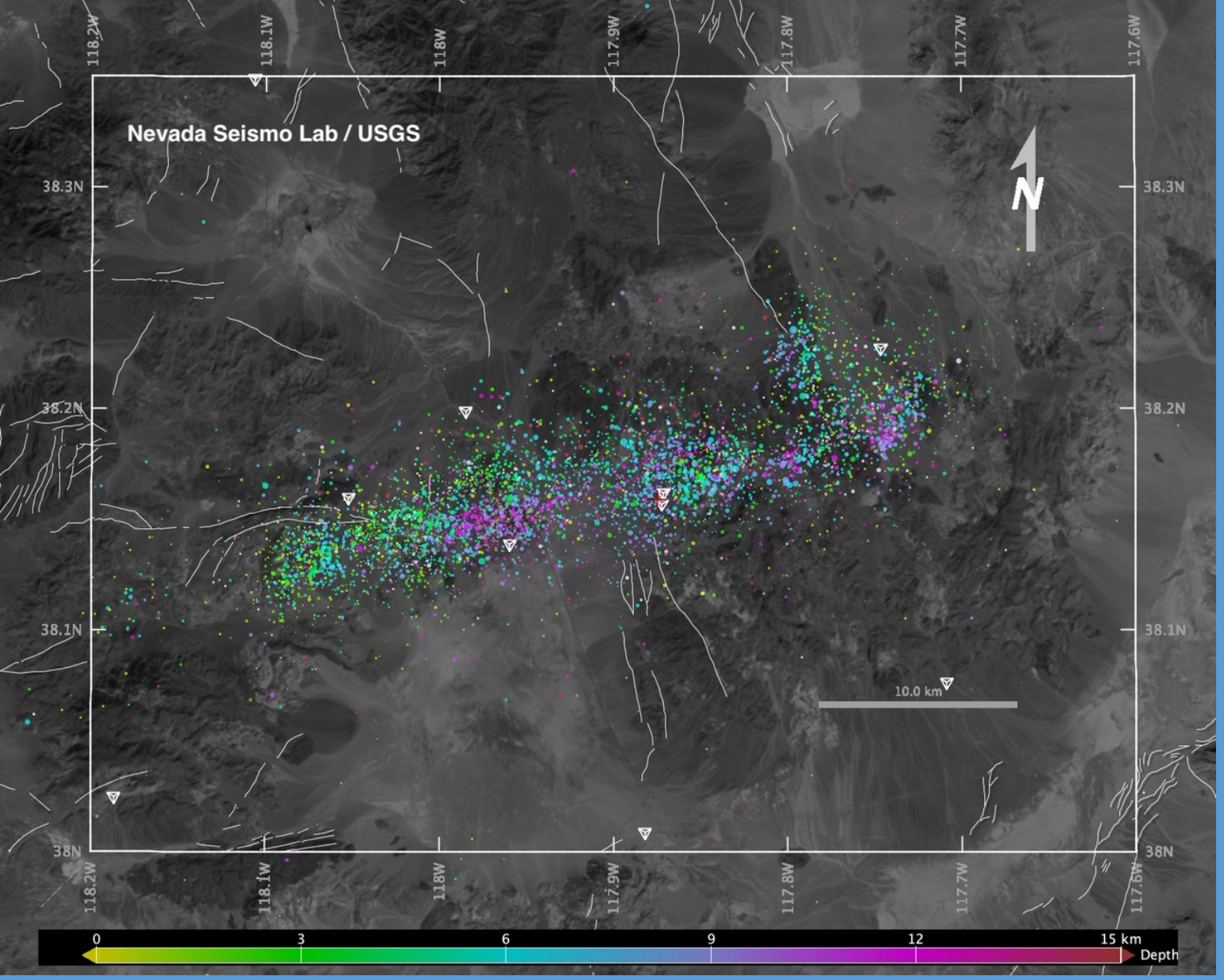
Social distancing camping
One person per vehicle

Did you feel it and intensity maps

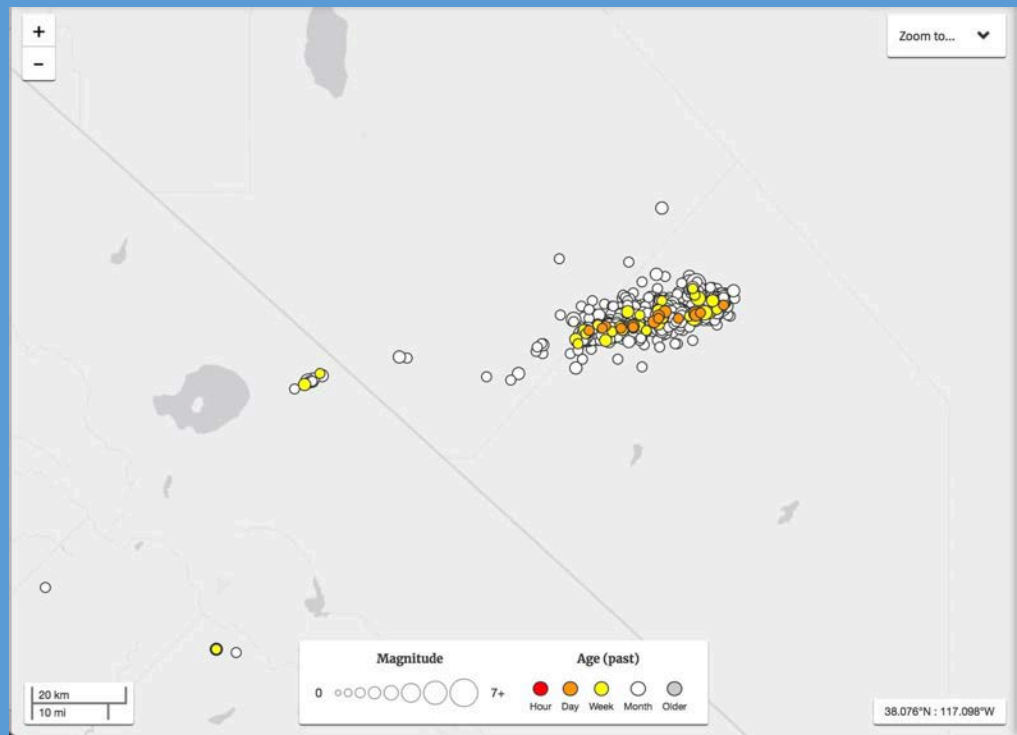




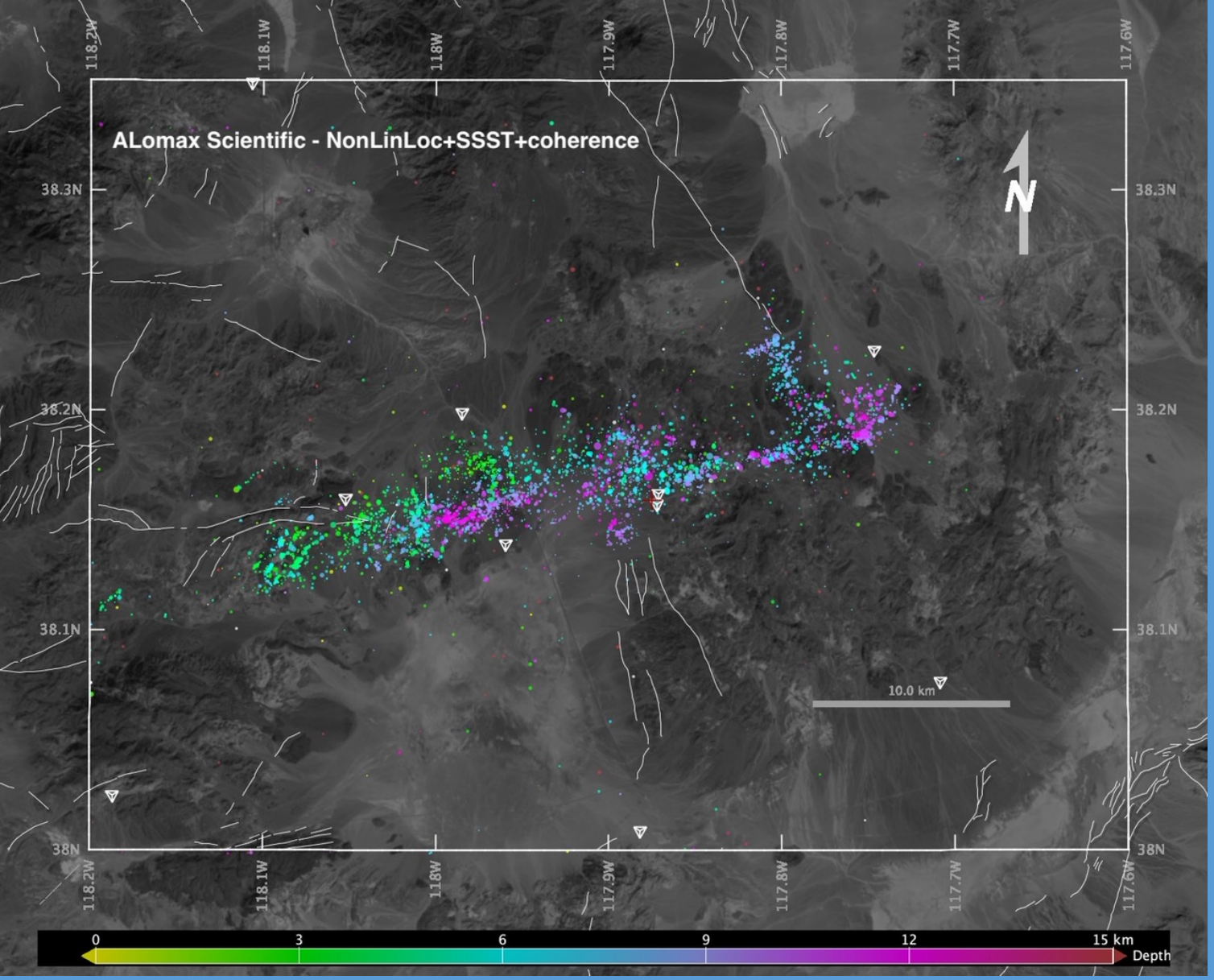
Seismicity



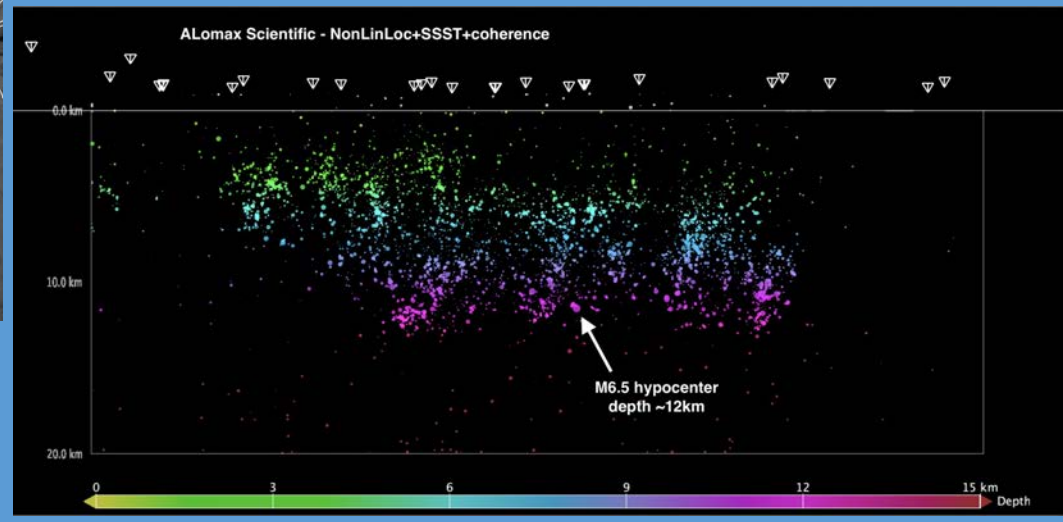
Last week



Seismicity

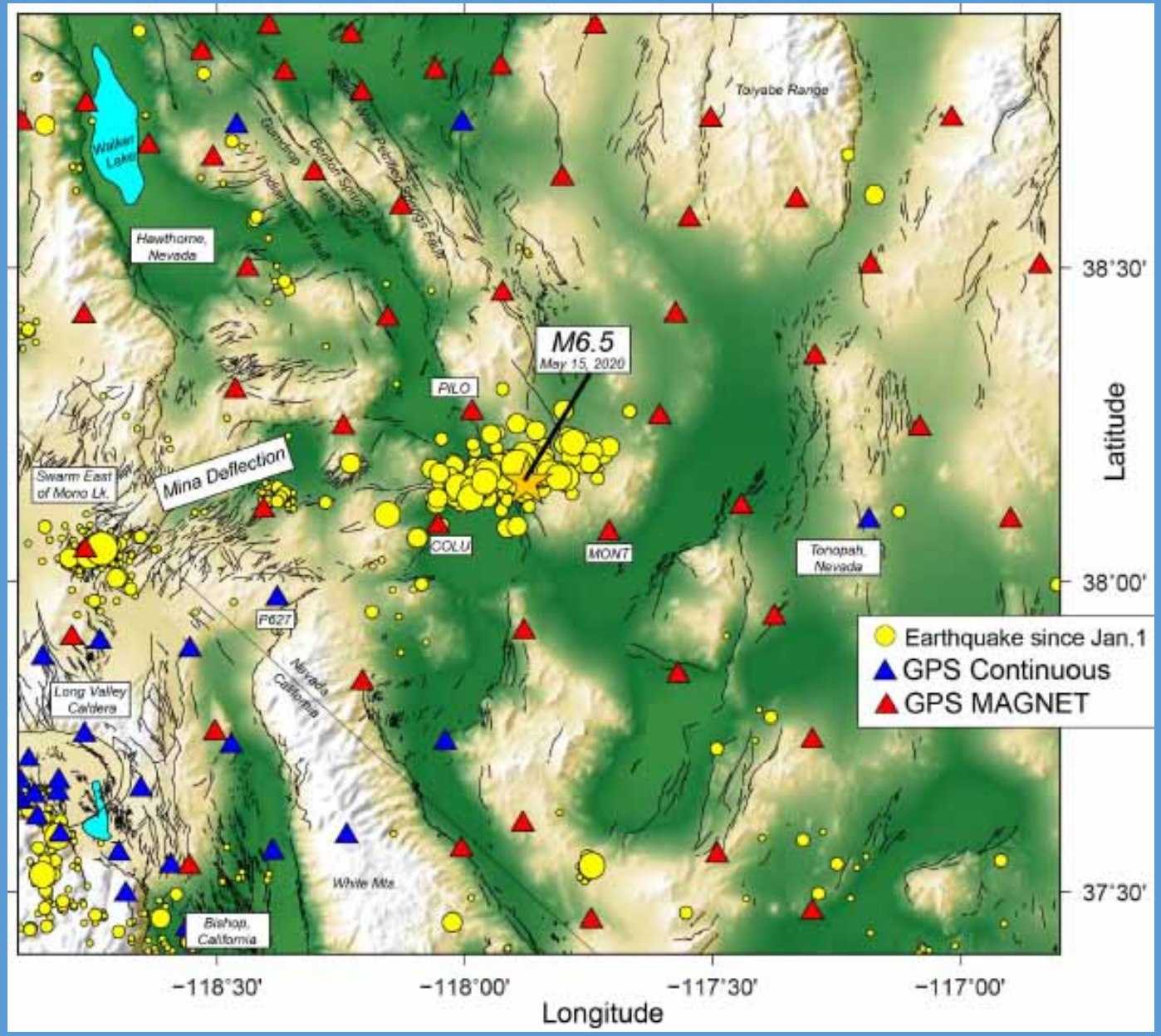


Relocations by Alomax Scientific, 2020



Geodesy

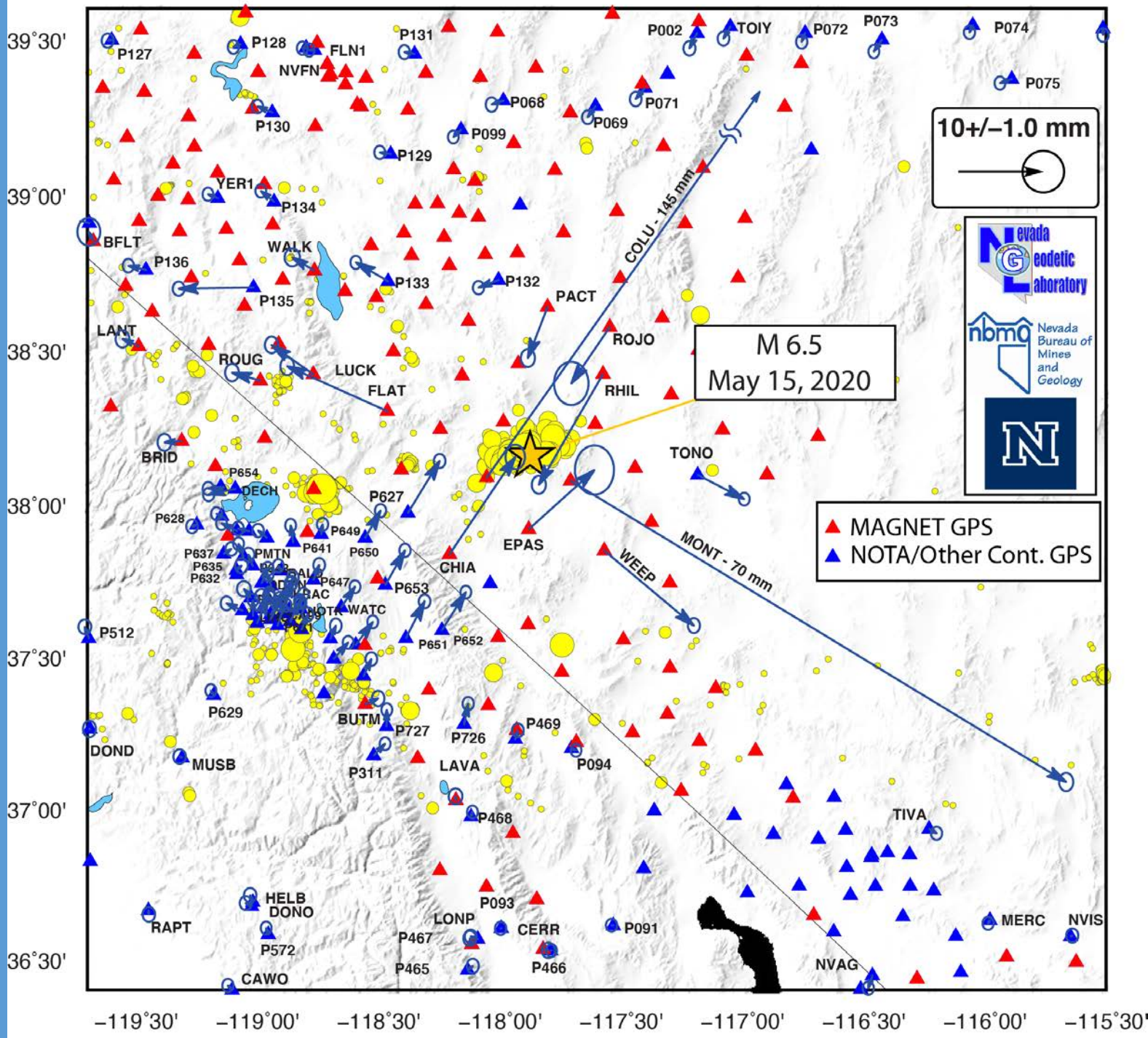
Nevada Geodetic Laboratory
MAGNET network



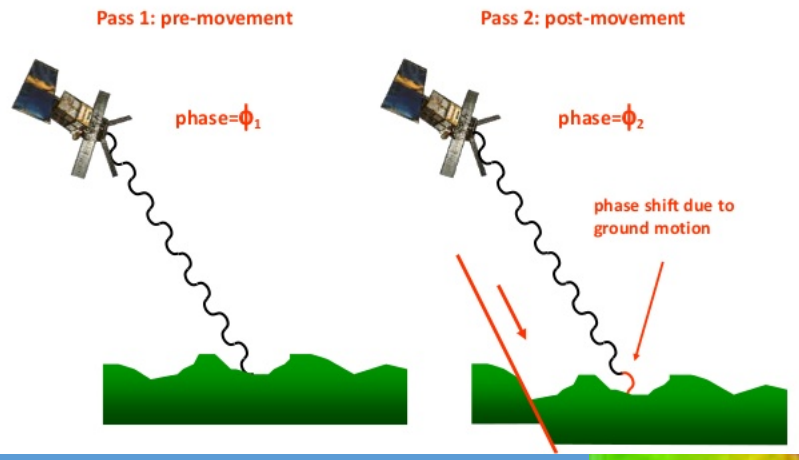
Geodesy

station COLU moved 145 mm northeast
Station MONT moved 70 mm southeast

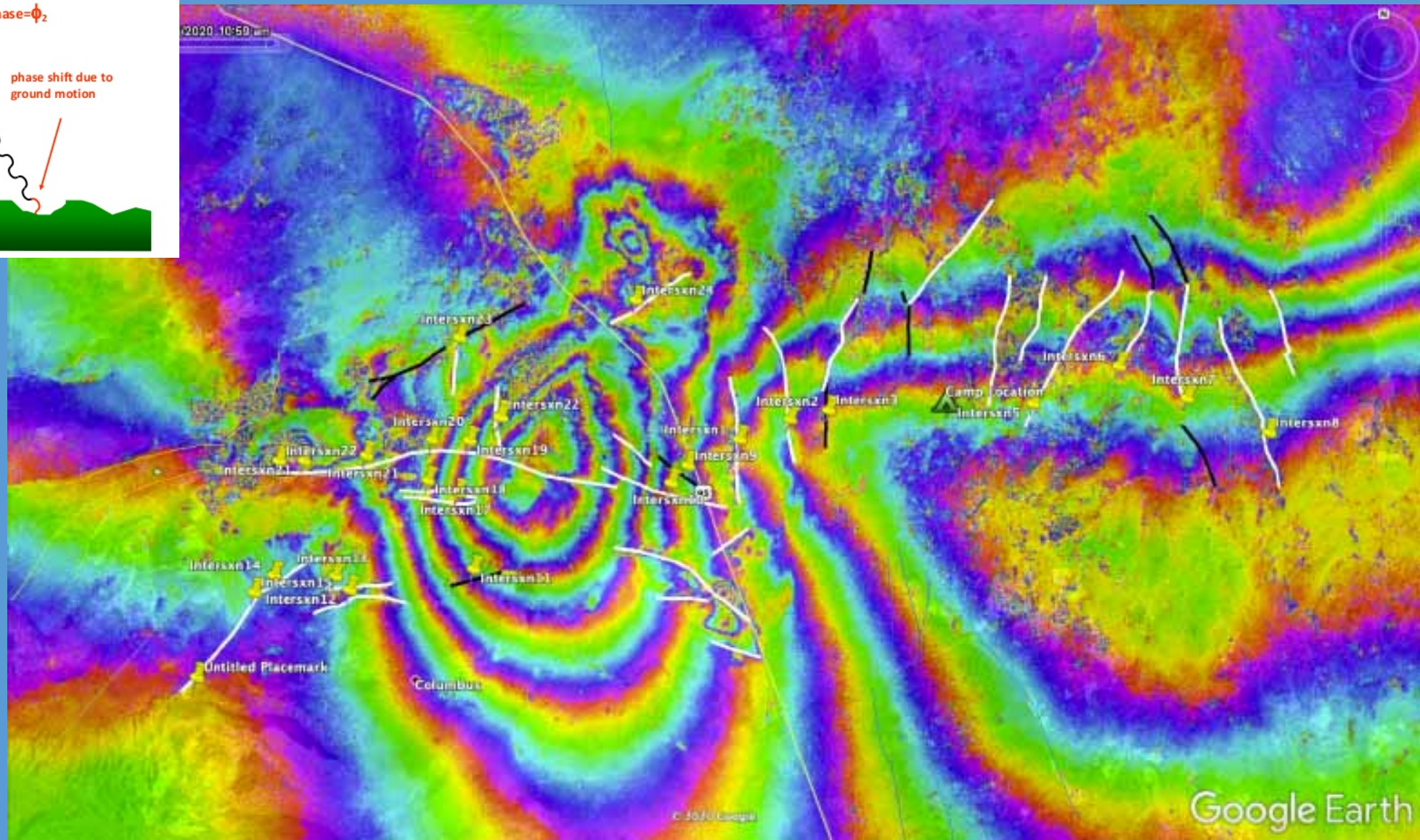
systematic horizontal NW-SE extension,
NE-SW contraction,
characteristic of a strike slip earthquake



InSAR: How it works



InSAR



Field observation
Points
May 15-20

Ground settlement along Hwy 95

Saturated lacustrine sediments
Strong ground motions, basin effects

Drone photos: Conni de Masi

Ground settlement along Hwy 95

photos: Conni de Masi, NBMG

Surface rupture east of Hwy 95

Generally north trending fractures, extensional, left stepping pattern suggestive of right slip.

1-6 cm along individual fractures.

Surface rupture west of Hwy 95

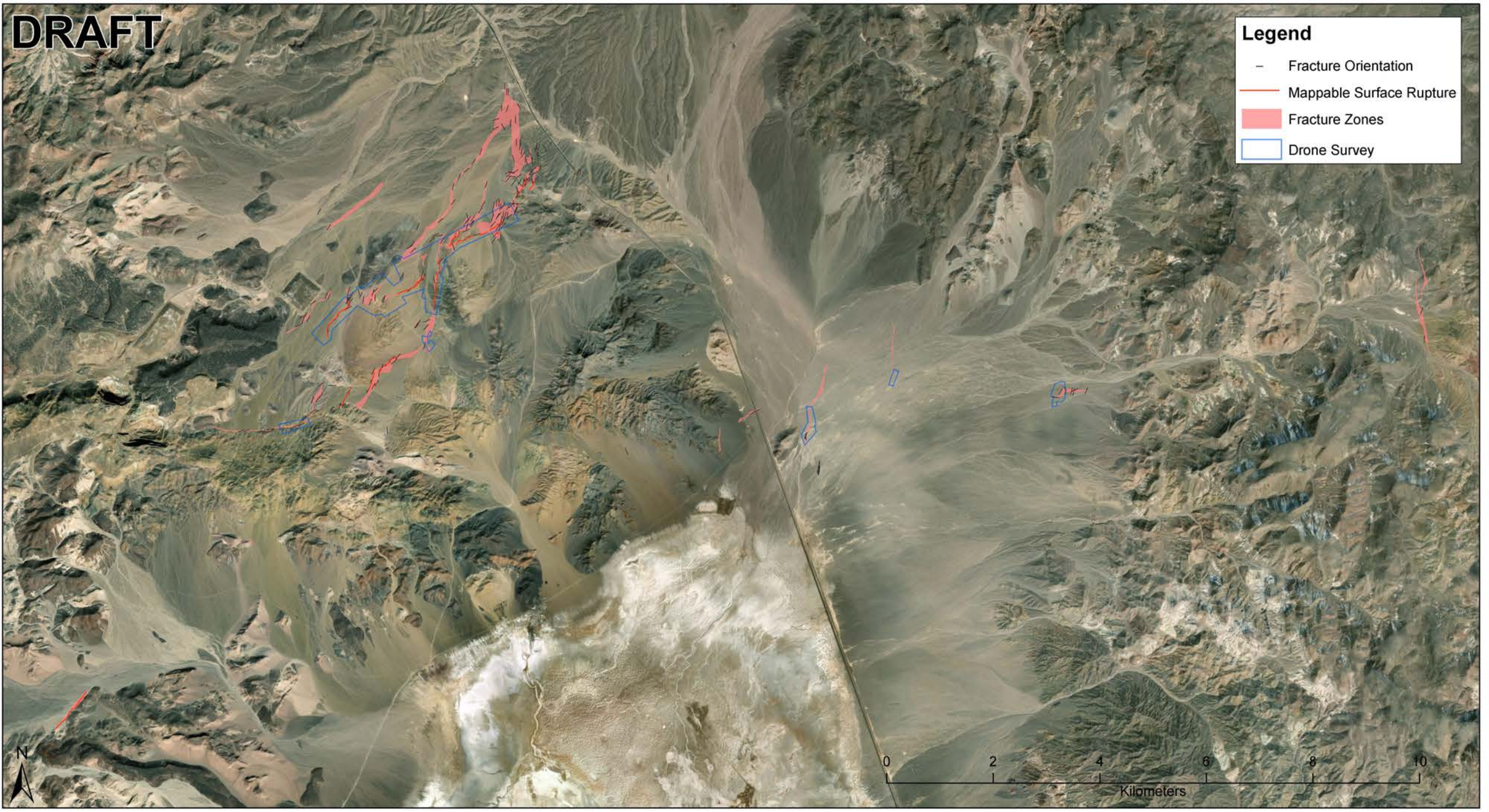
Northeast to east-west trending ruptures, extensional and left-lateral, right stepping pattern.
Max lateral 10-15 cm, vertical 2-8 cm.

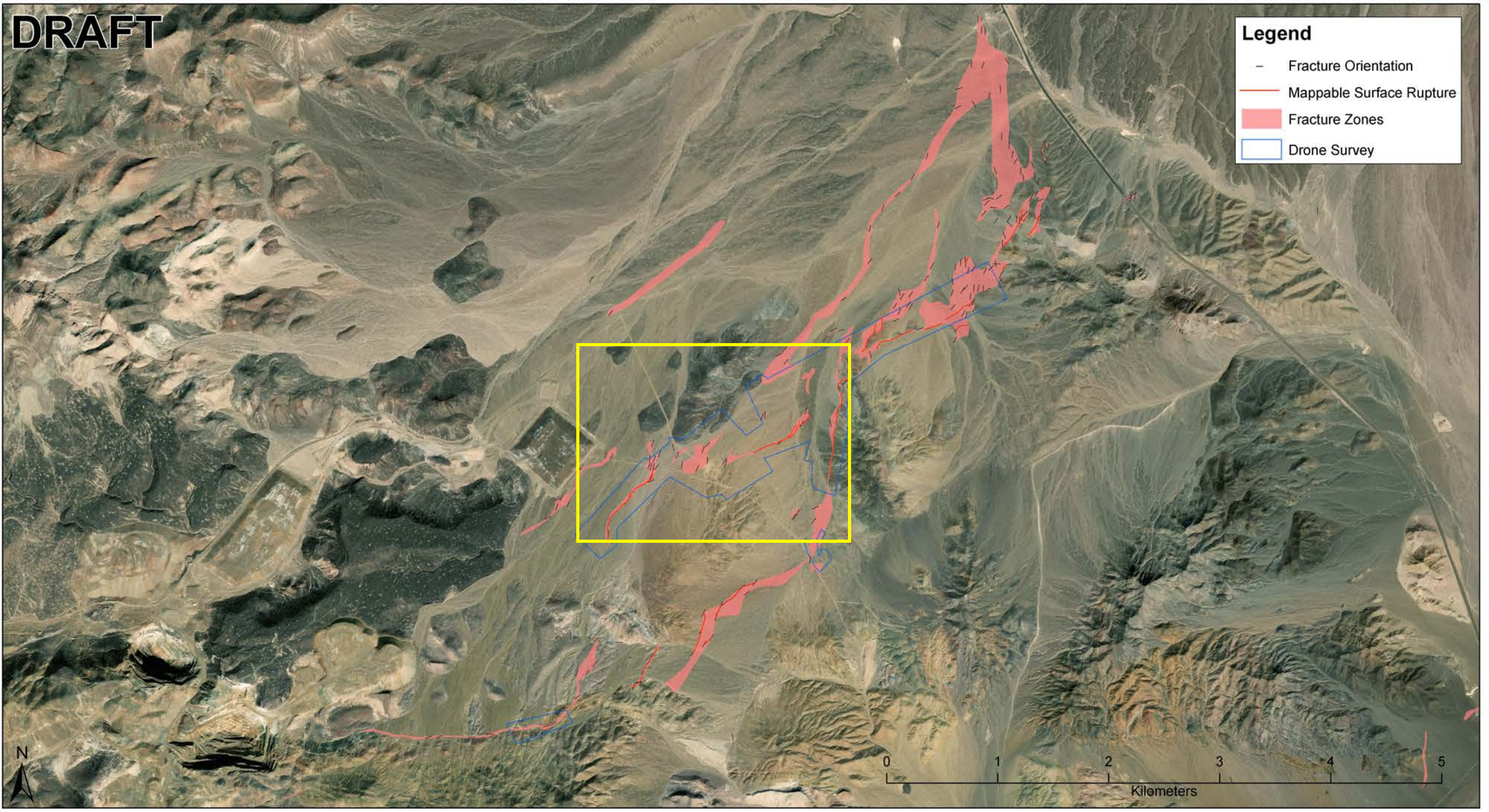
Photos: Seth Dee, NBMG

Surface rupture west of Hwy 95

Photos: Seth Dee, NBMG

Surface rupture west of Hwy 95

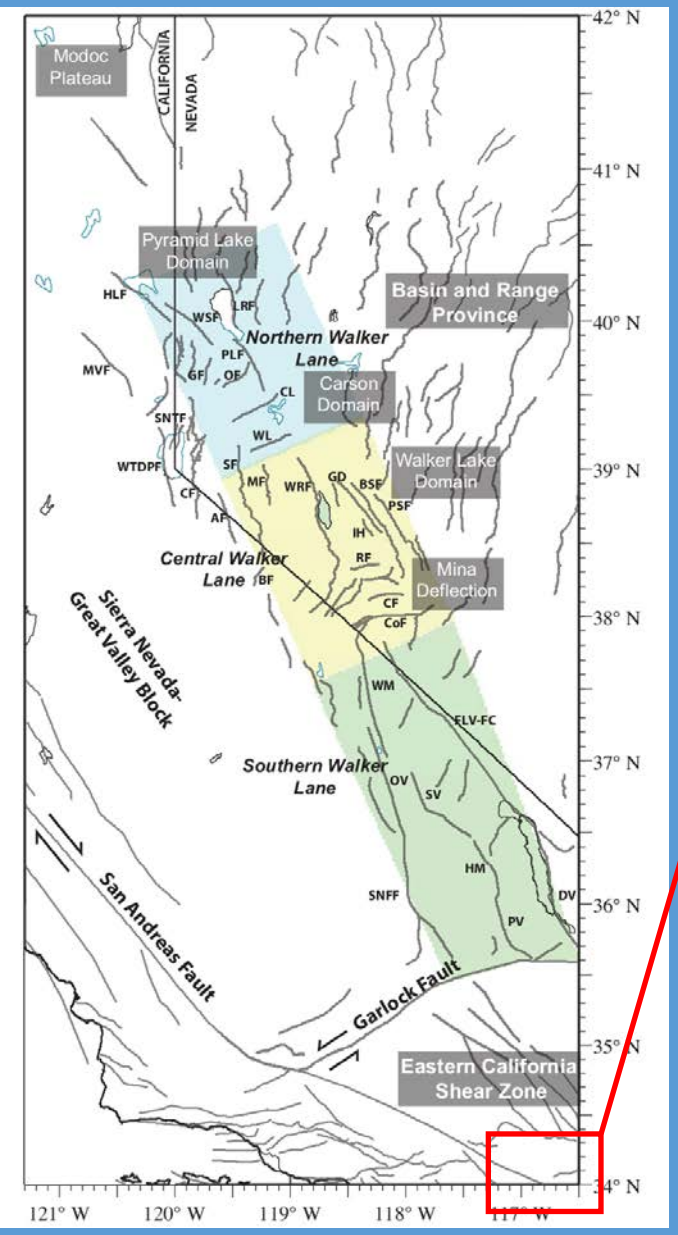

DRAFT
Legend
Fracture Orientation
Mappable Surface Rupture
Fracture Zones
Drone Survey
N
0
2
4
6
8
10
Kilometers

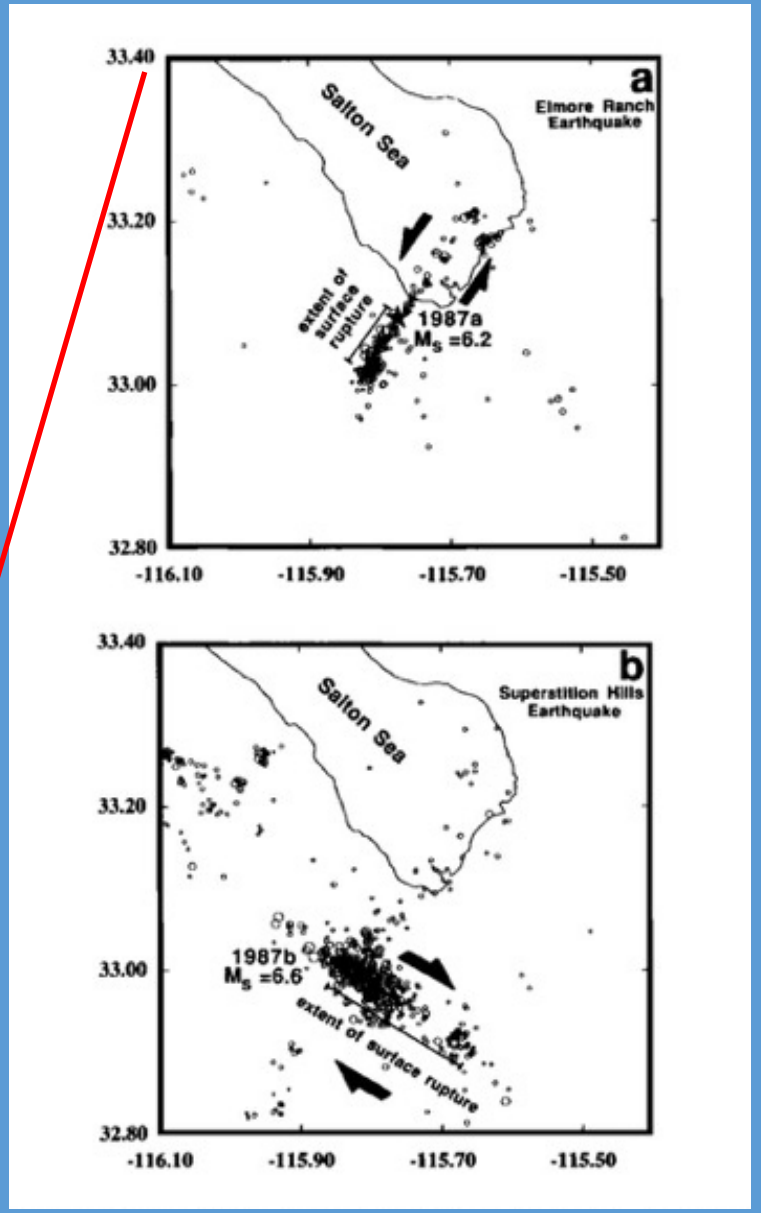

DRAFT
Legend
Fracture Orientation
Mappable Surface Rupture
Fracture Zones
Drone Survey
N
0
1
2
3
4
5
Kilometers

Ongoing rupture mapping

Continuous ruptures
Fracture orientations
Zones of fracturing
Drone imagery coverage

Conjugate (cross) faulting: a common mode of deformation in the Eastern California Shear Zone and Walker Lane



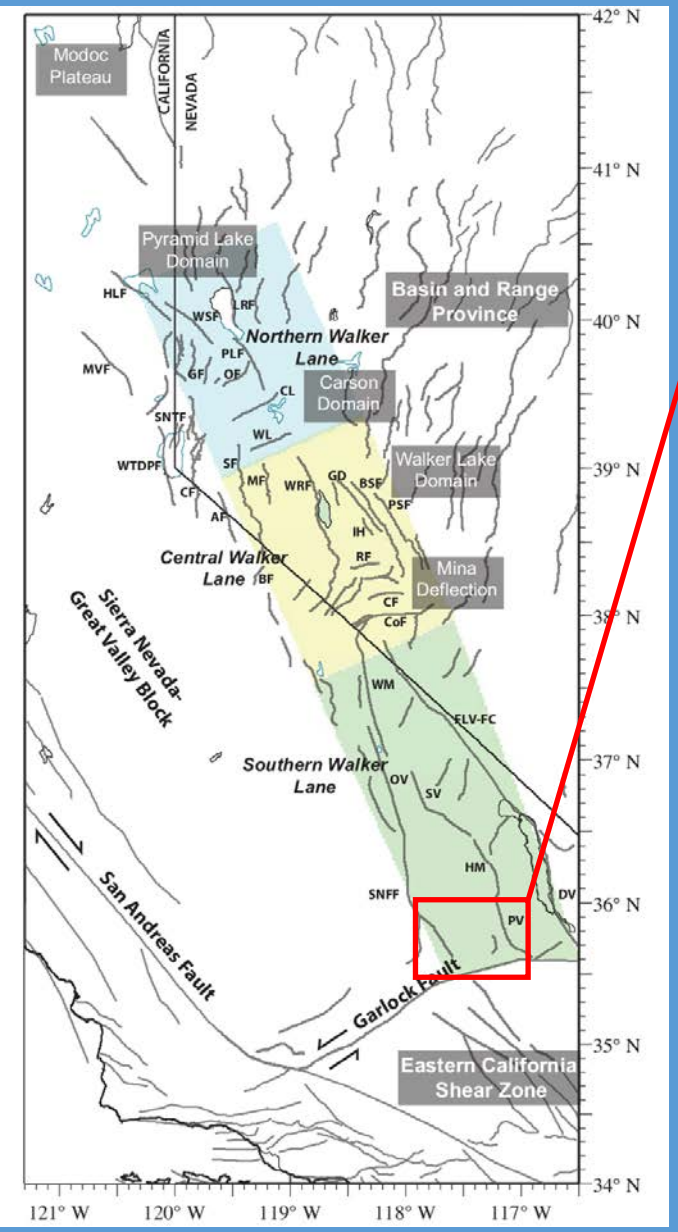


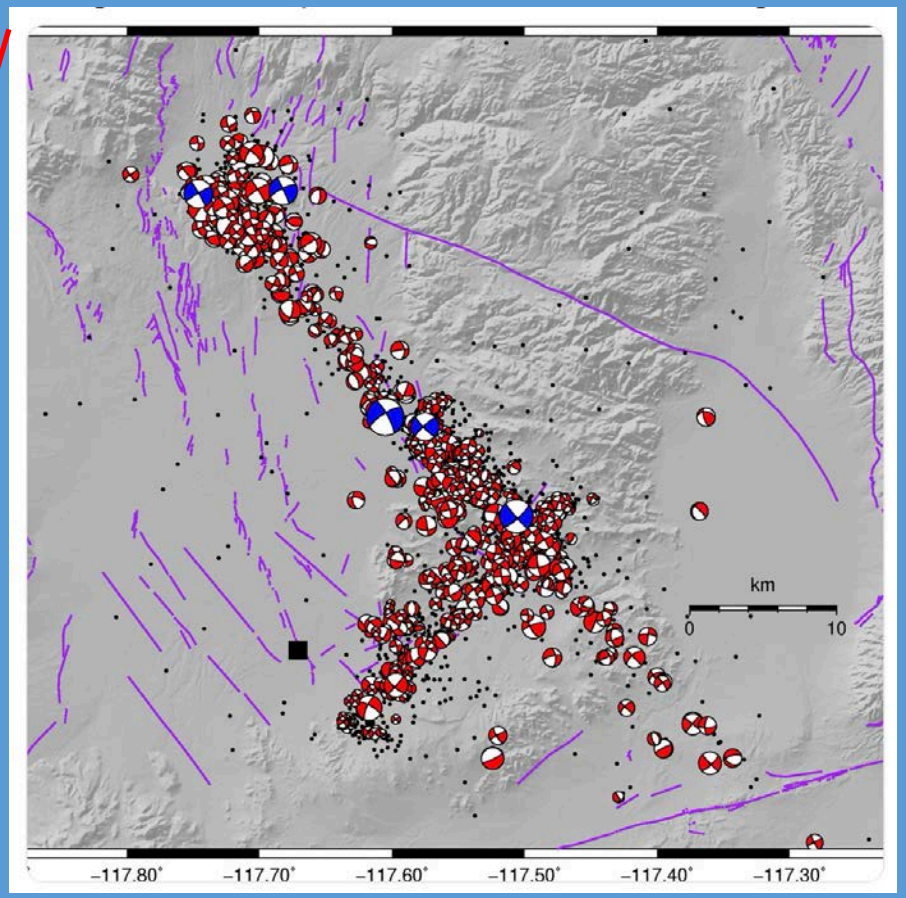
1987 Elmore Ranch and Superstition Hills earthquakes

11 hours apart.

Hudnut et al., GRL 1989

Conjugate (cross) faulting: a common mode of deformation in the Eastern California Shear Zone and Walker Lane



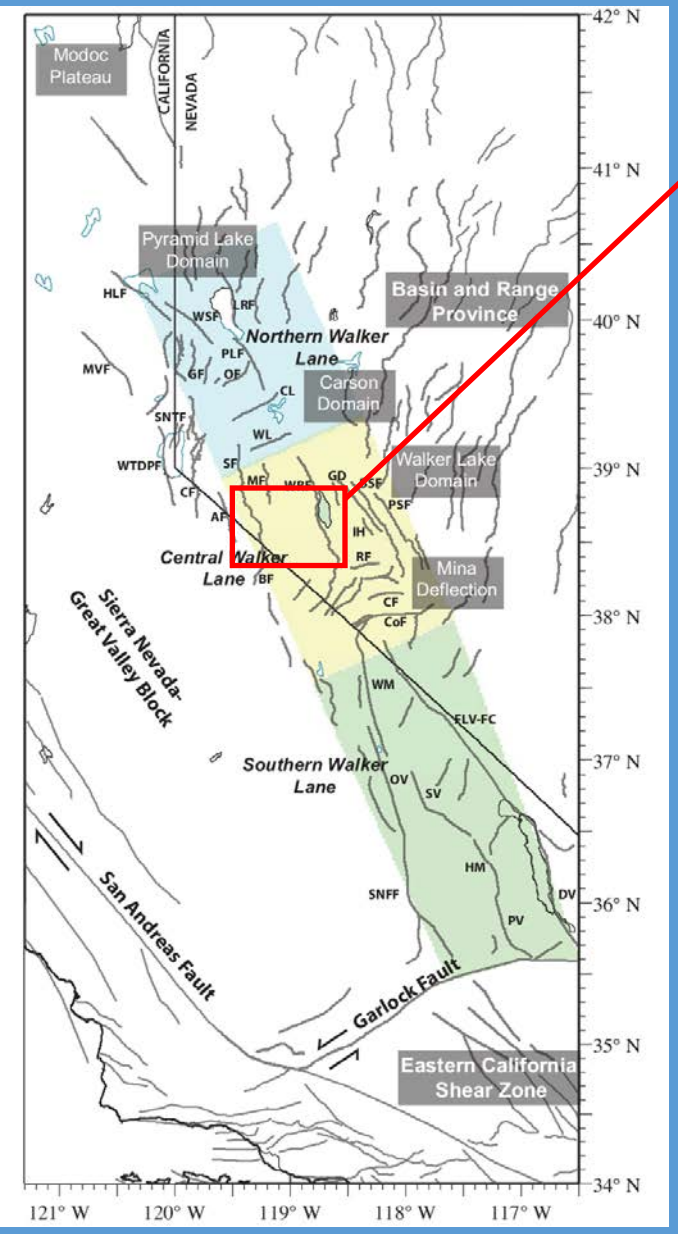


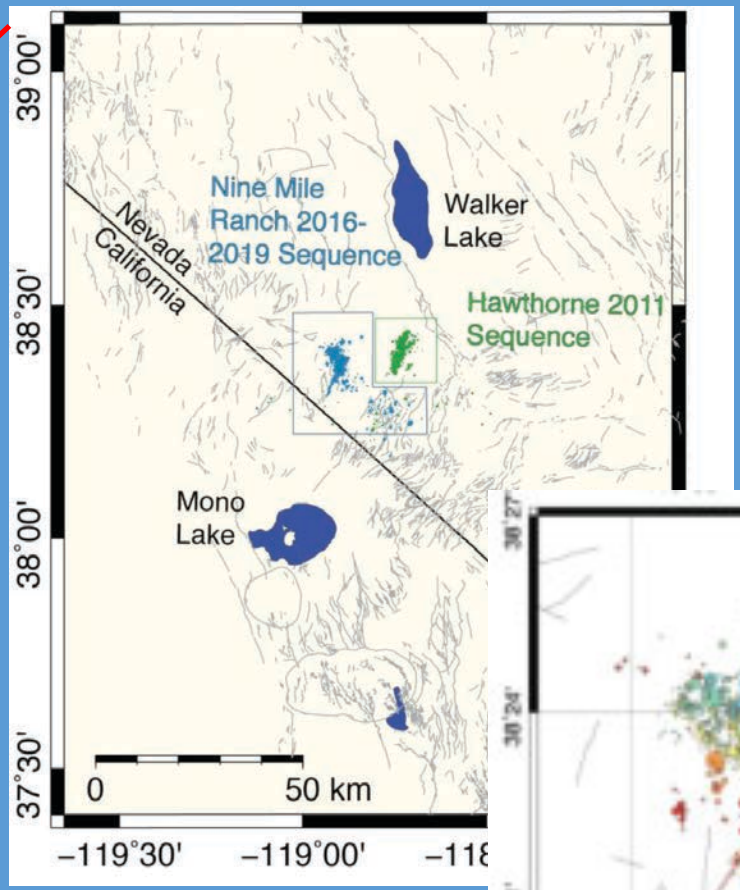
Jascha Polet, CalPoly

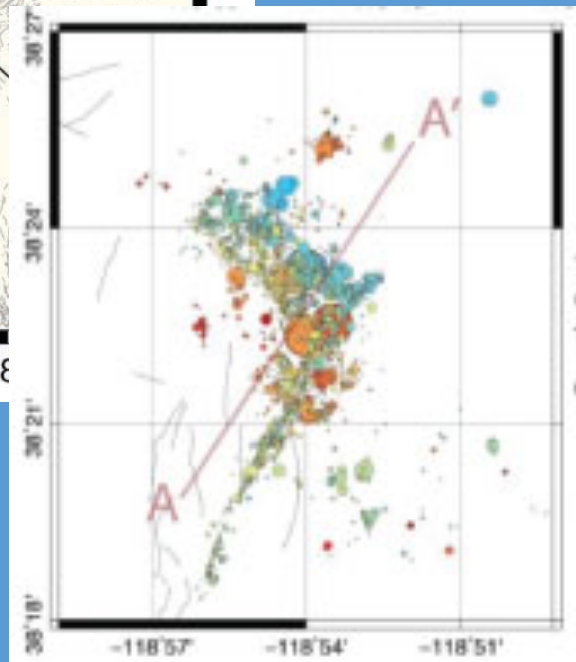
2019 M6.4 and M7.1 Ridgecrest earthquakes

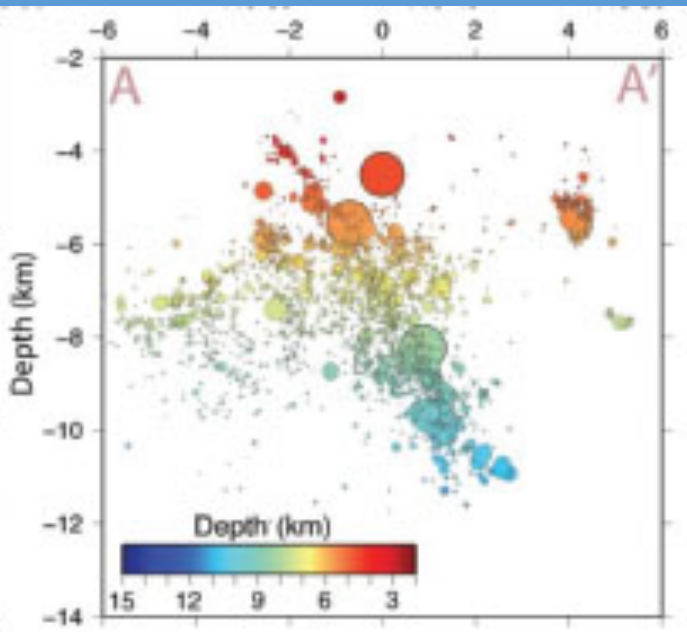
34 hours apart.

Conjugate (cross) faulting: a common mode of deformation in the Eastern California Shear Zone and Walker Lane







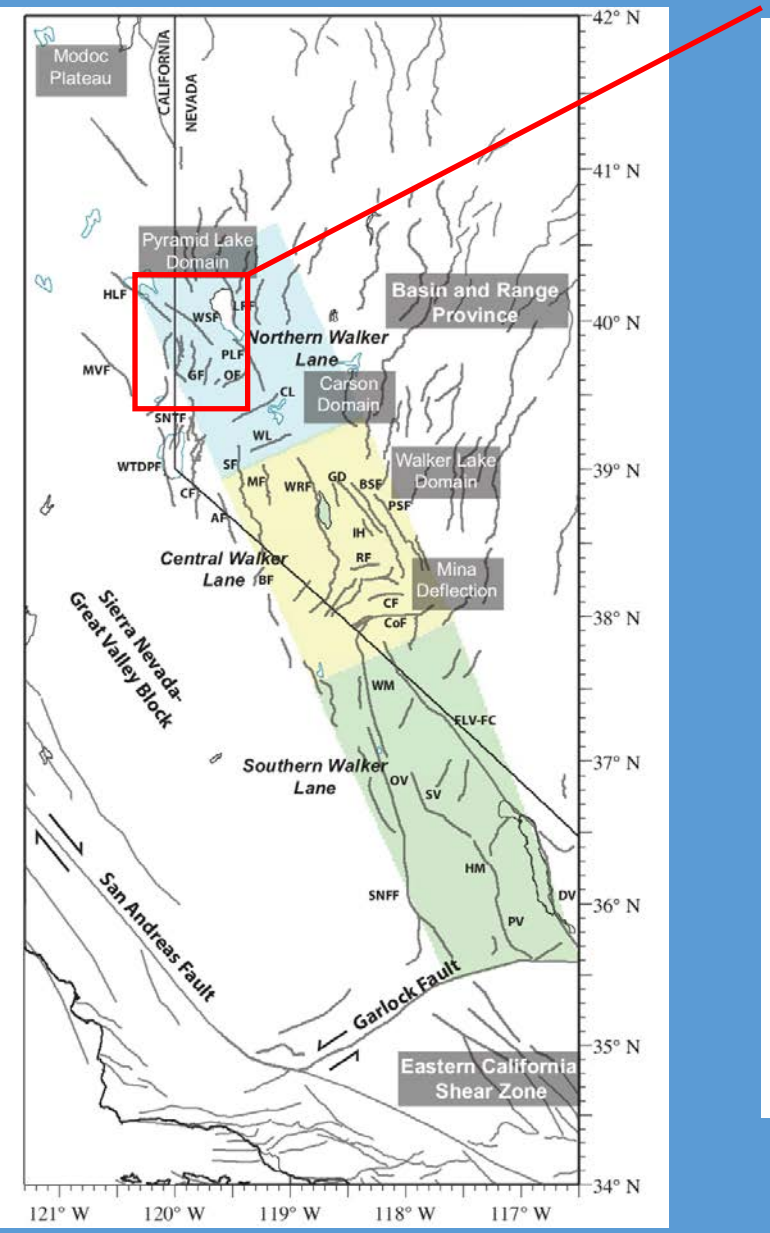


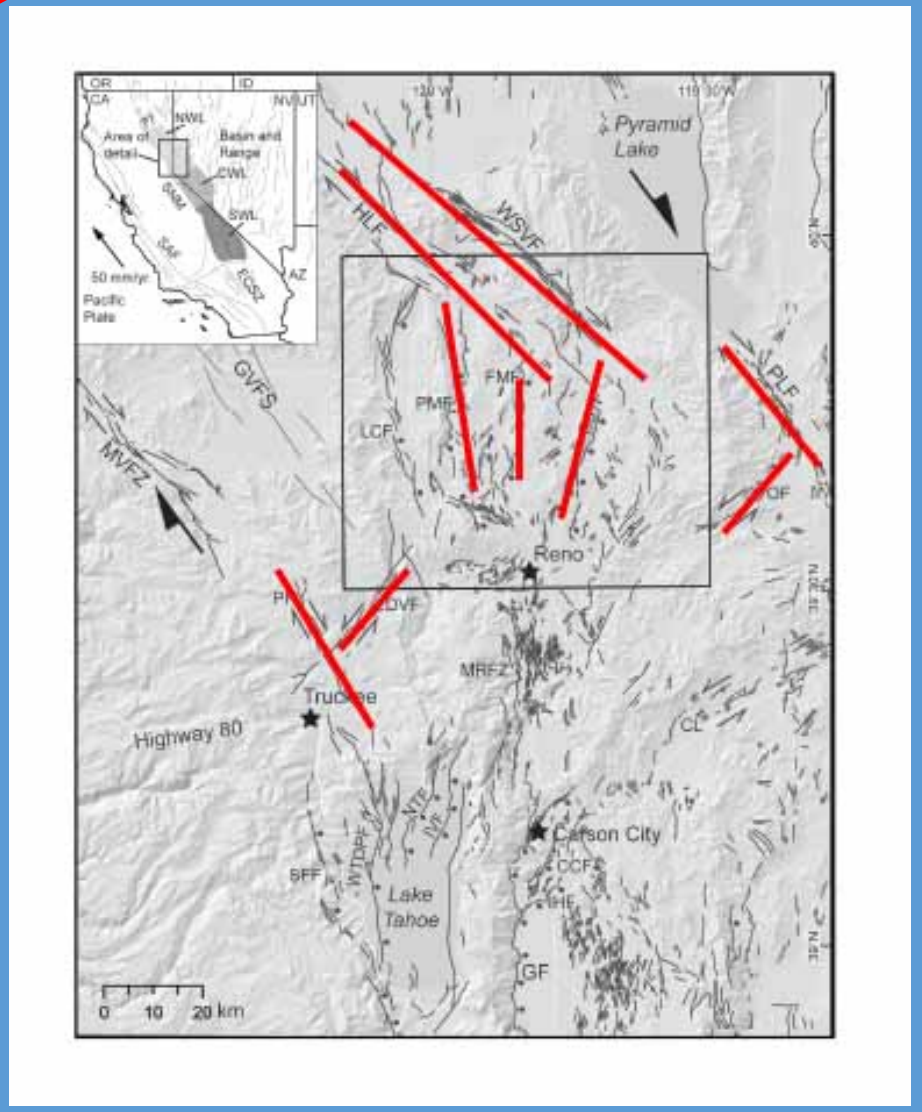
Nine Mile Ranch earthquake sequence Dec. 28, 2016

3 M5.4-5.6 events

Hatch, 2019

Conjugate (cross) faulting: a common mode of deformation in the Eastern California Shear Zone and Walker Lane





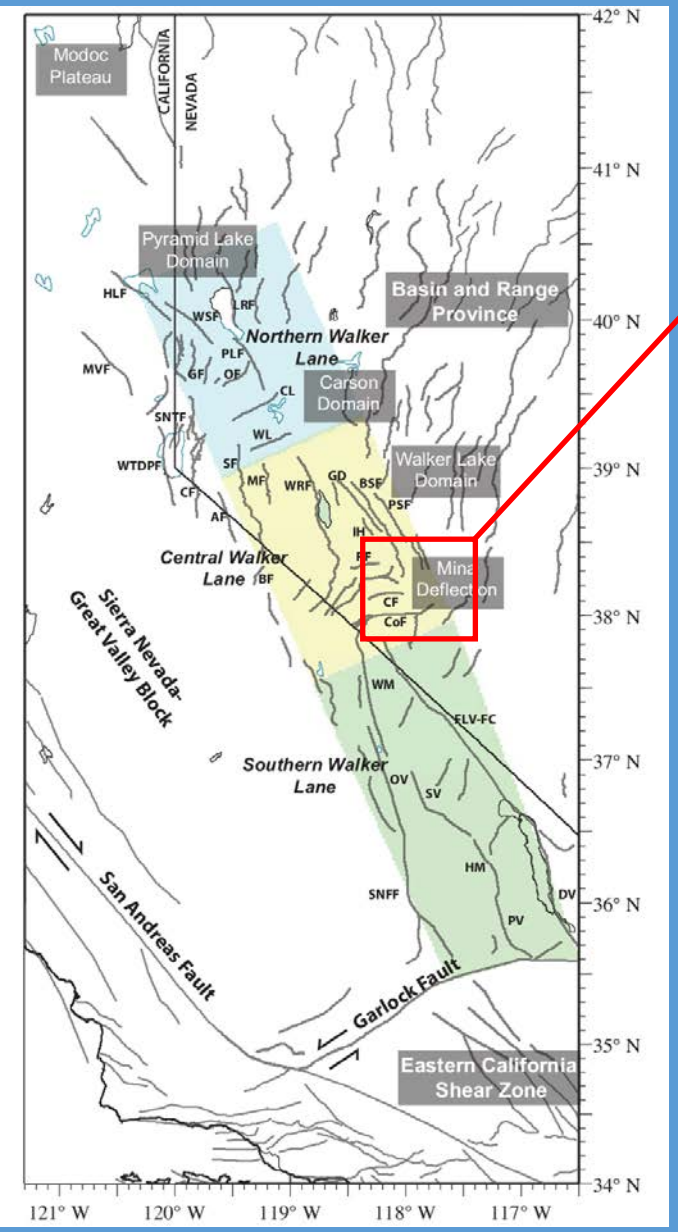
Koehler, 2019

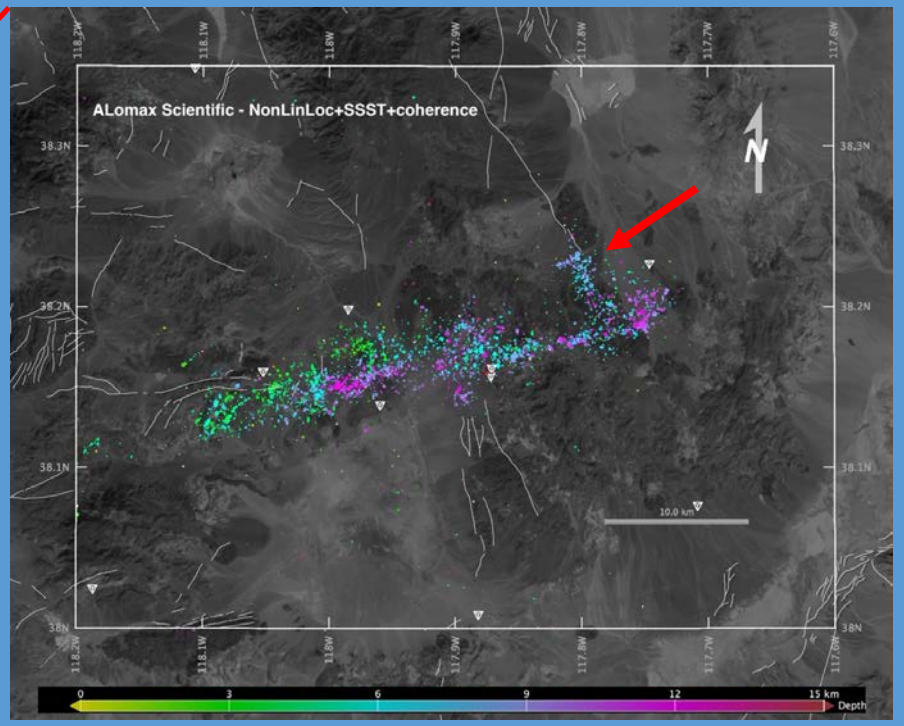
Northern Walker Lane

Numerous faults optimally oriented for cross faulting

No large historical events

Conjugate (cross) faulting: a common mode of deformation in the Eastern California Shear Zone and Walker Lane



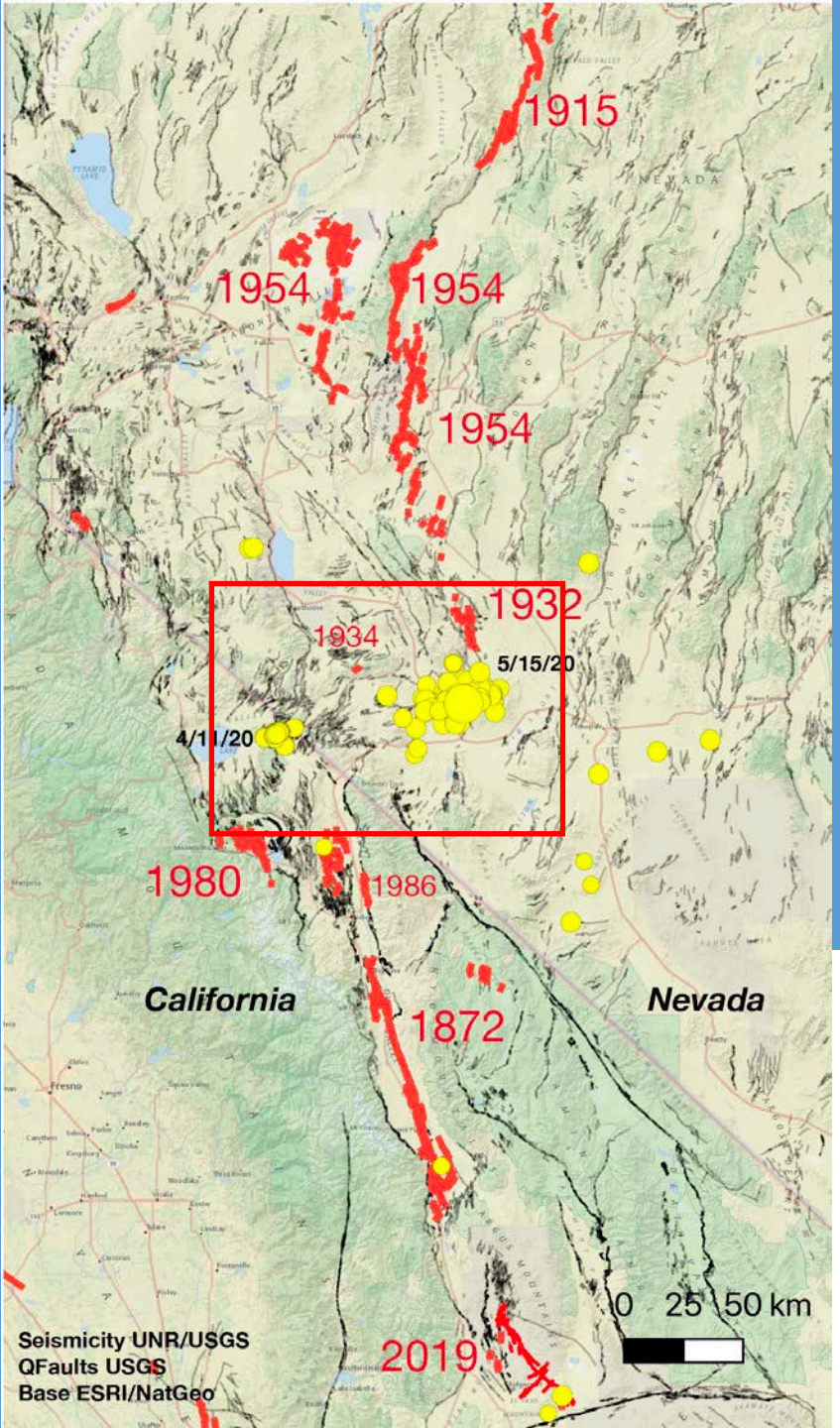


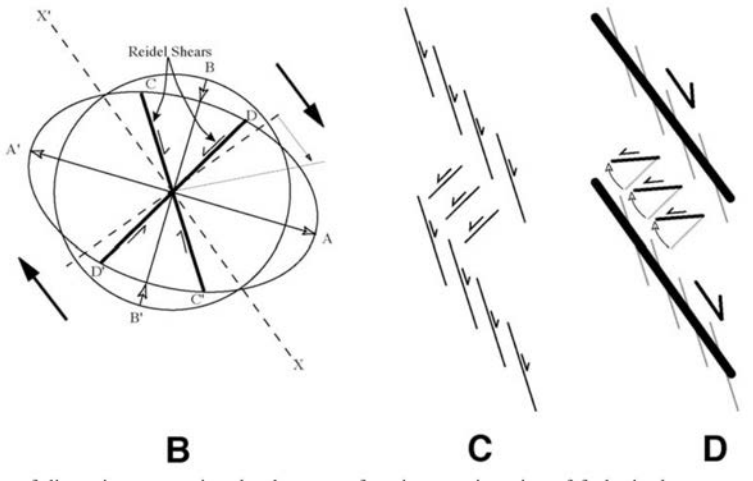
Elevated seismicity along the Pilot Mts. Fault Zone. Projects towards the Petrified Springs fault.

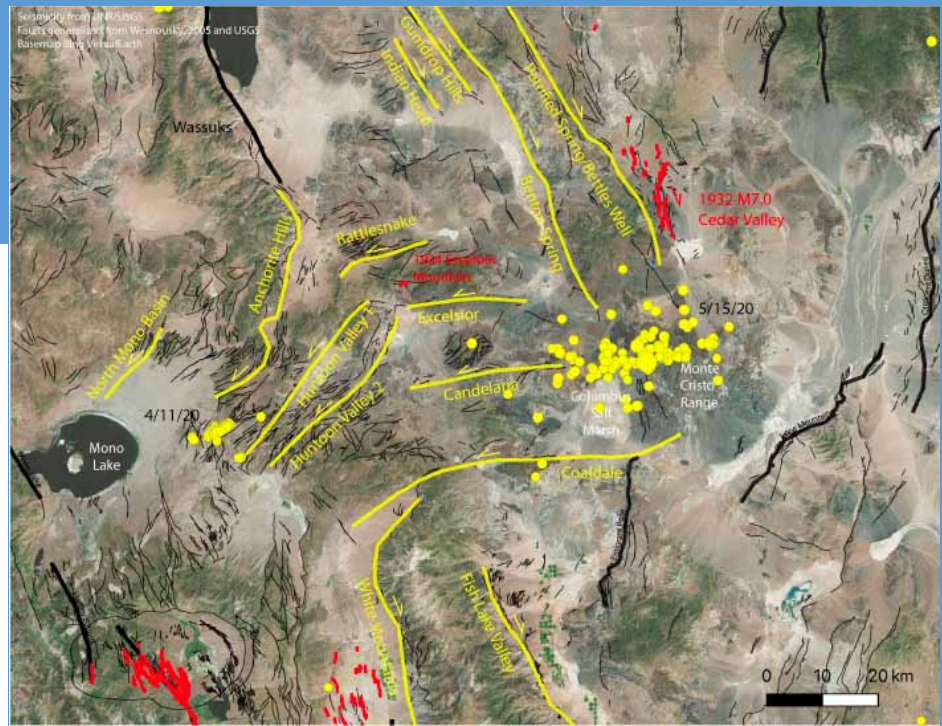
Monte Cristo Mts. earthquake

Ongoing active research

- Complex fault interactions (locally)
- Belts of seismicity (regional)
- Paleoseismology
- Deformation models.
- Future earthquake potential








Thanks!