Earthquake Considerations for TMWA Facilities

Dr. Craig M. dePolo

Nevada Bureau of Mines and Geology
University of Nevada, Reno

- **Earthquake Hazard of the Northern Reno-Carson City Urban Corridor.**
- **Some Effects Earthquakes have on Water Systems.**
- **Approaches to Enhance TMWA's Earthquake Resiliency, Emergency Response, and Earthquake Recovery.**
- **Personal Earthquake Safety**

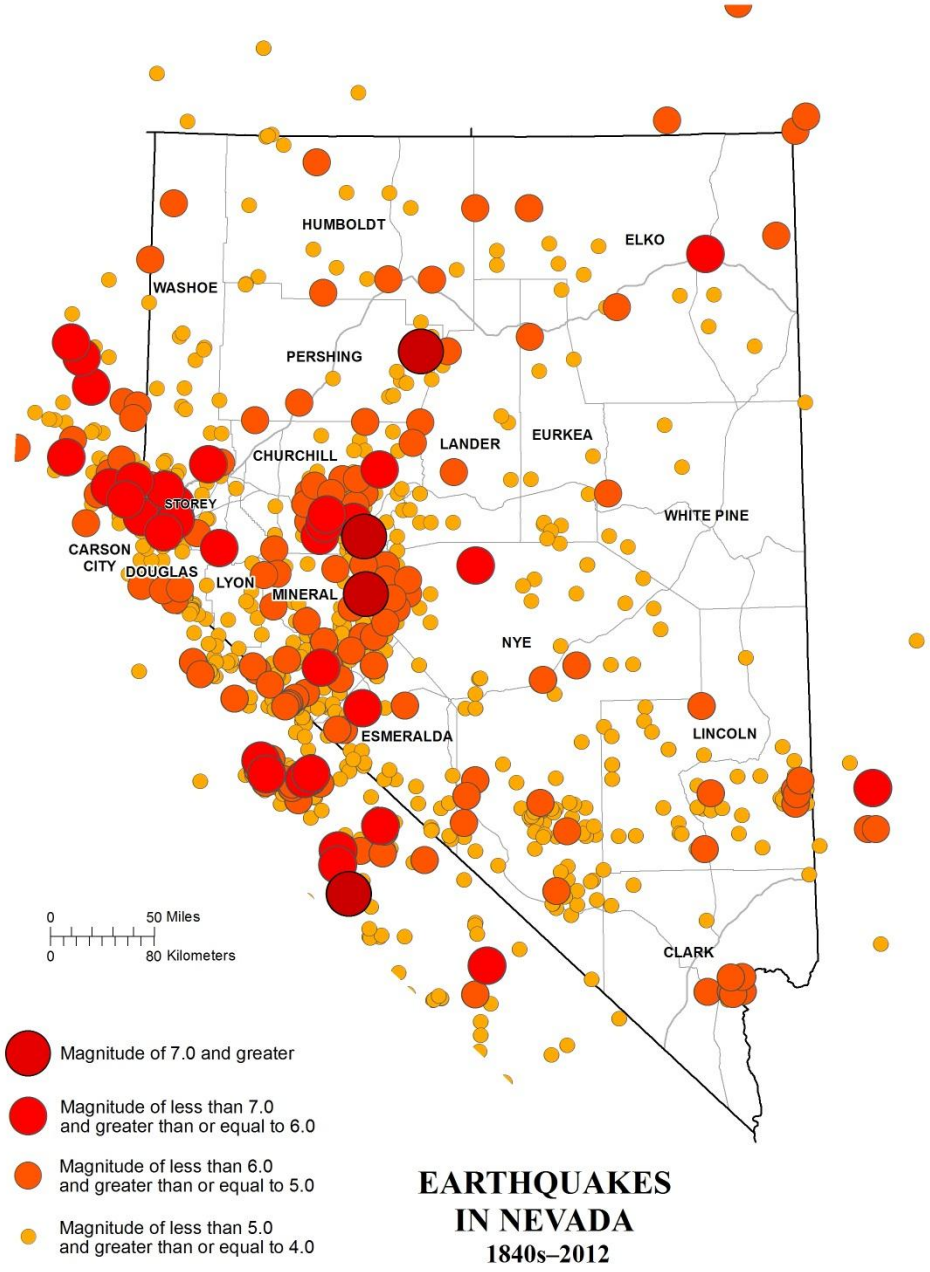
Earthquake Truths

- The consequences of damaging earthquakes to unprepared communities are unacceptable.

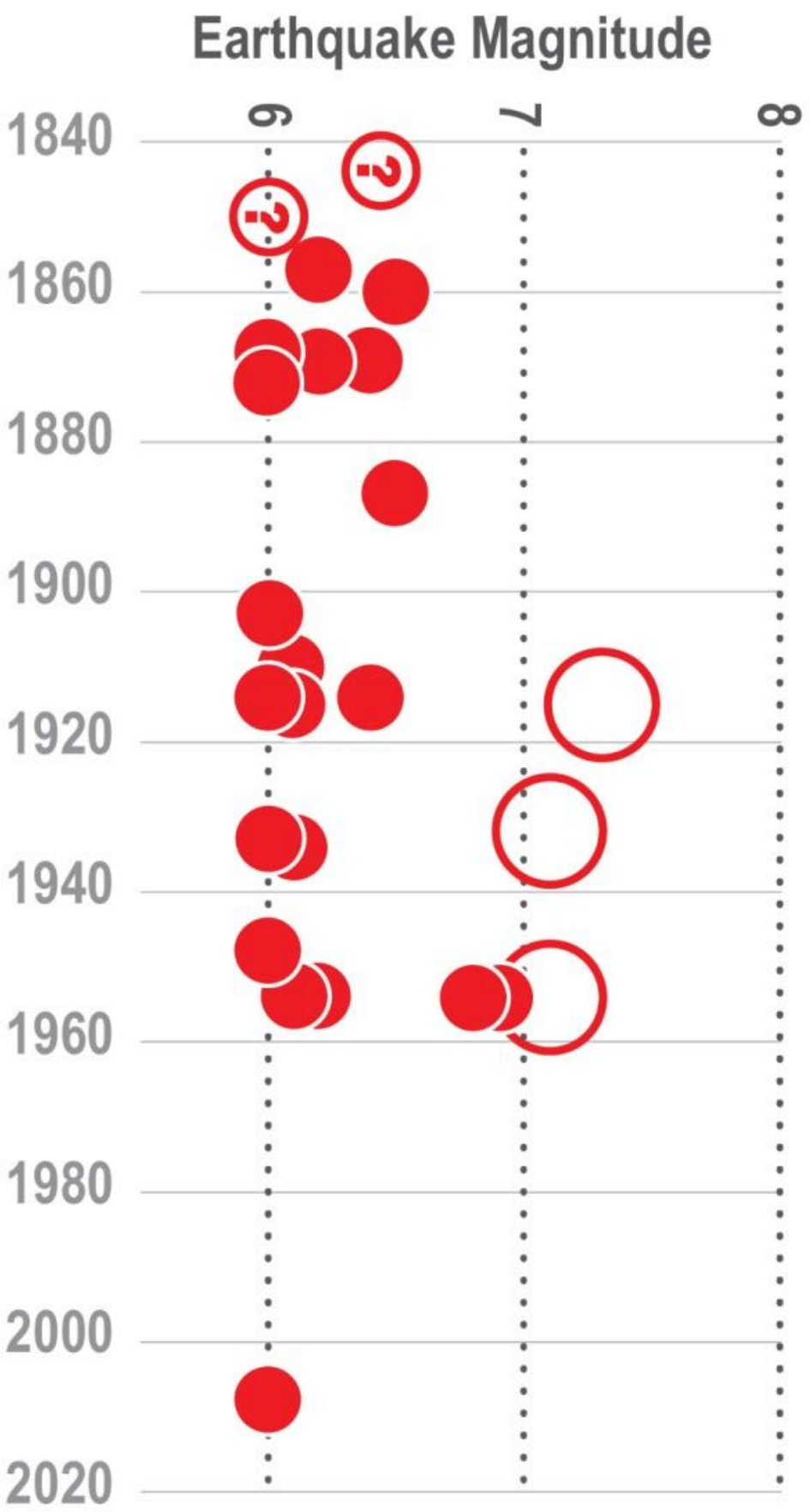
- We know how to ***plan for, prepare for, and mitigate against disastrous earthquake effects***. We know how to minimize injuries and property loss.

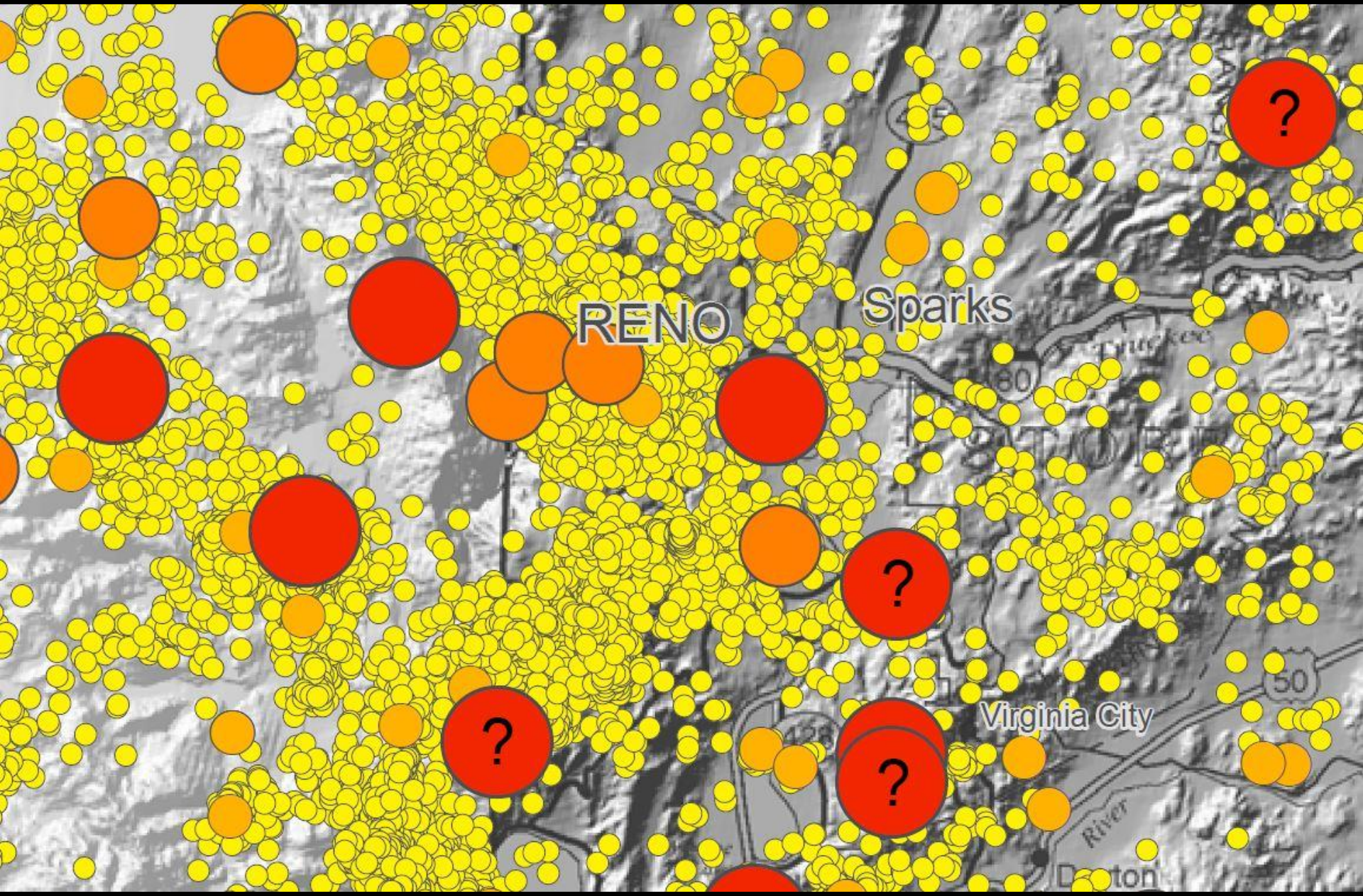
Earthquake Hazard

- Earthquakes
- Earthquake faults (Quaternary faults)
- Crustal movement based on geodesy



Earthquakes in the Nevada region recorded from the1840s to 2012. (Nevada Seismological Laboratory)


Earthquake Magnitude
6
7
8
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
?
?


RENO
Sparks
Virginia City
80
50
?
?
?
?

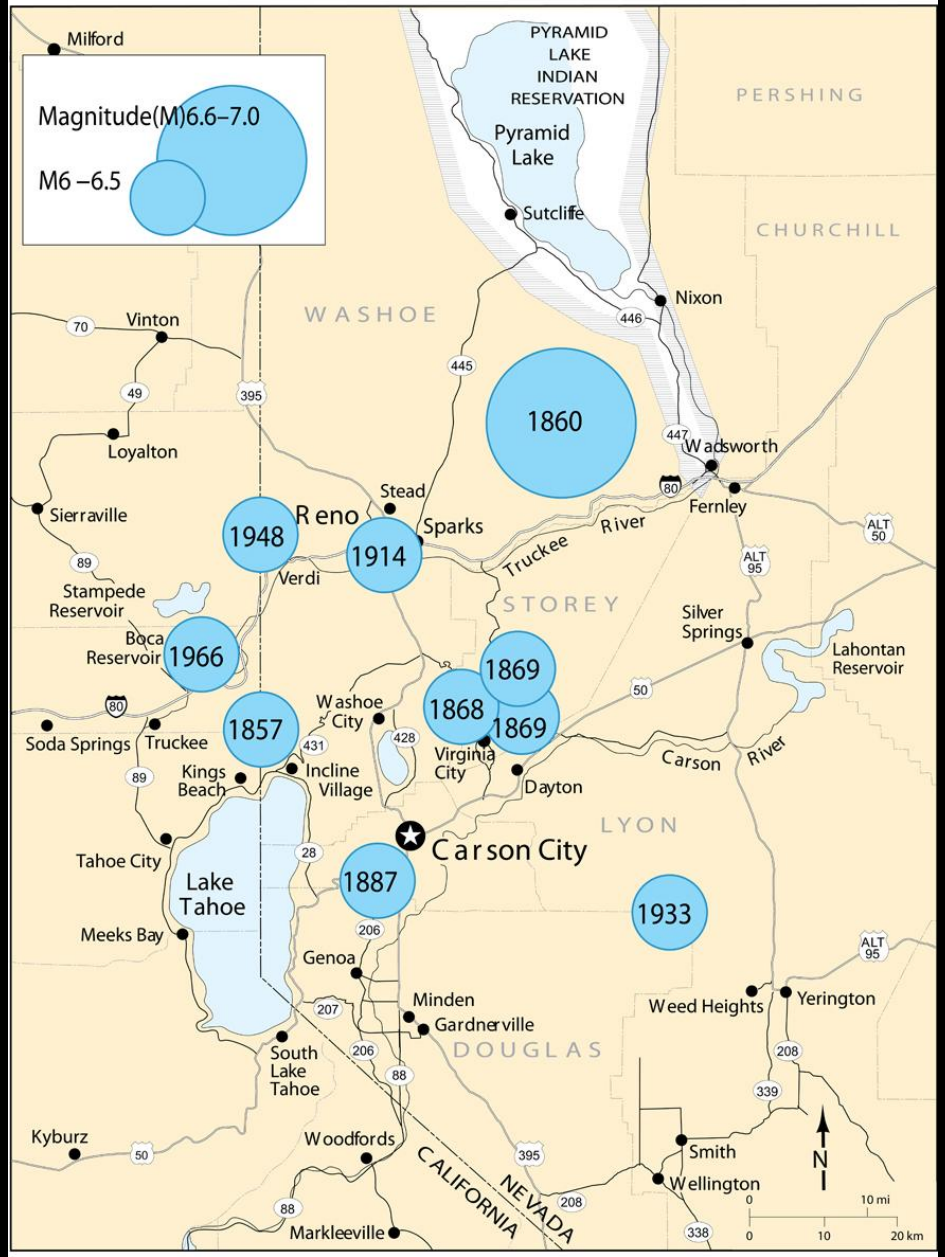
Periods of Damaging Earthquakes in Washoe County

- **1857 – 1869** [1957, 1860, 1868, 1869(2)]
- **1914 – 1915** [1914(2), 1915]
- **1948 – 1954** [1948, 1952, 1953, 1954]
- **2008 – ?**

Preparing for earthquakes in Nevada will likely have a more than one time benefit.

Nevada Bureau of Mines and Geology

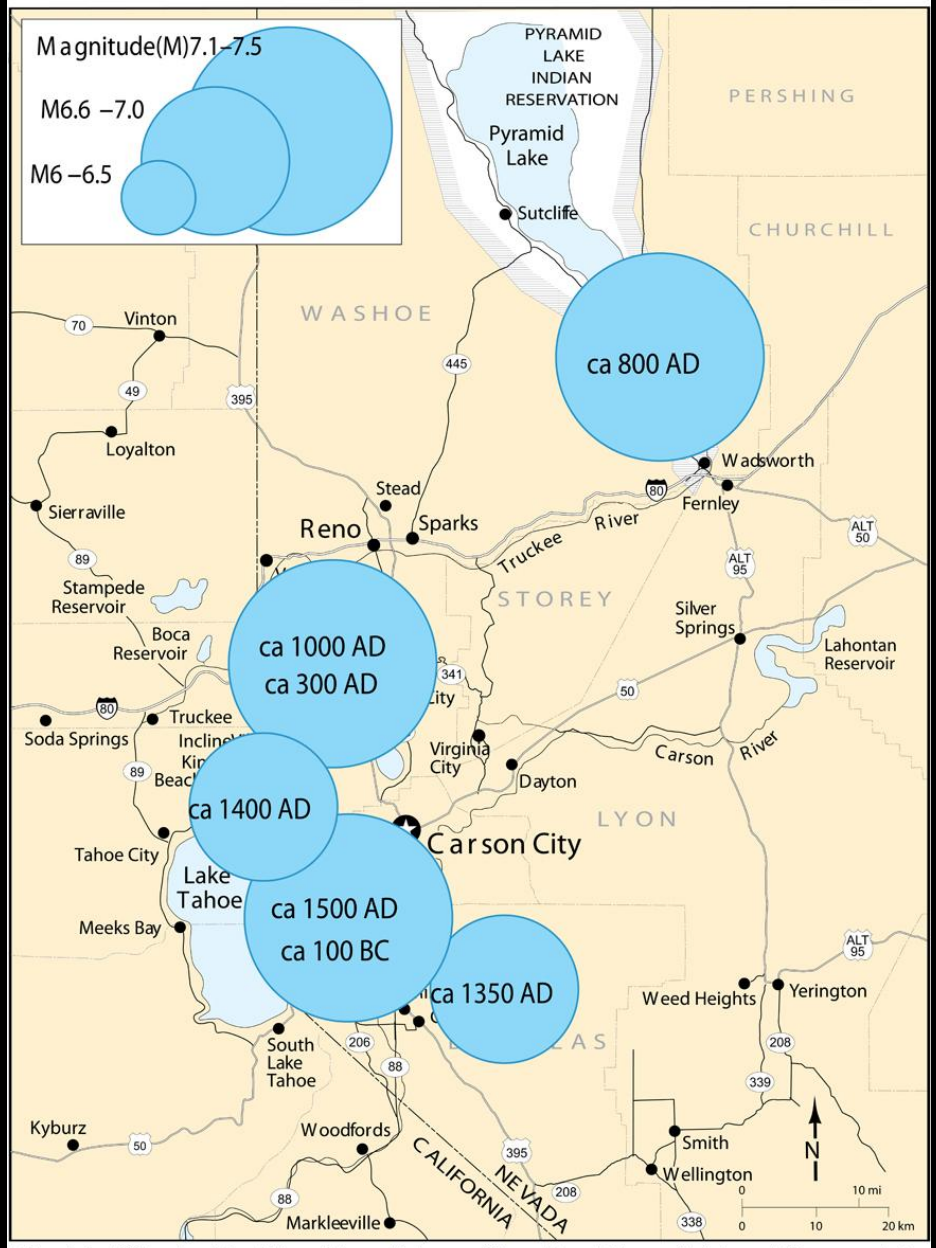
Major Historical Earthquakes in Western Nevada*



dePolo and others (2007 unpub. res.), Nevada Bureau of Mines and Geology

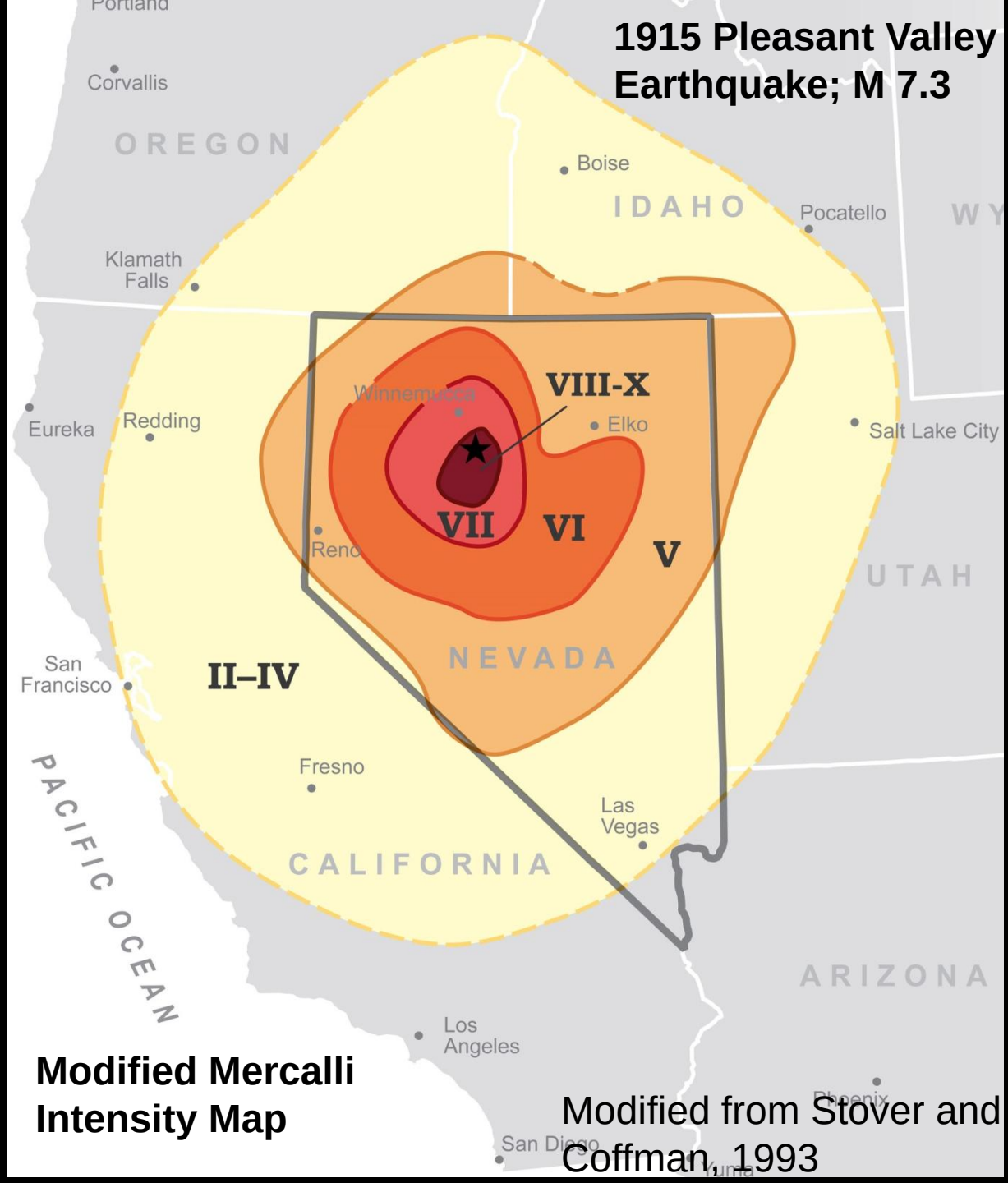
Nevada Bureau of Mines and Geology

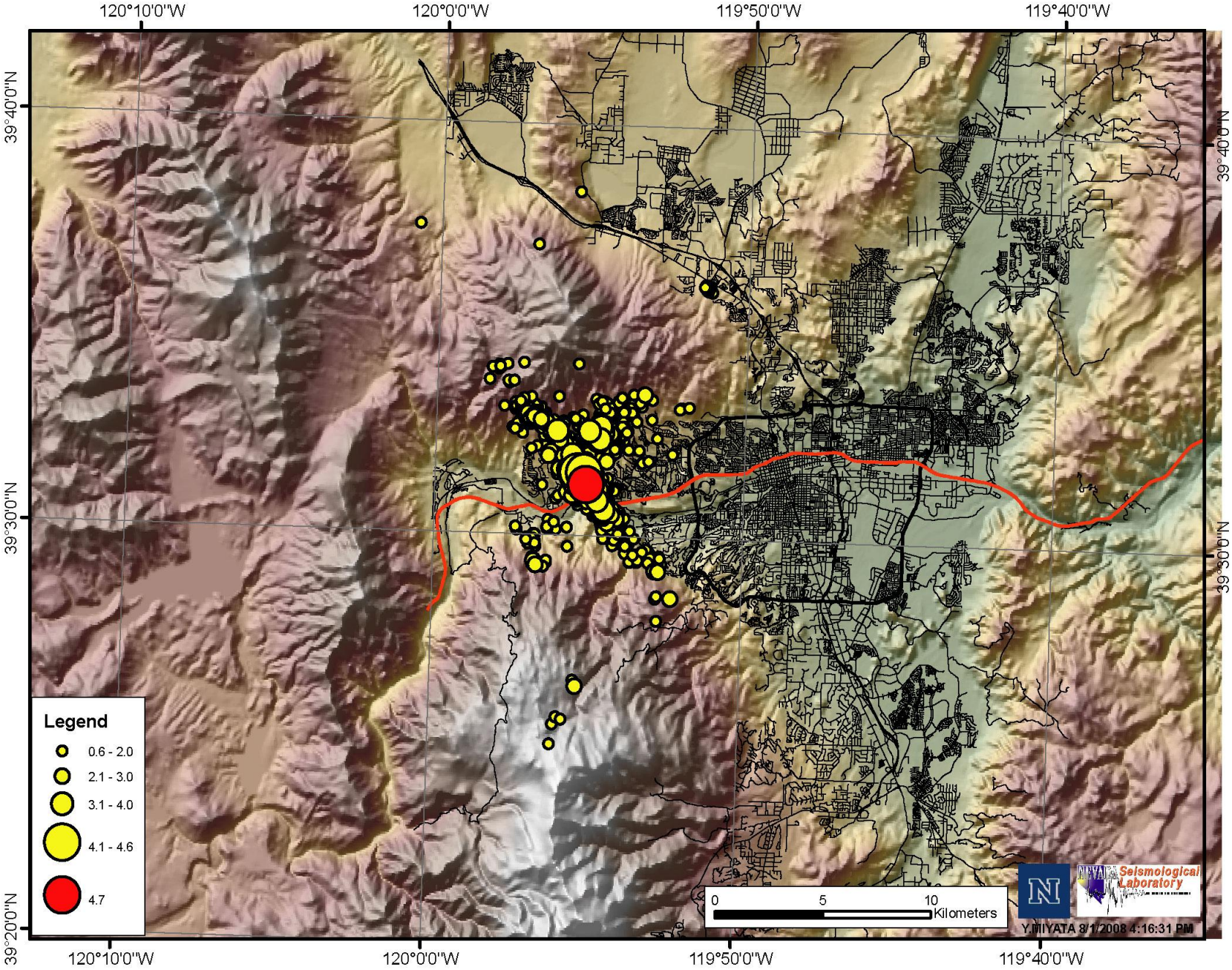
Some Major Earthquakes in Western Nevada (approximately 100 BC—1850 AD)*

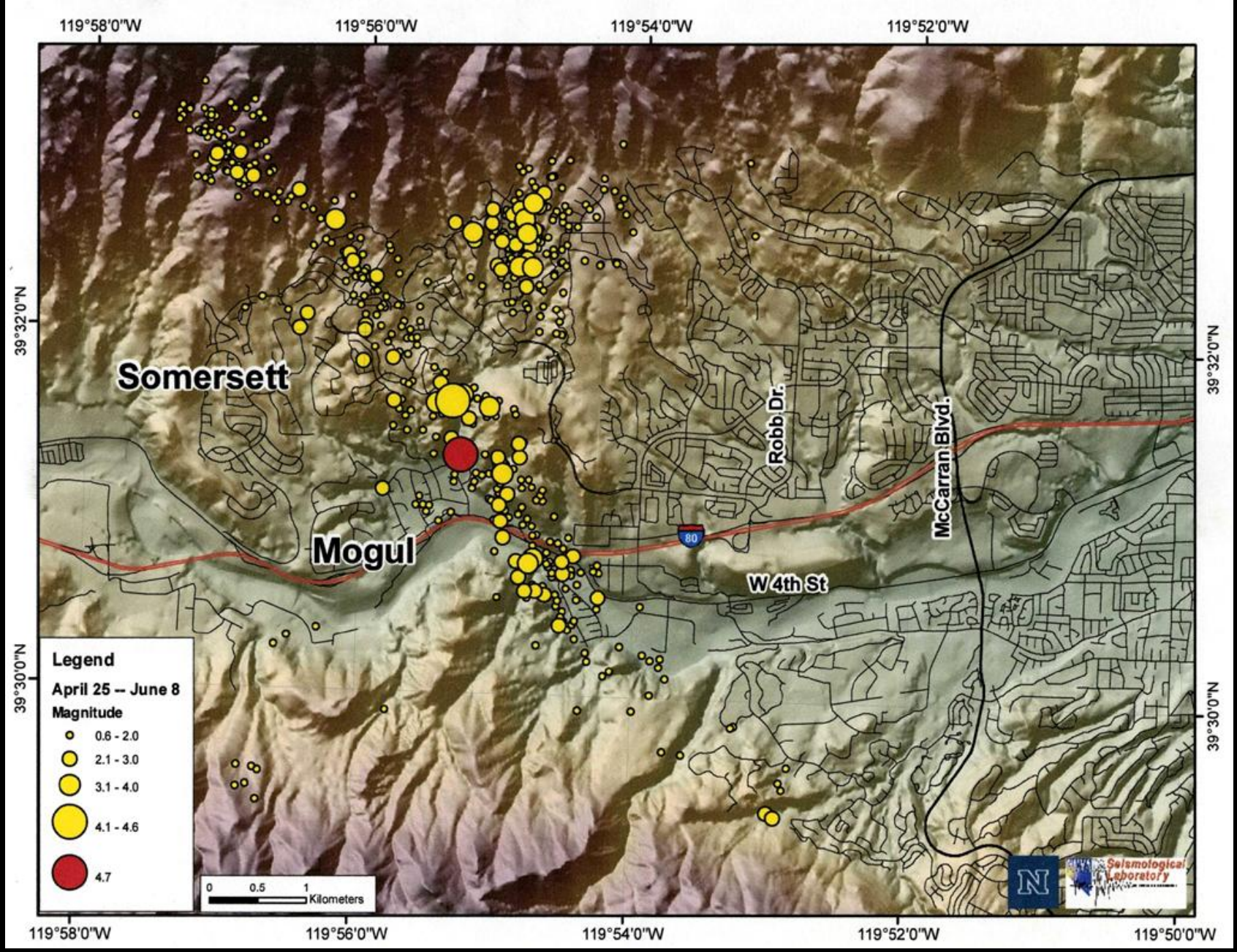


dePolo and others (2007 unpub. res.), Nevada Bureau of Mines and Geology

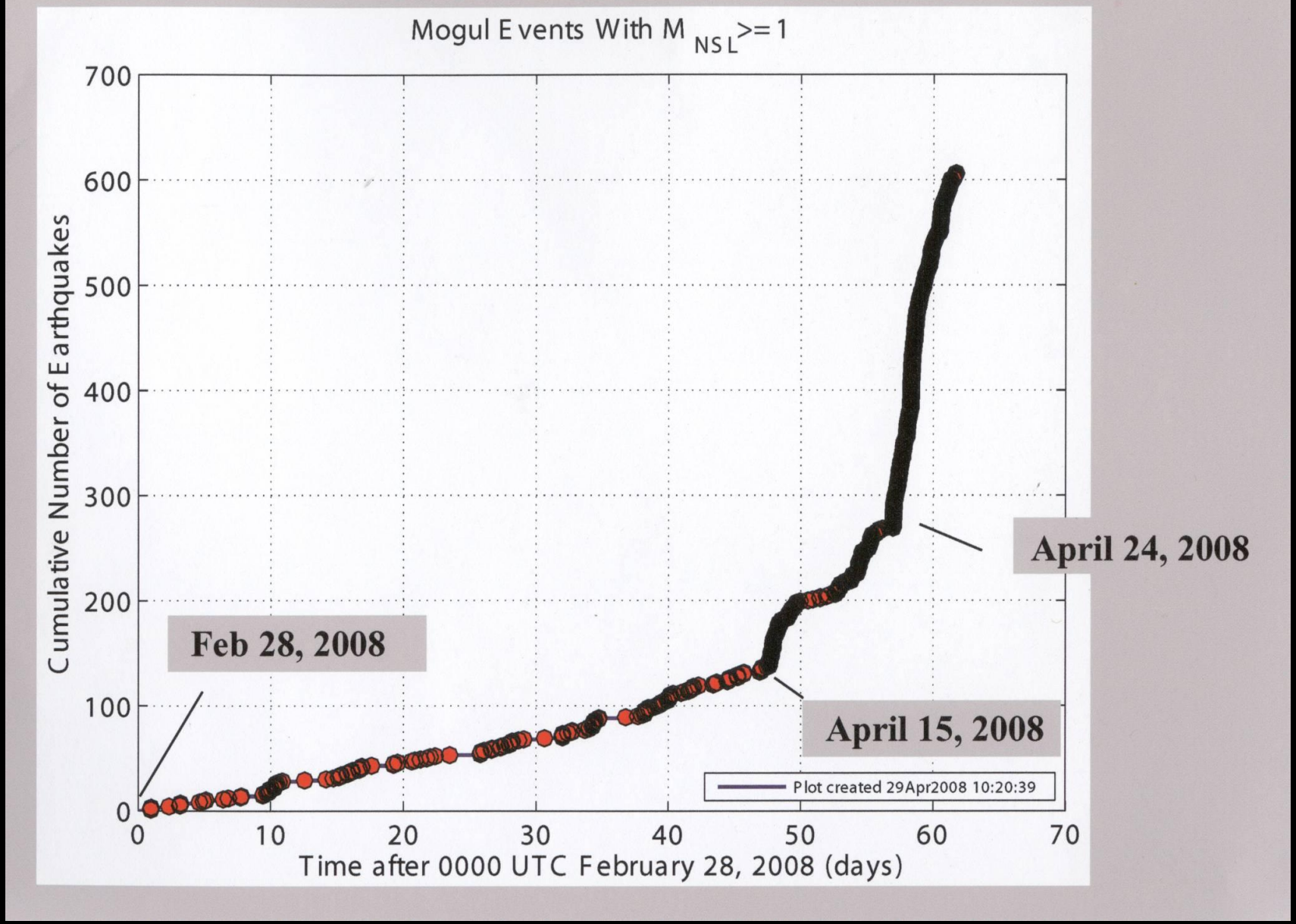
*This map is incomplete because of limited research. Dates are approximate. Earthquake magnitudes are estimated from the size of the fault and the amount of offset of the ground.


1915 Pleasant Valley Earthquake; M 7.3
Portland
Corvallis
OREGON
Boise
IDAHO
Pocatello
WY
Klamath Falls
Winnemucca
VIII-X
Elko
Eureka
Redding
Salt Lake City
VII
VI
V
Reno
UTAH
NEVADA
San Francisco
II–IV
Fresno
Las Vegas
CALIFORNIA
PACIFIC OCEAN
ARIZONA
Los Angeles
San Diego
Phoenix
Yuma
Modified Mercalli Intensity Map
Modified from Stover and Coffman, 1993


120°10'0"W
120°0'0"W
119°50'0"W
119°40'0"W
39°40'0"N
39°30'0"N
39°20'0"N
Legend
0.6 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 4.6
4.7
0
5
10
Kilometers
Seismological Laboratory
Y.MIYATA 8/1/2008 4:16:31 PM



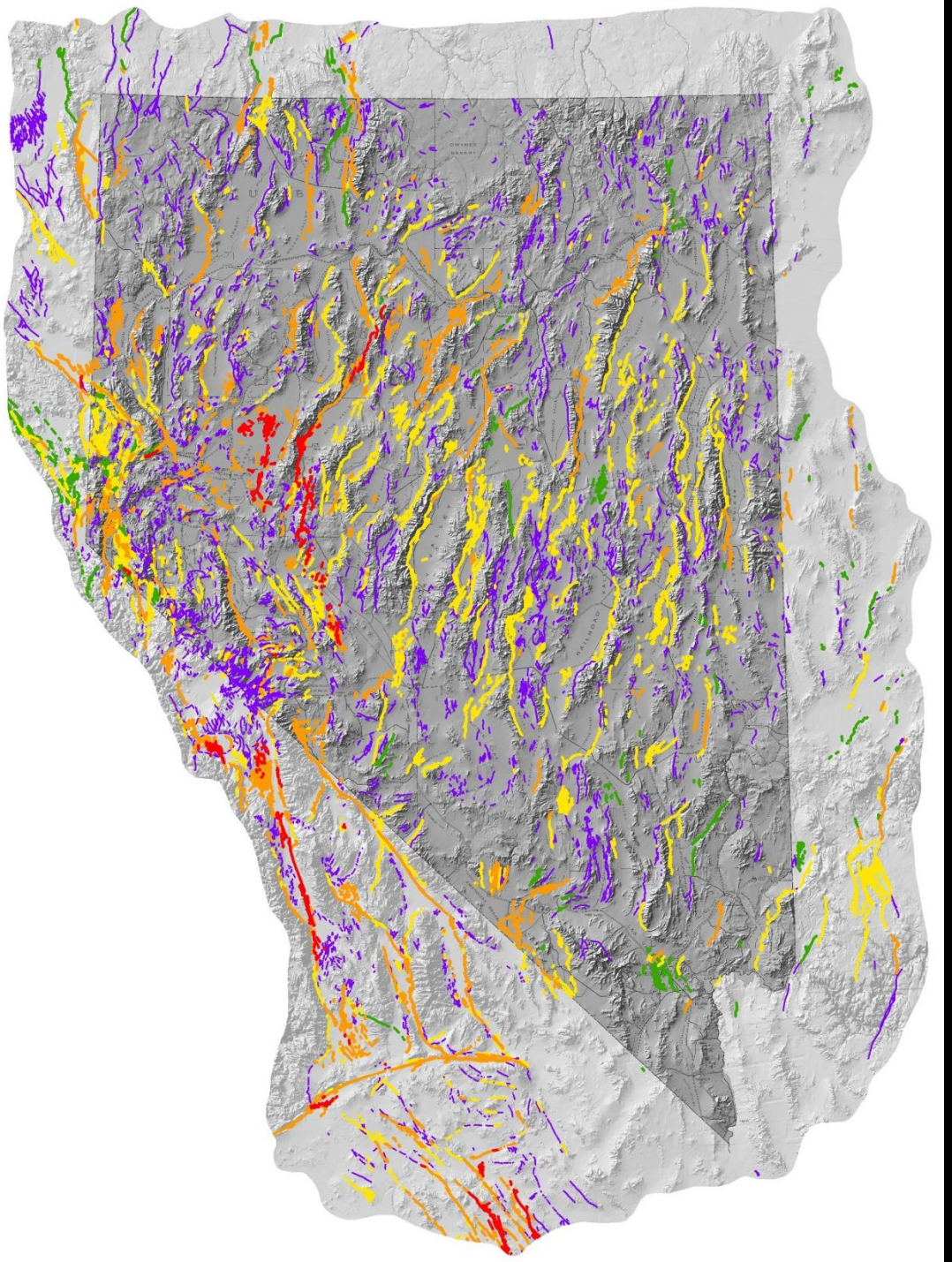
Aftershocks of the April 28th 2008 Mw 5 Earthquake (red) K. Smith relocations



Earthquake Activity Graph – John Anderson, Nevada Seismological Laboratory

Quaternary Faults

- Major normal dip-slip faults
- Moderate local strike-slip faults
- Major regional strike-slip faults
- Buried faults
- Blind faults
- Background earthquake sources



Years Before Present of Latest Fault Rupture

<150	Historical
<15,000	Latest Pleistocene and Holocene
<130,000	Latest Quaternary
<750,000	Mid-Quaternary
<1,800,000	Quaternary

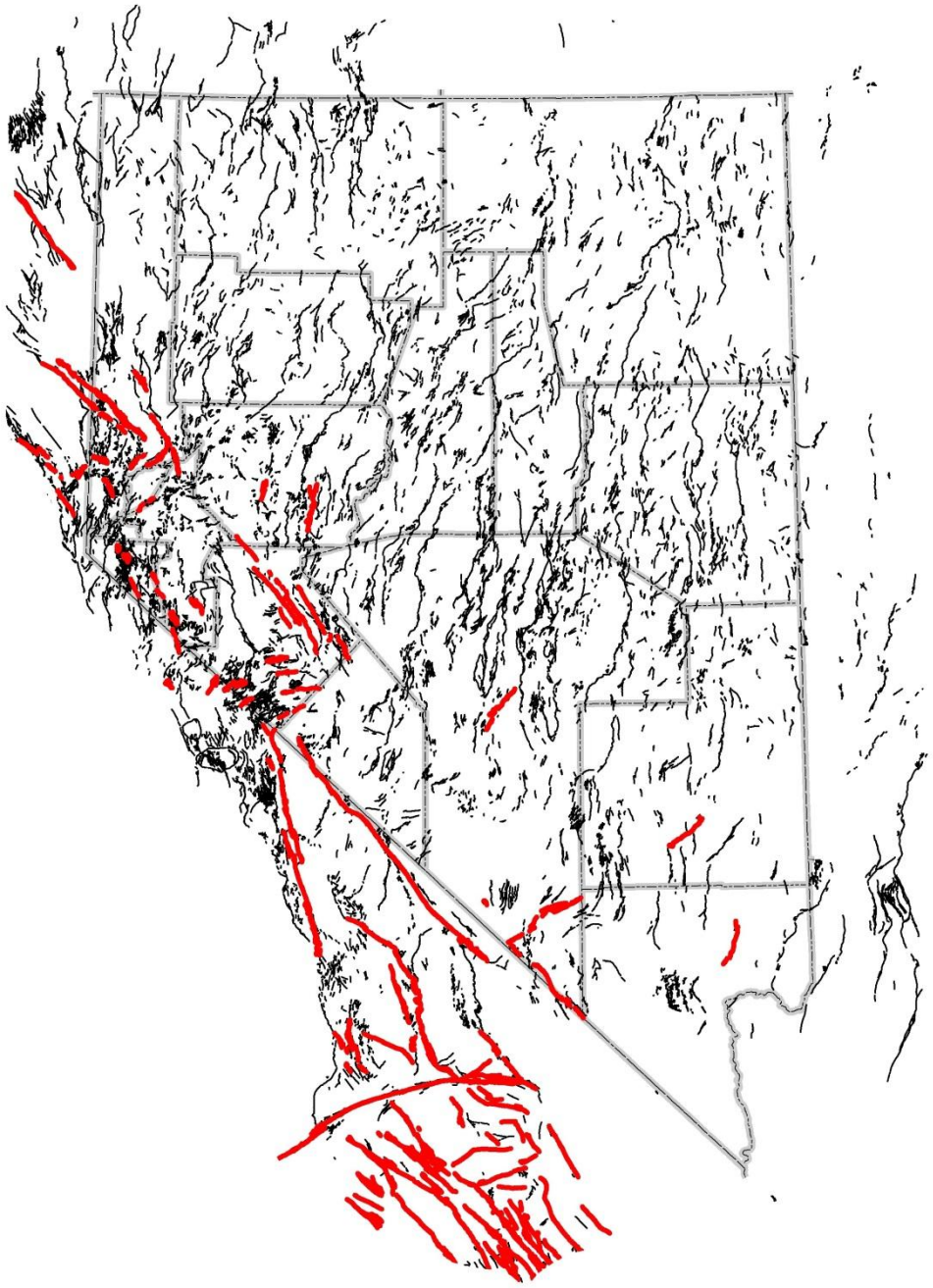
Fault Movement in Nevada

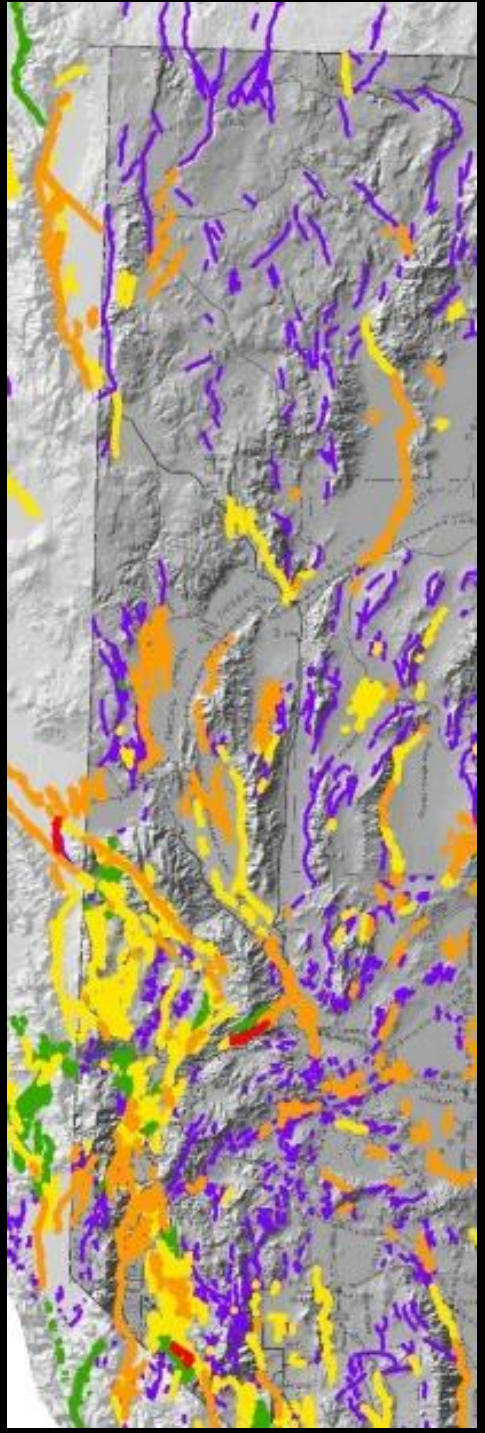
Normal dip-slip fault

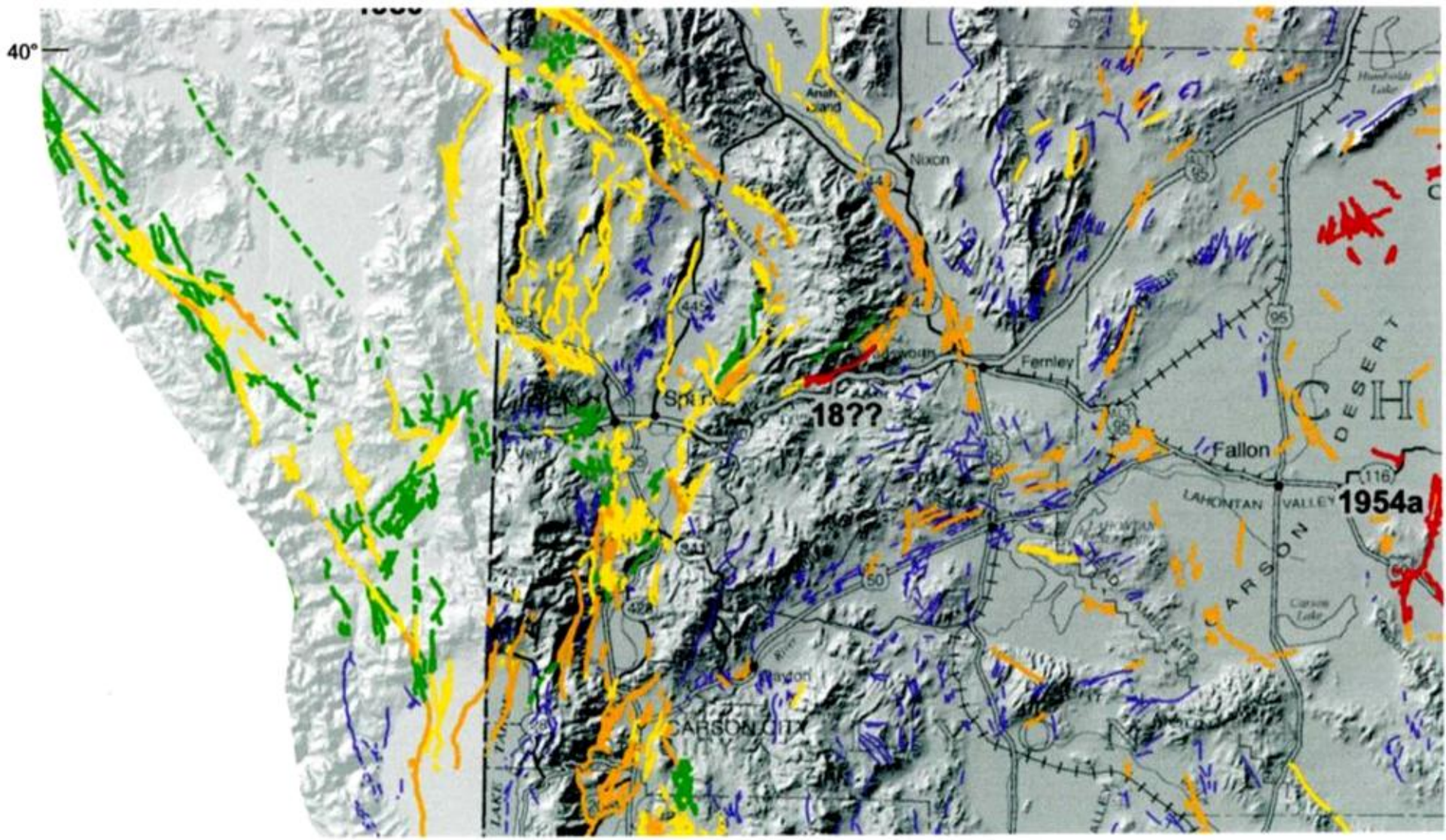
(includes oblique-slip or unknown slip)

Strike-slip fault

(includes historical ruptures, some oblique-slip faults, inferred strike-slip movements, and some wrench patterns resulting from strike-slip movement)







Quaternary Fault Map of Nevada
dePolo (2008)

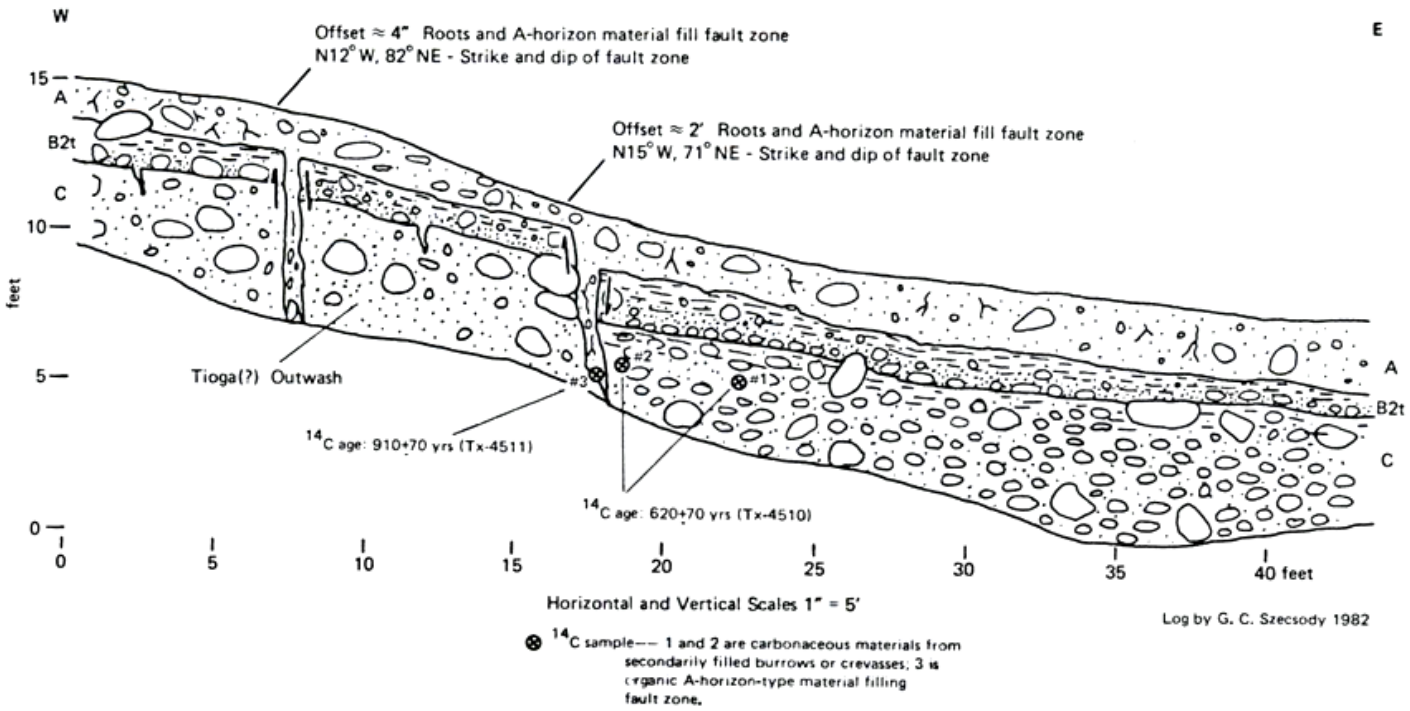
Photo by Alan Ramelli

Peavine Peak fault

Photo by
Burt Slemmons

WHITE'S CREEK
TRENCH 1
North wall

Trend of trench-N61° E
T.18N., R.19E., Sec. 34, NW¼



Explanation – Trench 1

A

A soil horizon – Stony sandy loam, dark brown (10 YR 3/3, dry). Loose, granular, non-sticky, non-plastic; weak, medium, subangular blocky structure; up to 25% gravel, cobbles, stones and boulders up to 18" in diameter. Clear, irregular boundary with B2t.

u B2t d

B2t soil horizon – B2t upthrown – Cobbly sandy loam to cobbly loam, brown (7.5 YR, 5/4, dry). Hard, sticky, plastic; moderate, coarse, subangular blocky structure; clay films common around gravel and cobbles; 25% to 35% gravel and cobbles. Diffuse irregular boundary with C.
B2t downdropped – Cobbly sandy loam, strong brown (7.5 YR, 5/8). Slightly hard, slightly sticky, slightly plastic; weak, medium, subangular, blocky structure; clay films common around gravel and cobbles; approximately 30% gravel and cobbles. Diffuse, smooth boundary with C.

u C d

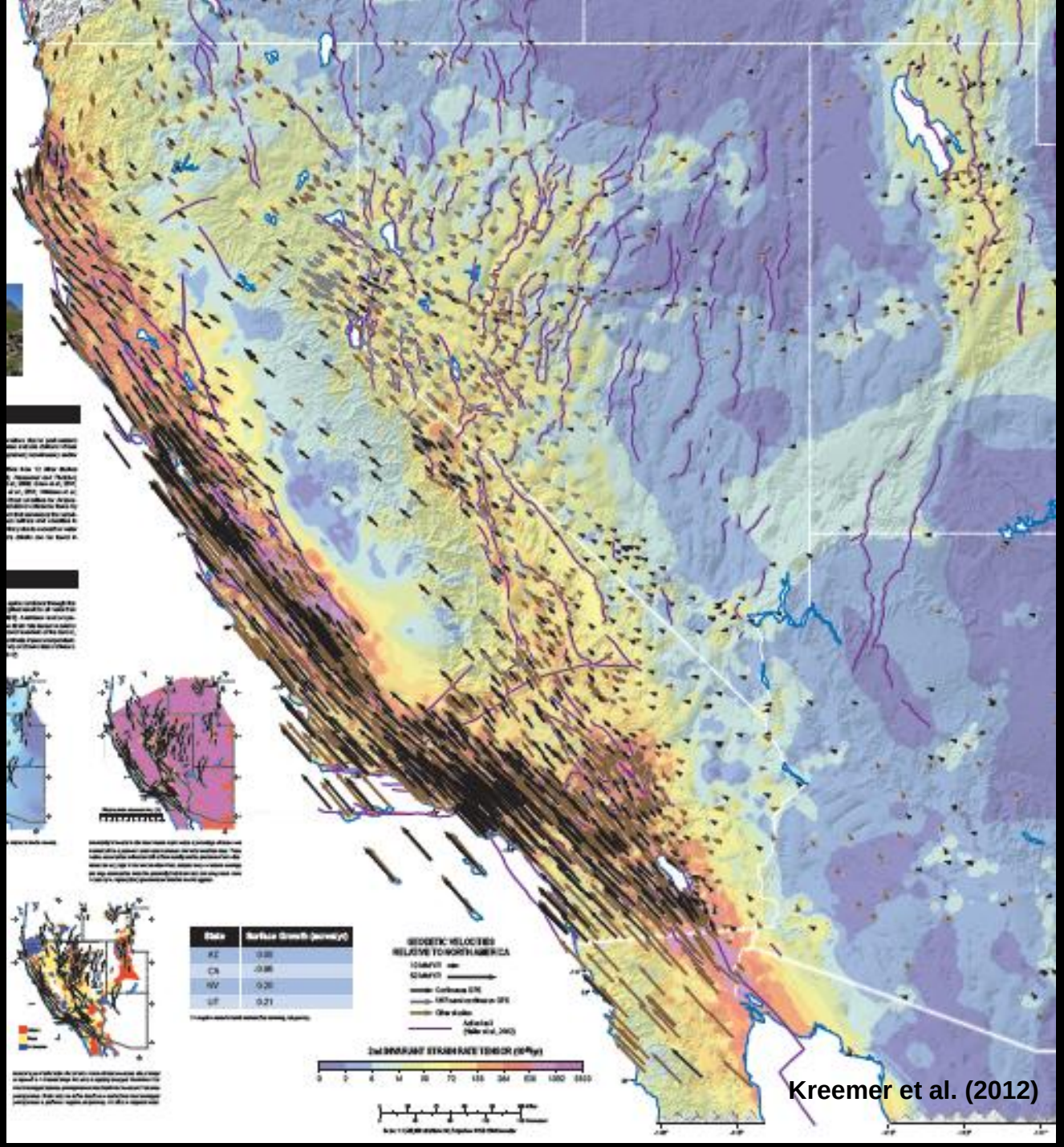
C horizon – Unaltered parent material – C upthrown – Very stony sandy loam, brownish yellow (10 YR, 6/6, dry). Soft, slightly sticky, non-plastic; weak to moderate, medium to coarse, subangular, blocky structure; very thin clay films common around gravel and cobbles; 65% to 70% gravel, cobbles, and boulders.
C downdropped – Very cobbly sand, brownish yellow (10 YR, 6/6). Soft to loose, non-sticky, non-plastic; granular except near contact with B2t, weak, very coarse subangular blocky structure; 60% gravel and cobbles with few boulders, poorly developed stratification of gravel and cobbles.

FIGURE 26: Partial log of exploratory trench across major strand of the Sierra Nevada frontal fault zone at Whites Creek (Szecsody, 1982).

Fault Earthquake Sources

- Maximum earthquakes: **Magnitude 6.5-7.3**

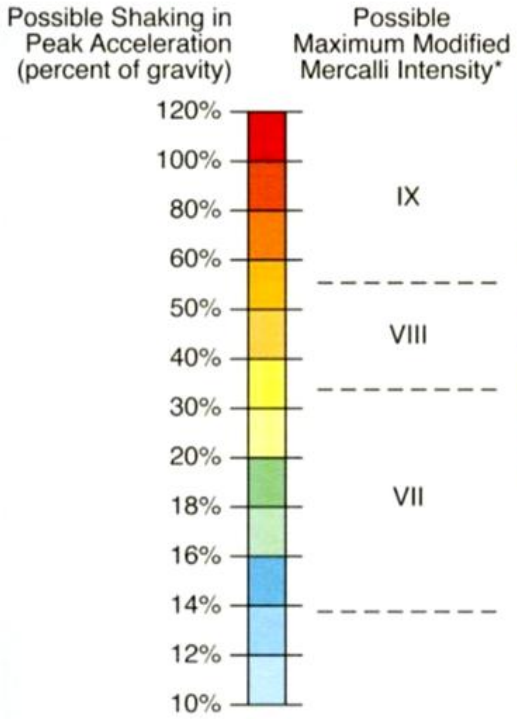
- Amount of water system effected:
  - **M5** localized part
  - **M6** part damaged, whole system felt
  - **M6.5** half? damaged, whole system stressed
  - **M7** whole system damaged?


GEODETIC VELOCITIES
RELATIVE TO NORTH AMERICA
Kreemer et al. (2012)

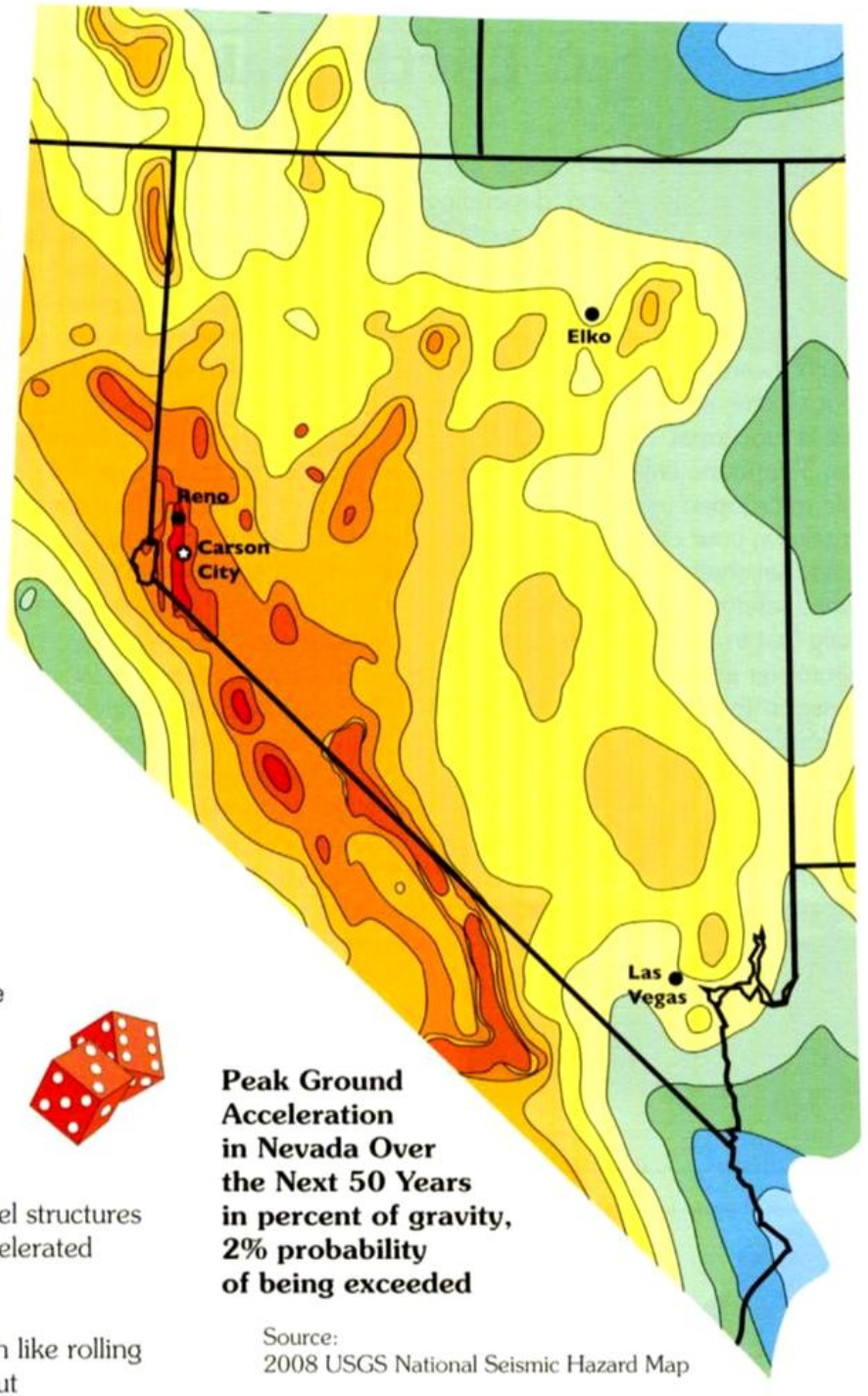
Strong Ground Motion

- Low velocity sediments:
  - greater displacements
- Basin effects:
  - enhancement of waves
    - greater amplitudes
    - monotonic wave trains
  - increased duration
  - basin geometry; tapered-edge effect
- Source effects:
  - type of earthquake
  - directivity effects

Shaking Potential Map for Nevada



* See page 4 for descriptions of Intensity VII and VIII. In Intensity IX, general panic occurs and there may be damage to some well-built structures.

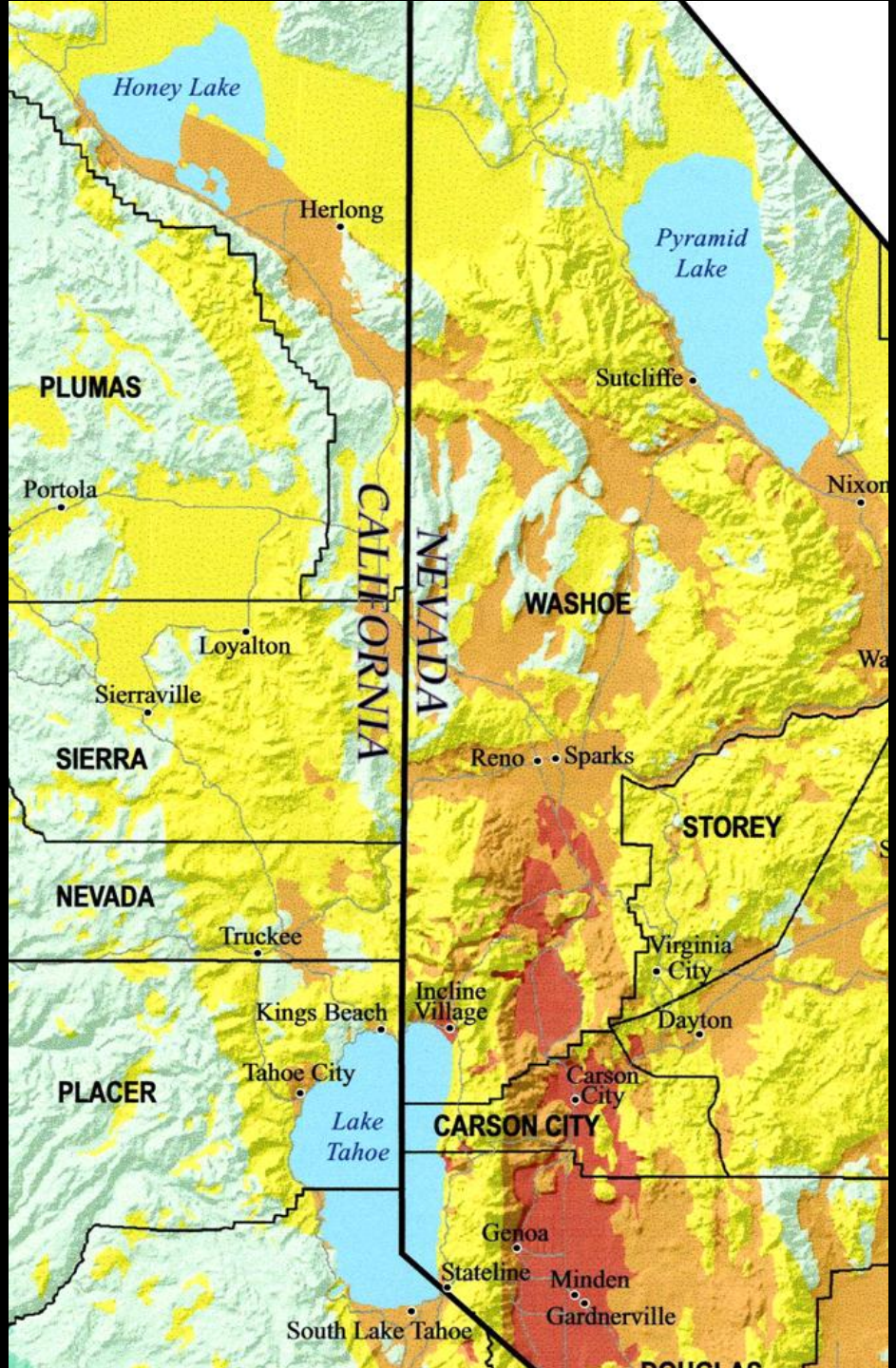


Peak Ground Acceleration in Nevada Over the Next 50 Years in percent of gravity, 2% probability of being exceeded

Source:
2008 USGS National Seismic Hazard Map

Engineers use computer models and model structures to see how buildings hold up to being accelerated sideways by a seismic wave.

The notion of a map like this is very much like rolling the dice and calculating odds. If a rarer, but

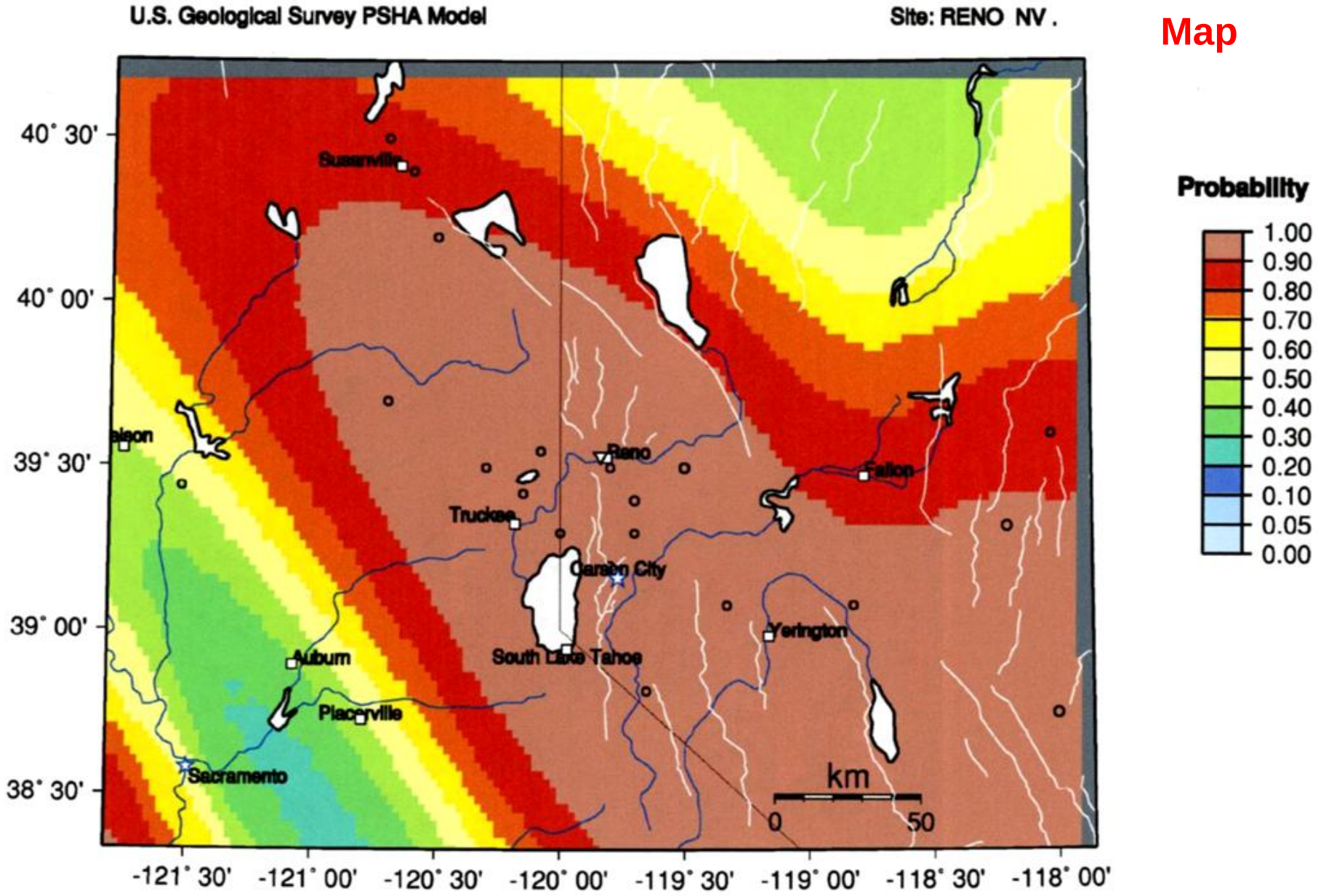


Earthquake Hazard Map –

Branum and others (2005)

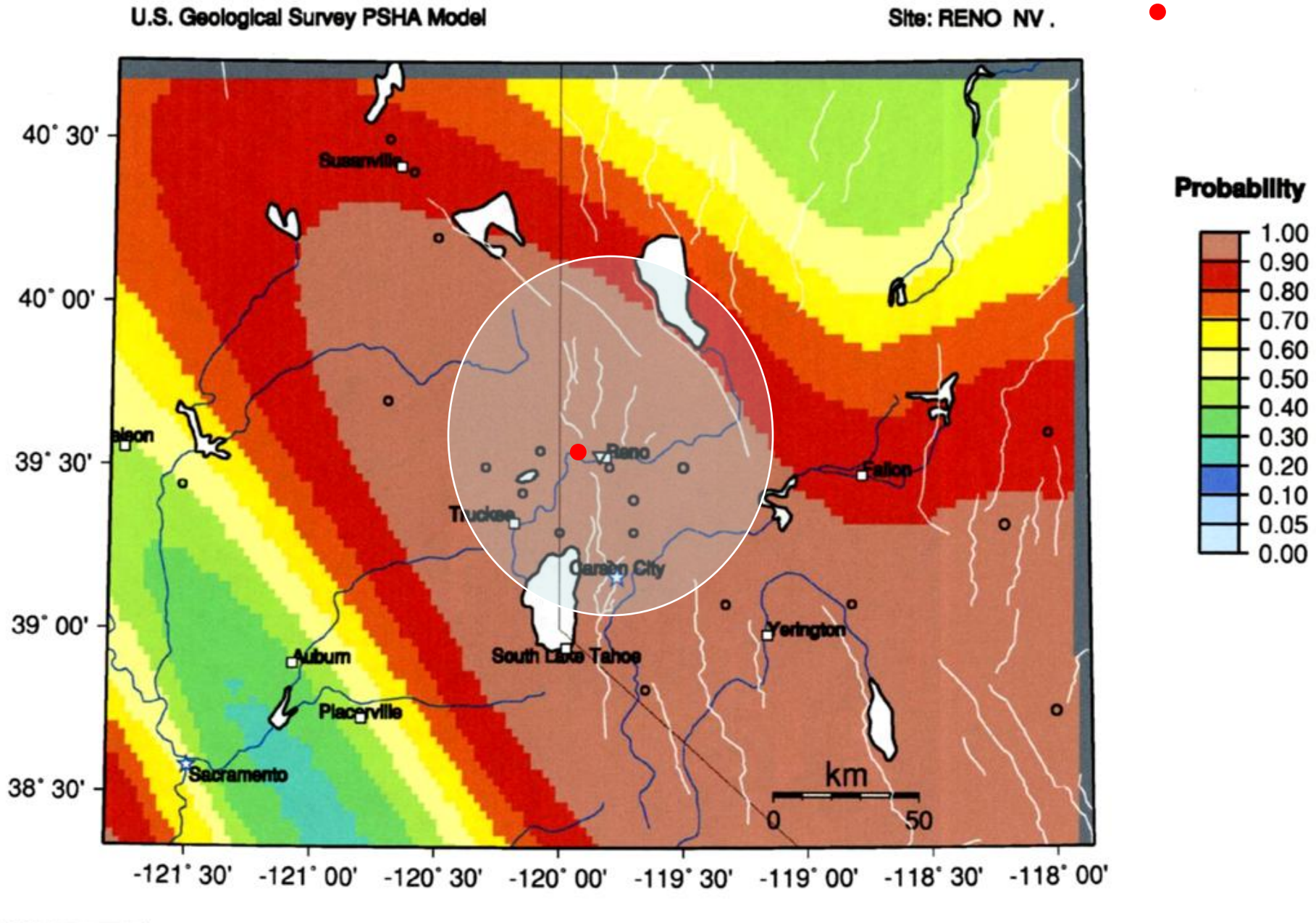
Probability of earthquake with M ≥ 5.0 within 50 years & 50 km

2005 Map



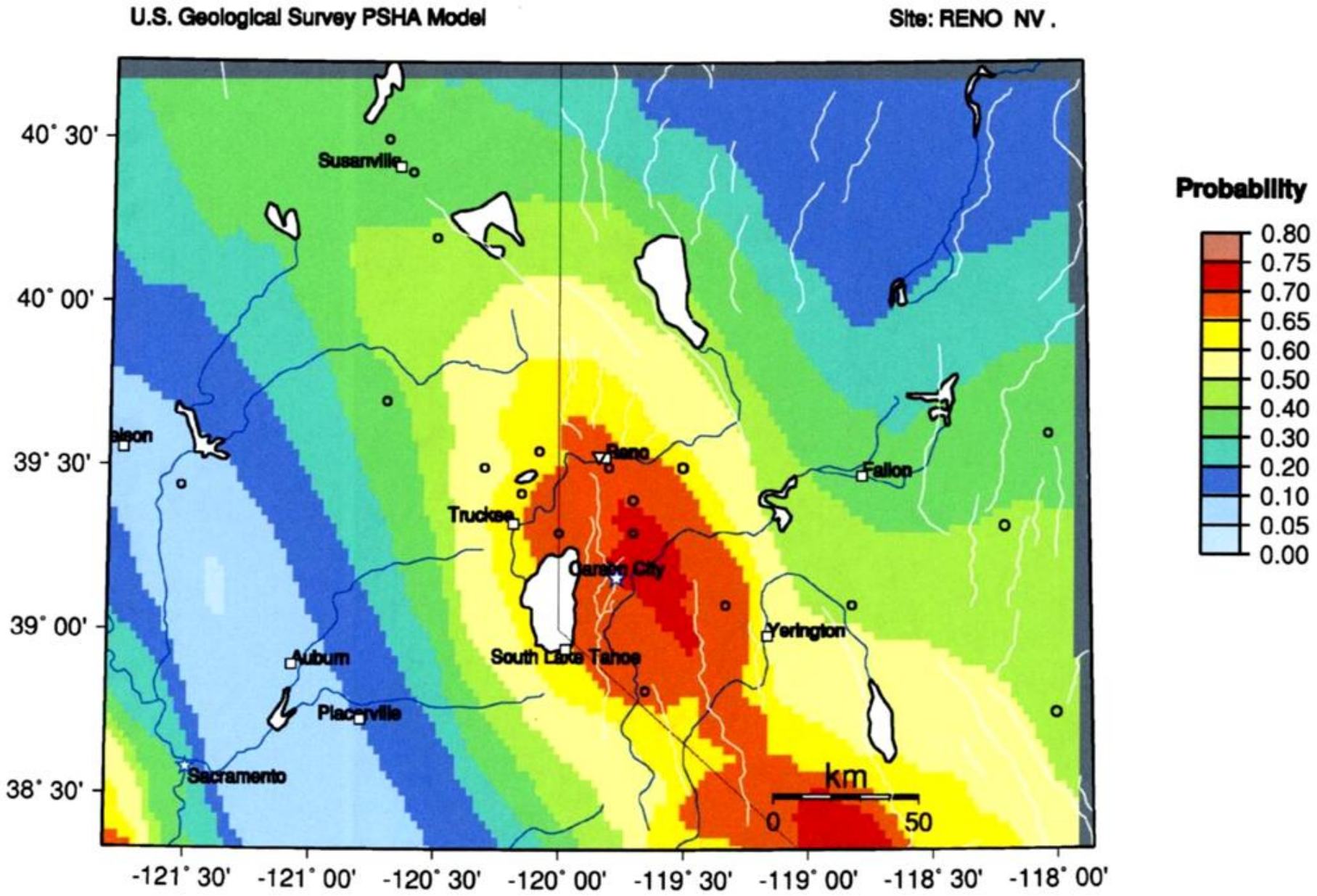
GMT May 4 09:51 Earthquake probabilities from USGS 2002 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are white; rivers blue. Epicenters M>=6.0 circles.

Probability of earthquake with M ≥ 5.0 within 50 years & 50 km



GMT May 4 09:51 Earthquake probabilities from USGS 2002 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are white; rivers blue. Epicenters M>=6.0 circles.

Probability of earthquake with M ≥ 6.01 within 50 years & 50 km

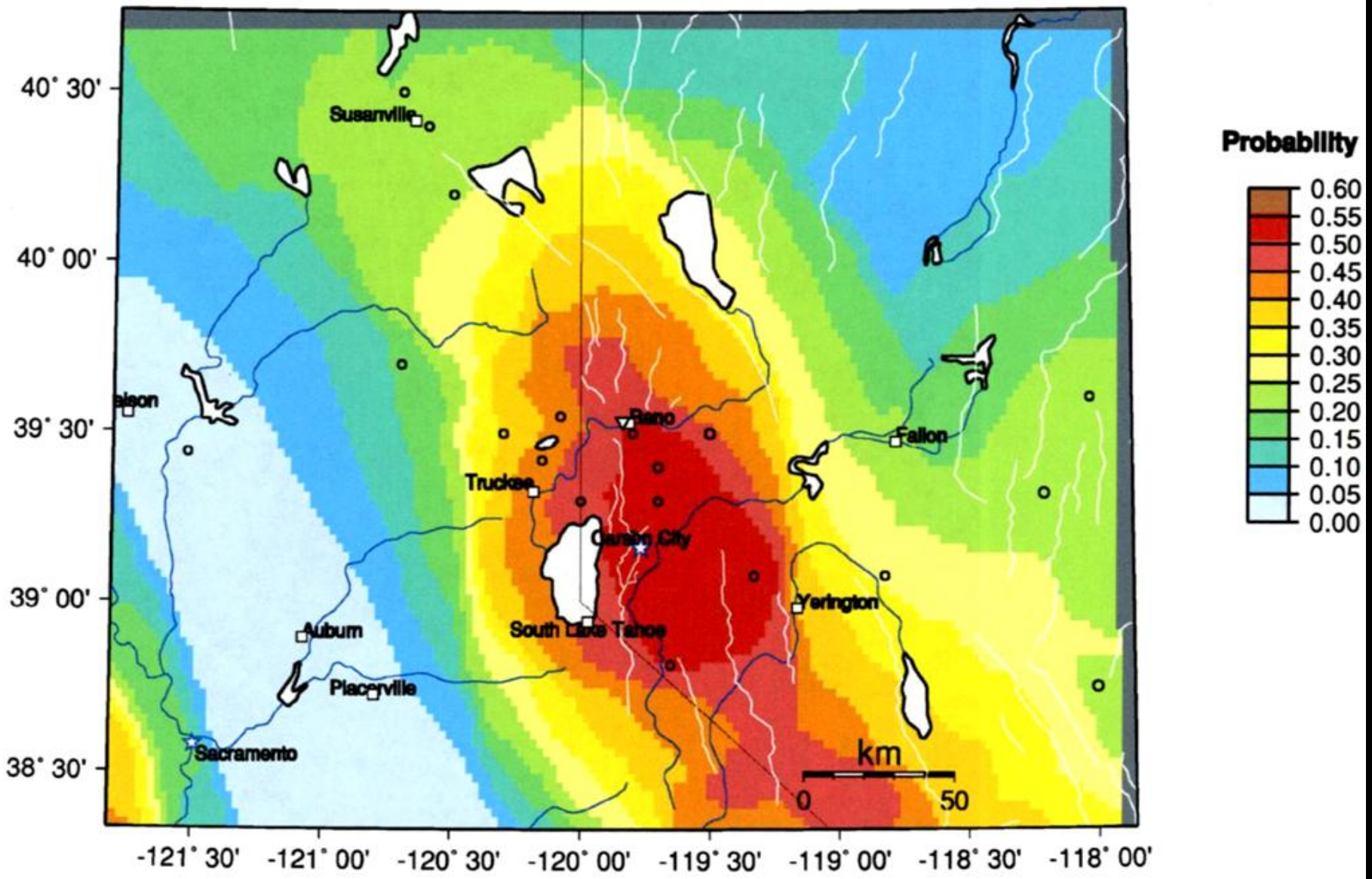


GMT May 4 09:16 Earthquake probabilities from USGS 2002 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are white; rivers blue. Epicenters M>=6.0 circles.

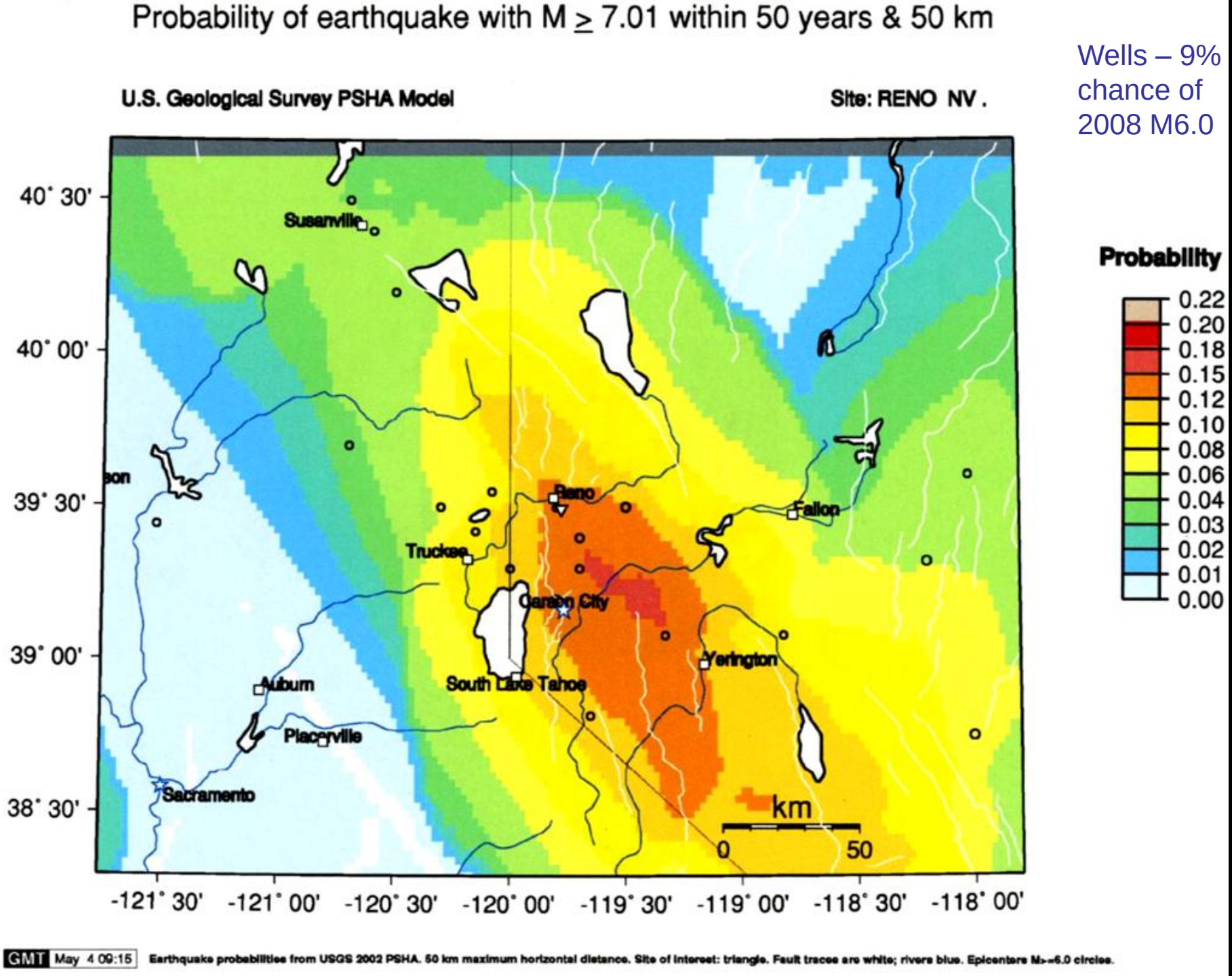
Probability of earthquake with M ≥ 6.5 within 50 years & 50 km

U.S. Geological Survey PSHA Model

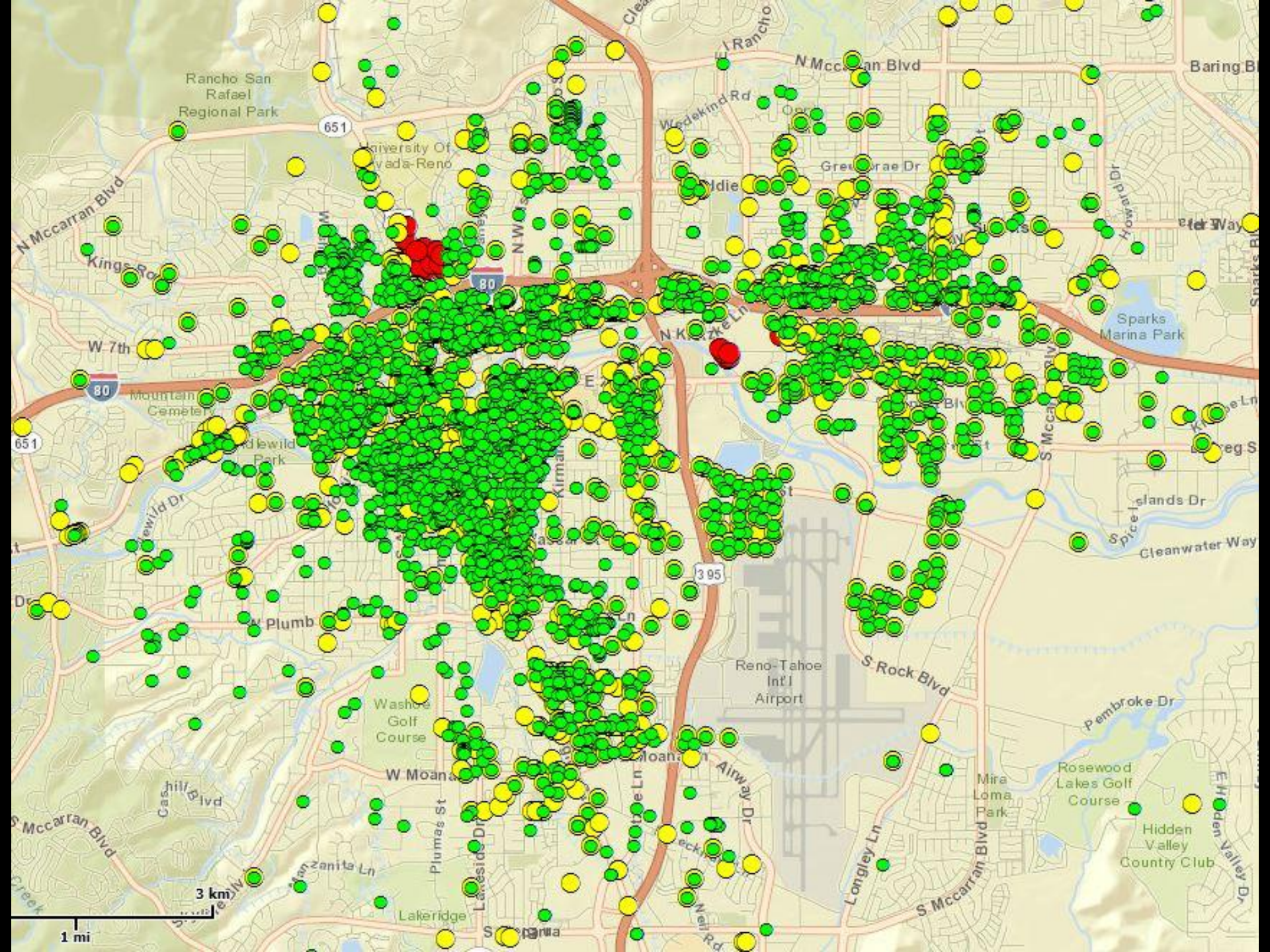
Site: RENO NV .



GMT May 4 09:17 Earthquake probabilities from USGS 2002 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are white; rivers blue. Epicenters M>=6.0 circles.


Probability of earthquake with M ≥ 7.01 within 50 years & 50 km
U.S. Geological Survey PSHA Model
Site: RENO NV.
Wells – 9% chance of 2008 M6.0
Probability
0.22
0.20
0.18
0.15
0.12
0.10
0.08
0.06
0.04
0.03
0.02
0.01
0.00
40° 30'
40° 00'
39° 30'
39° 00'
38° 30'
-121° 30'
-121° 00'
-120° 30'
-120° 00'
-119° 30'
-119° 00'
-118° 30'
-118° 00'
Susanville
Reno
Fallon
Truckee
Carson City
Yerington
South Lake Tahoe
Auburn
Placerville
Sacramento
km
0
50
GMT May 4 09:15
Earthquake probabilities from USGS 2002 PSHA. 50 km maximum horizontal distance. Site of interest: triangle. Fault traces are white; rivers blue. Epicenters M>=6.0 circles.

BAR
306
302
RENO


Rancho San Rafael Regional Park
651
University Of Nevada-Reno
N Mccarran Blvd
Wedekind Rd
Greenbrae Dr
Howard Dr
Baring Bl
Kings Rd
80
W 7th
Mountain Cemetery
Idlewild Park
Idlewild Dr
N Kietzke Ln
Sparks Marina Park
S Mccarran Blvd
Spice Islands Dr
Cleanwater Way
395
W Plumb
Reno-Tahoe Int'l Airport
S Rock Blvd
Pembroke Dr
Washoe Golf Course
W Moana
Airway Dr
Mira Loma Park
Rosewood Lakes Golf Course
Hidden Valley Country Club
E Hidden Valley Dr
Longley Ln
Plumas St
Lakeside Dr
Manzanita Ln
Lakeridge
Neil Rd
3 km
1 mi

Some Earthquake Effects on Water Systems

- Tank failures
- Pipe failures
- Power failures (got backup power?)
- Water treatment plant damage
- Pump station damage
- Well station damage and discolored water
- Distribution system damage

- Contaminated water lines
- Multiple failures at once
- HAZMAT issues (e.g., Chlorine)
- Nonstructural damage to headquarters
  - light fixtures?
  - computers?
  - contents?
  - backup power?

TABLE 24.1 Summary — Performance of Water Systems in Earthquakes

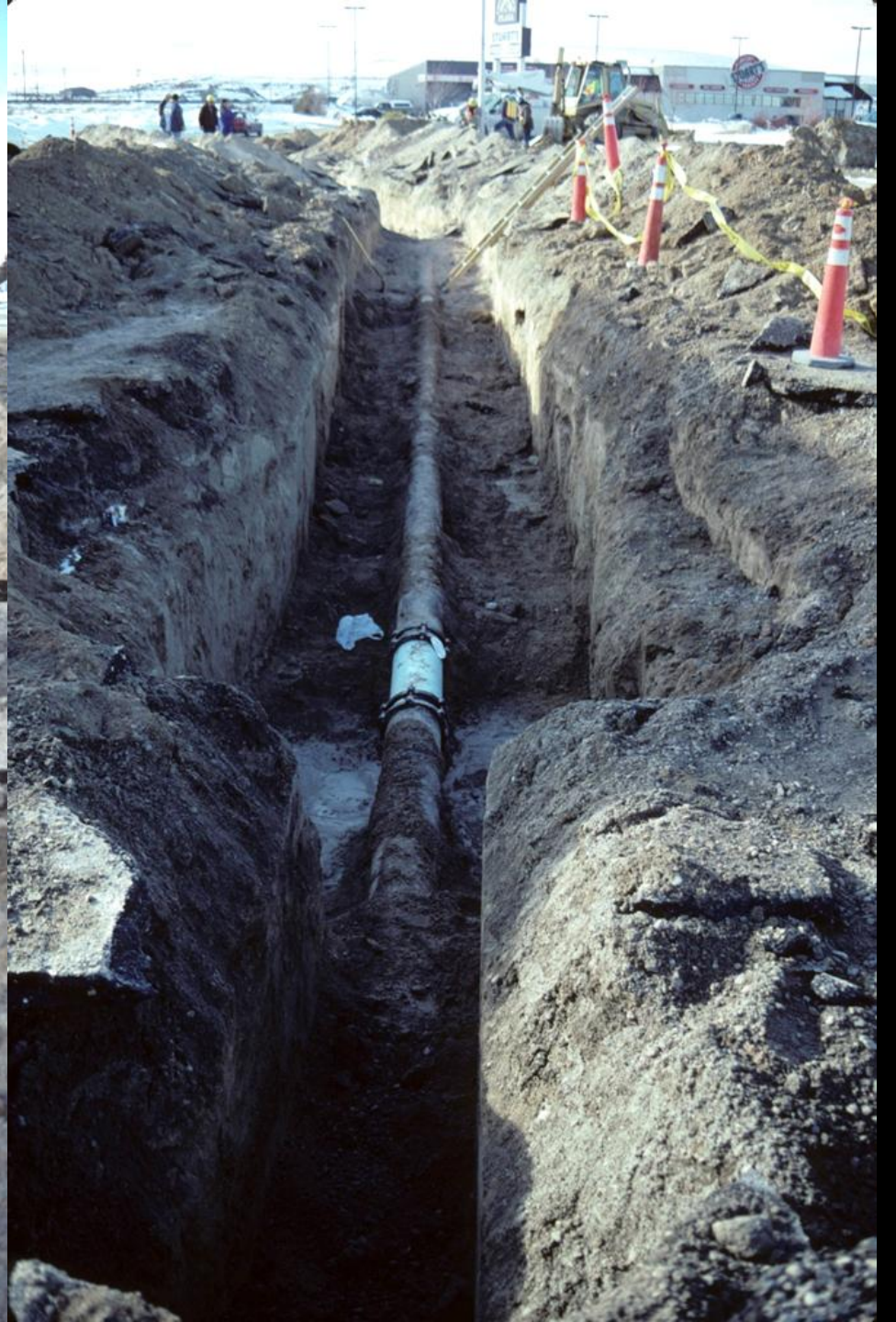
		Failure Consequences				System Component Failure									
						Supply/Treatment					Tank		Pipe		
Disaster Event	Year	Fire Suppression/Lacked Water Supply	Fire	Used Alt. Supply	Cooling Telephone COs and Computers	Surface Supply Failure	Raw Water Transmission	WTP Damage	Well Casing/Equipment Damage	Loss of Power	Shell/Structure	Inlet/Outlet Pipe	PGD (lateral spread, landslide, fault offset)	Wave Propagation	Building Services
Earthquakes															
San Francisco	1906	5	5	5	na	2	5	na	na	1	1	1	5	3	5
Kanto	1923	5	5	5	na	4	5	3	1	1	1	1	5?	3?	5
Whittier	1987	3	1	3	na	1	1	1	1	4	3	4	5?	3?	1
Loma Prieta (San Francisco, EBMUD only)	1989	4	4	1	1	1	3	1	na	1	1	na	5	3	3
Landers/Big Bear	1992	5	1	na	na	1	na	na	1	3	3	4	5	5	1
Cape Mendecino	1993	5	3	1	na	1	na	na	na	1	1	1	5?	3?	1
Northridge	1994	5	4	5	4	1	5	3	na	4	3	5	5	5	1
Kobe	1995	5	5	3	?	1	5	3	na	3	1	2	5	5	5
Other Disasters															
Oakland Hills Fire	1991	4	5	2	na	na	na	1	na	4	na	na	na	na	5
Des Moines Flood	1993	5	3	2	4	1	1	5	na	4	1	1	2	1	1
Average		4.6	3.6	3.0	3.0	1.4	3.6	2.4	1.0	2.6	1.7	2.4	4.7	3.4	2.8

Note: ? indicates data unclear.

Ballantyne (2003)

2008 Mw 6.0 Wells Earthquake
Wells, Nevada
BJ'S STEAD
BARGAIN BARN
S. QUILICI & SONS

CAT



Approaches to Earthquake Resiliency

Water Systems are Lifelines

- Identifying and Prioritizing Seismic Vulnerabilities
- Emergency Response and Rapid Assessment Capabilities

Which Facilities are likely to:

- Have foundation deformation, strong shaking, or wave damage (surface rupture, liquefaction, low-velocity sediments)?
- Have collateral issues (e.g., rockfall), access issues (e.g., road failures), connection/transmission issues?
- Unreinforced masonry walls?

- Matrix of hazard/risk – prioritize list.
- Seismic mitigation/rehabilitation opportunities; maintenance schedule.

Emergency Response

- General Plan. Short plan for facility restoration including potential parts needed, equipment needed, manpower estimate, and time required.

- List highest needs sections of water system – first restoration.

- Decision guide – preloaded with intelligence. Where is demand highest. What can be brought back easiest? Dynamic prioritization of actions?

- Response Command/Decision Structure.

- Communication system – cell and land-lines out, internet maybe. Radios needed. Patch to state channels needed? Text?

- Employee Preparedness.
  - Earthquake reaction (no injuries)
  - Seismically mitigated home so family safe
  - Earthquake/Safety kits (in cars?; office)

- Out of Earthquake Effected Area utility pre-event agreements; parts, equipment, people.

- Practice/Exercise Emergency Response to earthquake scenarios.

Recovery

- Assess damages and needs; develop repair strategy and schedule.
- Gear up operations and staffing; expansion capabilities.
- Set up communication channels: Washoe County EOC, public.
- Begin emergency repairs; interim solutions.
- Disaster loans and grants – keep receipts and volunteer work hours – match.

- Opportunities: seismic rehabilitation, upgrade capability; maintenance cycles.

Earthquake Preparedness

1) Be Prepared to Respond – Drop, Cover, and Hold,

What do I do when an earthquake hits?

Do Not Run Out Of A Building During An Earthquake!!!

FIRST & GOAL INC.
AND
CUTTING EDGE
CONCEPTS
1000 FIRST AVENUE SOUTH
SUITE 200
ENTRANCE
Reserved
VIOLATORS
Will Be Towed
FIRST & GOAL
Stadium Exhibition Center
Located on Floor 2

Earthquake Preparedness

1) Be Prepared to Respond – Drop, Cover, and Hold,
2) Identify potential earthquake hazards in you home and workplace and mitigate them,

What are you protecting yourself from?

Nonstructural damage often can be easily prevented.

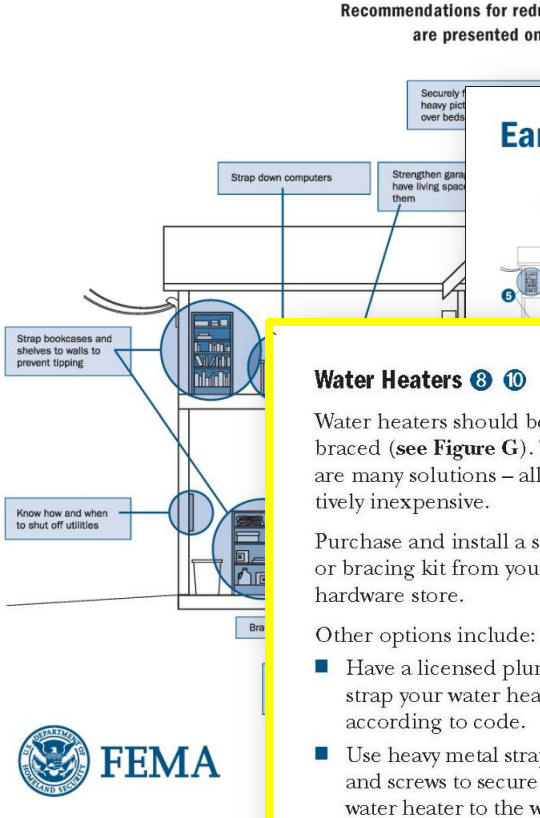
Secured computers at the
Clark County Building Department

Earthquake-secure bookshelves in the office of the State Geologist

Earthquake Home Hazard Hunt

FEMA 528 9/2005

Recommendations for reducing earthquake hazards in your home are presented on the other side of this poster.



FEMA

Earthquake Home Hazard Hunt

Correcting Problems

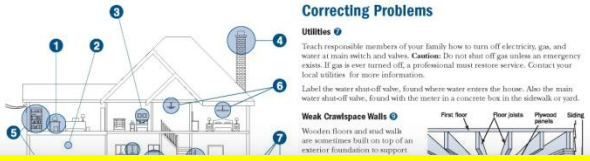
Utilities

Teach responsible members of your family how to turn off electricity, gas, and water at main switch and valves. **Caution:** Do not shut off gas unless an emergency exists. If gas is ever turned off, a professional must restore service. Contact your local utilities for more information.

Label the water shut-off valve, found where water enters the house. Also the main water shut-off valve, found with the meter in a concrete box in the sidewalk or yard.

Weak Crawlspace Walls

Wooden floors and stud walls are sometimes built on top of an exterior foundation to support



Hanging Objects

Prevent wall hangings from bouncing off walls:

- Secure mirrors, pictures, plants, and other objects on closed hooks.
- Secure the bottom corners with earthquake putty or adhesive pads.
- Place only soft art such as tapestries over beds and sofas.

Home Electronics

Electronics are heavy objects and costly to replace. Secure TVs, stereos, computers, and microwaves with earthquake-resistant flexible nylon straps and buckles for easy removal and relocation (**see Figure D**).

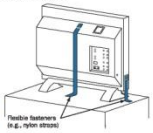
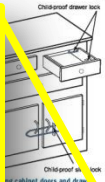


Figure D. Securing home electronics.



In the Kitchen

Cabinet doors, refrigerators, and gas appliances should be secured so that they will not move or fall over during an earthquake.

- First, secure all cabinets above waist level securely to the wall studs.
- Use latches designed for earthquake, child-proofing, or boat safety to keep cabinet doors from flying open and contents falling (**see Figure E**).
- Have a plumber install flexible connectors on gas appliances.

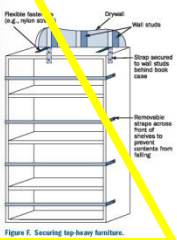


Figure F. Securing top-heavy furniture.

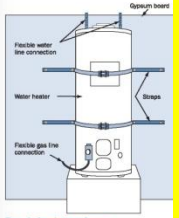


Figure G. Securing water heaters.

Take Action To Protect Yourself and Your Family From Earthquakes

Create and Practice Your Disaster Preparedness Plan

An emergency preparedness plan includes life-critical actions, life saving training, and the advance plans to enable you to respond to earthquakes and potential physical injuries and hazards no matter where you are.

Life-Critical Actions – Learn how to:

- Drop, cover, and hold.
- Signal for help, if you are trapped somewhere. Teach children and adults to use an emergency whistle and/or to knock three times repeatedly if trapped. Rescuers searching collapsed buildings will be listening for sounds.

Life Saving Training – Consider training in:

- First Aid
- CPR
- How to use a fire extinguisher
- How to shut off gas, water, and electricity

Your Disaster Preparedness Plan Should Include:

- Disaster Supplies Kits for home, workplace, and car
- Practicing Drop, Cover, and Hold
- Financial Plan
- Family Communications Plan that each family member understands
- Needs for all family members, including children, seniors, and pets

Financial Plan

You should store your family's documents, such as insurance policies, deeds, property records, birth certificates, and other important papers, in a safe place away from your home (e.g., safety deposit box). Make copies of important documents for your disaster supplies kit.

Consider saving money in an emergency savings account that could be used in any crisis. Back up critical files on your computer and keep a copy in a safe place away from your home.

Create Your Disaster Supplies Kit

Because you don't know where you and your family will be when an earthquake occurs, prepare a Disaster Supplies Kit for your home, workplace, and car. For detailed information about the items that should be included in your disaster supplies kit, refer to FEMA 526, *Earthquake Safety Checklist*.

Family Earthquake Drill

It's important to know where you should go for protection when your house starts to shake. By planning and practicing what to do before an earthquake occurs, you can condition yourself and your family to react correctly and spontaneously when the first jolt or shaking is felt. An earthquake drill can teach your family what to do in an earthquake.

- Each family member should know safe spots in each room.
- Safe spots: The best places to be are under heavy pieces of furniture, such as a desk or sturdy table; under supported archways; and against inside walls.
- Danger spots: Stay away from windows, hanging objects, mirrors, fireplaces, and tall, unsecured pieces of furniture.
- Reinforce this knowledge by physically placing yourself in the safe locations. This is especially important for children.
- In the days or weeks after this exercise, hold surprise drills.
- Be prepared to deal with what you may experience after an earthquake — both physically and emotionally.
- Following the drop, cover, and hold procedure is the best way to be safe during an earthquake.
- Take cover under a sturdy desk, table, or bench and hold on to the desk or table leg so that desk or table stays on top of you. Hold on until the earthquake shaking stops.
- Family members should practice drop, cover, and hold in the safe spots that you and your family have identified.

Further Information

For more information about earthquake preparedness and safety, refer to the following publications, which are available from the FEMA Distribution Facility at 1-800-480-2520. As noted, some are available for download from the FEMA website.

After Disaster Strikes: How to recover financially from a natural disaster, FEMA 292. Available in both English and Spanish.

Are You Ready? An In-depth Guide to Citizen Preparedness, IS-22, August 2004. Full publication and individual sections available online in both English and Spanish at **http://fema.gov/preparedness/prepare_guides_links.shtm**.

Before Disaster Strikes: How to make sure you're financially prepared to deal with a natural disaster, FEMA 291, May 1997. Available in both English and Spanish.

Earthquake Safety Checklist, FEMA 526, August 2005.

Earthquake Safety Guide for Homeowners, FEMA 530, September 2005.

Food and Water in an Emergency, FEMA 477, August 2004. Available online in both English and Spanish at **http://fema.gov/preparedness/prepare_guides_links.shtm**.

Preparing for Disaster for People with Disabilities and Special Needs, FEMA 476, August 2004. Available online in both English and Spanish at **http://fema.gov/preparedness/prepare_guides_links.shtm**.

Visit the FEMA website at **http://www.fema.gov/hazards/earthquakes/** for information about the National Earthquake Hazards Reduction Program (NEHRP) and more ways to address earthquake risks.

Water Heaters ❽ ❿

Water heaters should be braced (**see Figure G**). There are many solutions – all relatively inexpensive.

Purchase and install a strap kit or bracing kit from your local hardware store.

Other options include:

- Have a licensed plumber strap your water heater according to code.
- Use heavy metal strapping and screws to secure the water heater to the wall studs.

The gas and water lines should have flexible connector pipes. These are safer than rigid pipes during an earthquake. Be sure to check the straps once a year. They may come loose as a result of vibrations or other causes.

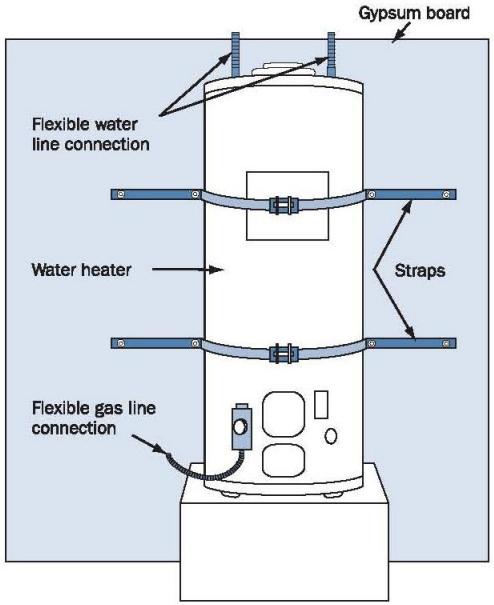
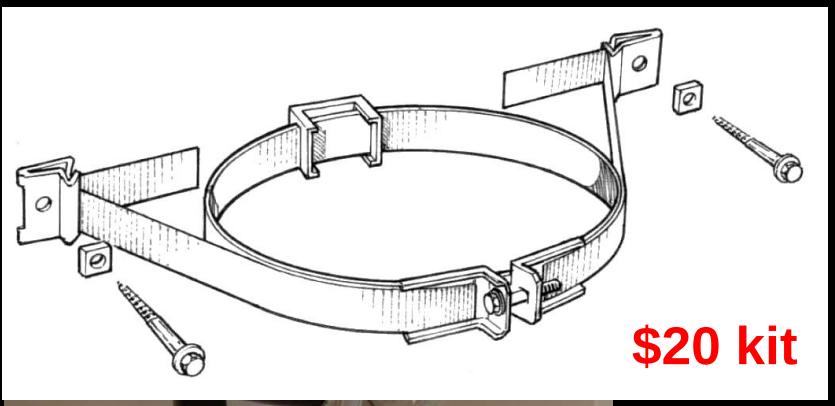
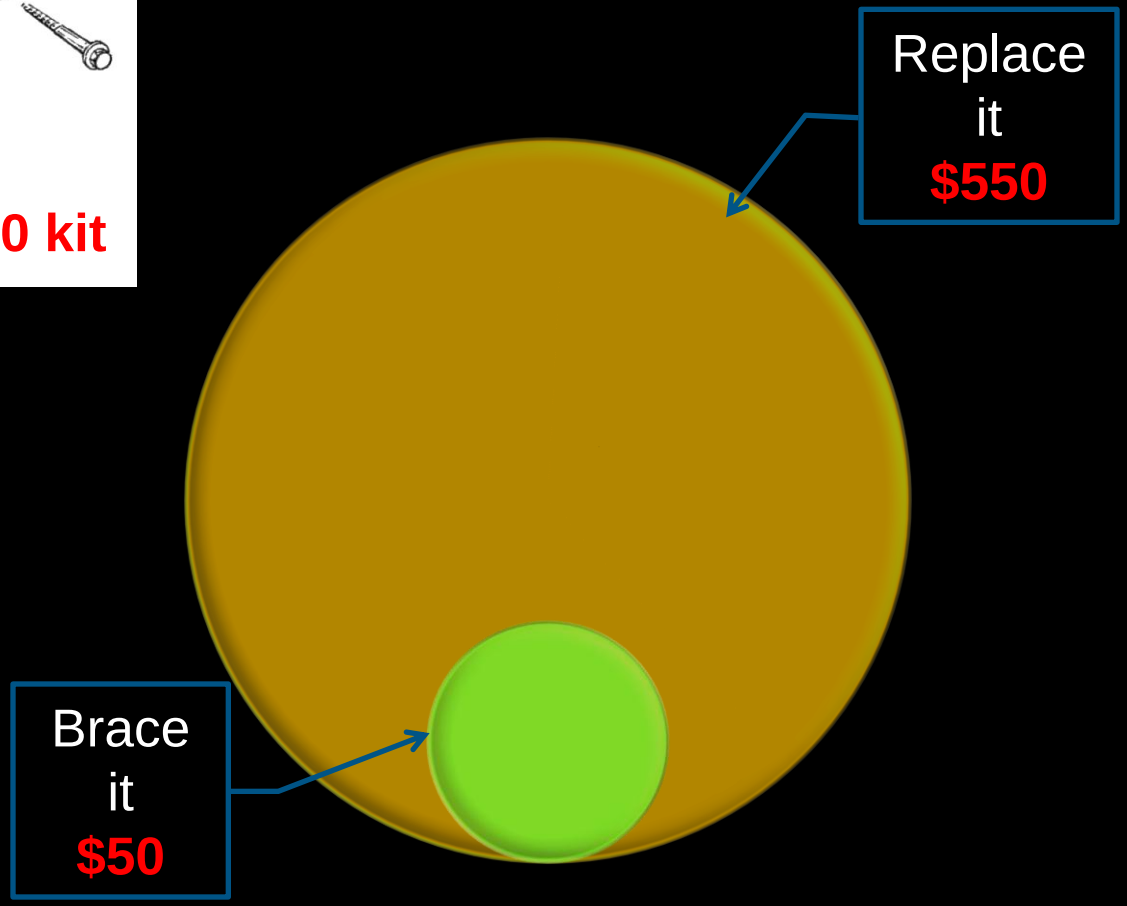


Figure G. Securing water heaters.

Brace it or replace it?





Earthquake Preparedness

1) Be Prepared to Respond – Drop, Cover, and Hold,
2) Identify potential earthquake hazards in you home and workplace and mitigate them,
3) Prepare a disaster kit (3 to 5 days),

Get Your Kit Together!

5 Days

Food, Supplies, Meds, Beer

Whatever You Need

Earthquake Preparedness

1) Be Prepared to Respond – Drop, Cover, and Hold,
2) Identify potential earthquake hazards in you home and workplace and mitigate them,
3) Prepare a disaster kit (5 days),
4) Create a disaster preparedness plan,

Earthquake Plan

The road to earthquake safety begins with your family earthquake plan. Follow these eight steps to prepare your plan. Then display it where you can review it with members of your household.

1 **Emergency locations.** Sketch you home's floor plan on this grid. Include symbols below for the safe and danger zones, supplies, utilities, evacuation routes, and reunion sites.

2 **Practice duck, cover, and hold** in the safe spots in every room. The earthquake drill should be exercised every three months. List dates practiced below.

_____

_____

_____

_____

_____

3 **Store supplies and prepare earthquake kits** (see lists on page 10).

- Safe spot
- Danger zone
- Evacuation Route
- Outside emergency reunion site
- First aid kit
- Utility shut-off valves
- Utility shut-off tool
- Fire extinguisher
- Personal earthquake kits
- Emergency supplies
- Critical papers
- Keys

4 **Family day locations and medical needs.** Discuss with your family what to do and where to go when an earthquake strikes at home, school, work, or wherever you regularly go during the day. List any allergies or medication needs for each family member below.

Person	Day Location	Meeting Place	Special Medical Needs

Note: Schools release children only to the person(s) authorized on the child's emergency information card. School officials do not have the authority to release your children to the Red Cross shelter set up at their school.

5 **Out-of-town contact:** _____ Phone: _____

Alternate contact: _____ Phone: _____

Earthquake Preparedness

1) Be Prepared to Respond – Drop, Cover, and Hold,
2) Identify potential earthquake hazards in you home and workplace and mitigate them,
3) Prepare a disaster kit (5 days),
4) Create a disaster preparedness plan,
5) Identify building weaknesses and fix.

Seismic Resilience

- Anchored to foundation?
- Built to building code?
- Lateral resistance?

Following An Earthquake

- Check on your neighbors, work together, reassure one another,

Following An Earthquake

- Check on your neighbors, work together, reassure one another,

- Begin clean up and recovery right away or as soon as it is safe to do so; taking control.

Following An Earthquake

- Check on your neighbors, work together, reassure one another,

- Begin clean up and recovery right away or as soon as it is safe to do so; taking control.

- Volunteer where you feel comfortable to do so; every agency and business will be stretched.

Great Nevada ShakeOut

Great Nevada ShakeOut

Register and Get Involved!

shakeout.org/nevada/

LIVING WITH EARTHQUAKES IN NEVADA

nbmg.unr.edu/dox/sp27.pdf

Nevada Bureau of Mines and Geology
nbmg.unr.edu

Nevada Seismological Laboratory
seismo.unr.edu

University of Nevada, Reno