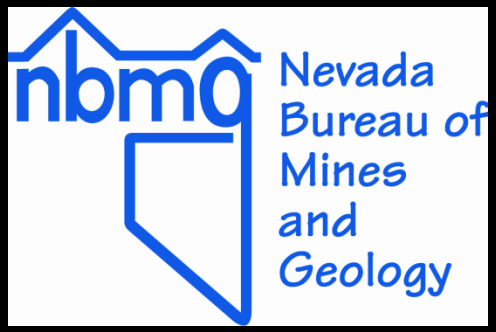
Earthquake Hazards in Carson City

Presentation by Jonathan G. Price and Craig M. dePolo
Nevada Bureau of Mines and Geology

Nevada Hazard Mitigation Planning Committee

7 February 2012

Earthquake faults occur throughout Nevada, and potential losses from earthquakes are high for many communities, including Carson City.



Earthquake faults occur throughout Nevada, and potential losses from earthquakes are high for many communities.

NBMG Map 167, *Quaternary Faults in Nevada*, is now available not only as a poster but also as an interactive map (Open-File Report 09-9) on line at www.nbmg.unr.edu. You can use it to locate your home or business.

Nevada Bureau of Mines and Geology

University of Nevada, Reno
Statewide • Worldwide

FEMA

Nevada Department of Public Safety
Division of Emergency Management

Nevada Earthquake Safety Council

USGS
science for a changing world

Nevada Seismological Laboratory

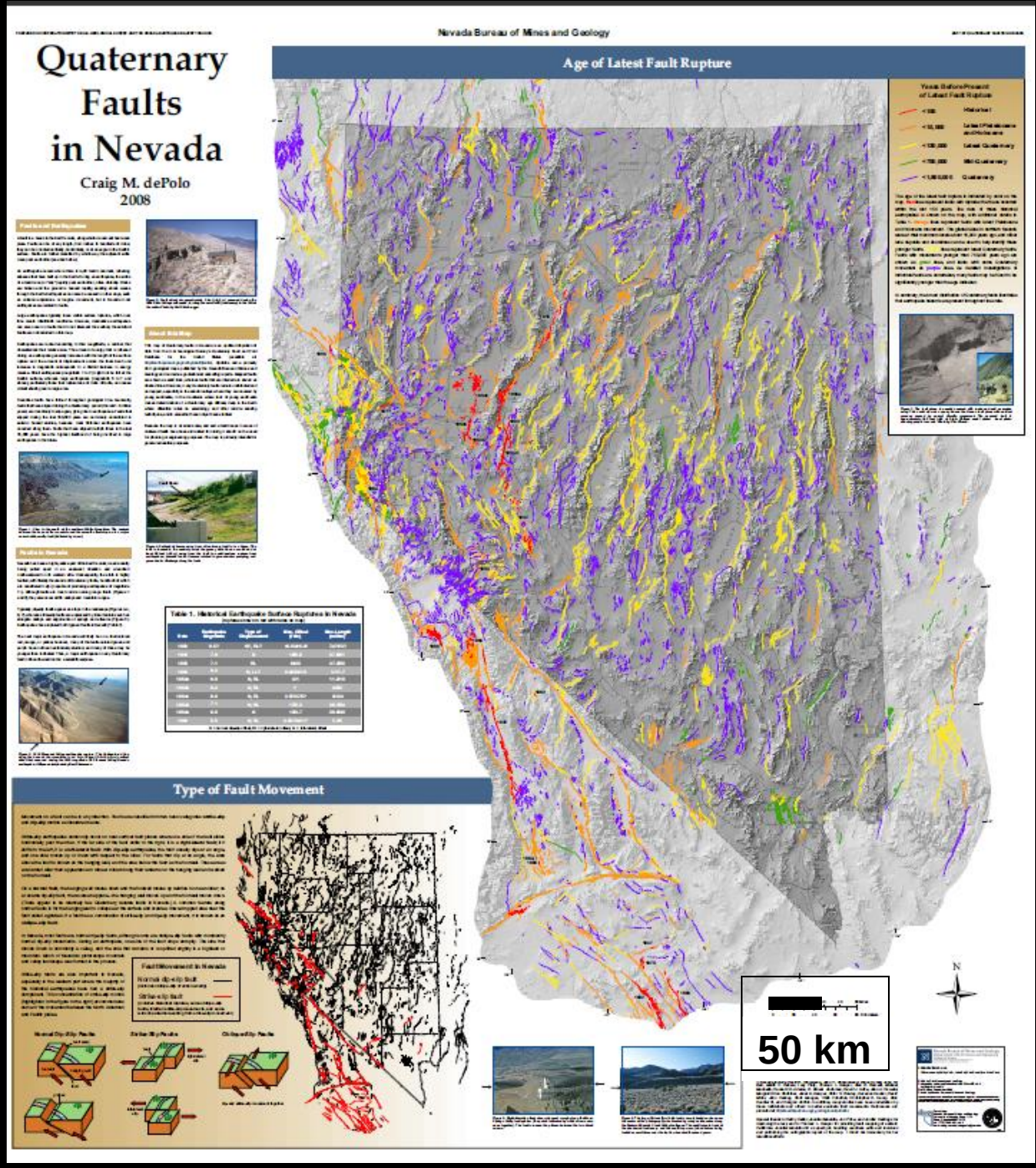
The Great Seal of the State of Nevada
All for our country

Age of Latest Fault Rupture

- < 150 years (historical)
- < 15,000 years
- < 130,000 years
- < 750,000 years
- < 1,800,000 years (Quaternary)

There are active faults nearly everywhere in Nevada.
A magnitude 6.0 earthquake can occur anywhere in Nevada.

www.nbmg.unr.edu



Quaternary Faults in Nevada - Online Interactive Map

www.nbmg.unr.edu

Look for a fault | Find Address

Easy to pinpoint an address

Results

Map Contents

Find Address

Street or Intersection: 1402 West King Street

City: Carson City

State: Nevada

ZIP:

Find Your Address

Quaternary Faults in Nevada - Online Interactive Map

www.nbmg.unr.edu

Look for a fault | Find Address

Easy to pinpoint an address

Results

- 1402 West King Street, Carson C
  - 1402 W King St, Carson City, NV

Map Contents

- Quaternary_Faults
  - Legend
  - Base Data
- 9i10glj_TOPO_data
  - Base Data
- USGS_aerial_photographs
  - Base Data

Quaternary Faults in Nevada - Online Interactive Map **www.nbmg.unr.edu**

Look for a fault | Find Address

Multiple ways to zoom in to a location

Results

- **1402 West King Street, Carson C**
  - 1402 W King St, Carson City, NV
    - Zoom to
    - Pan to
    - Remove

Map Contents

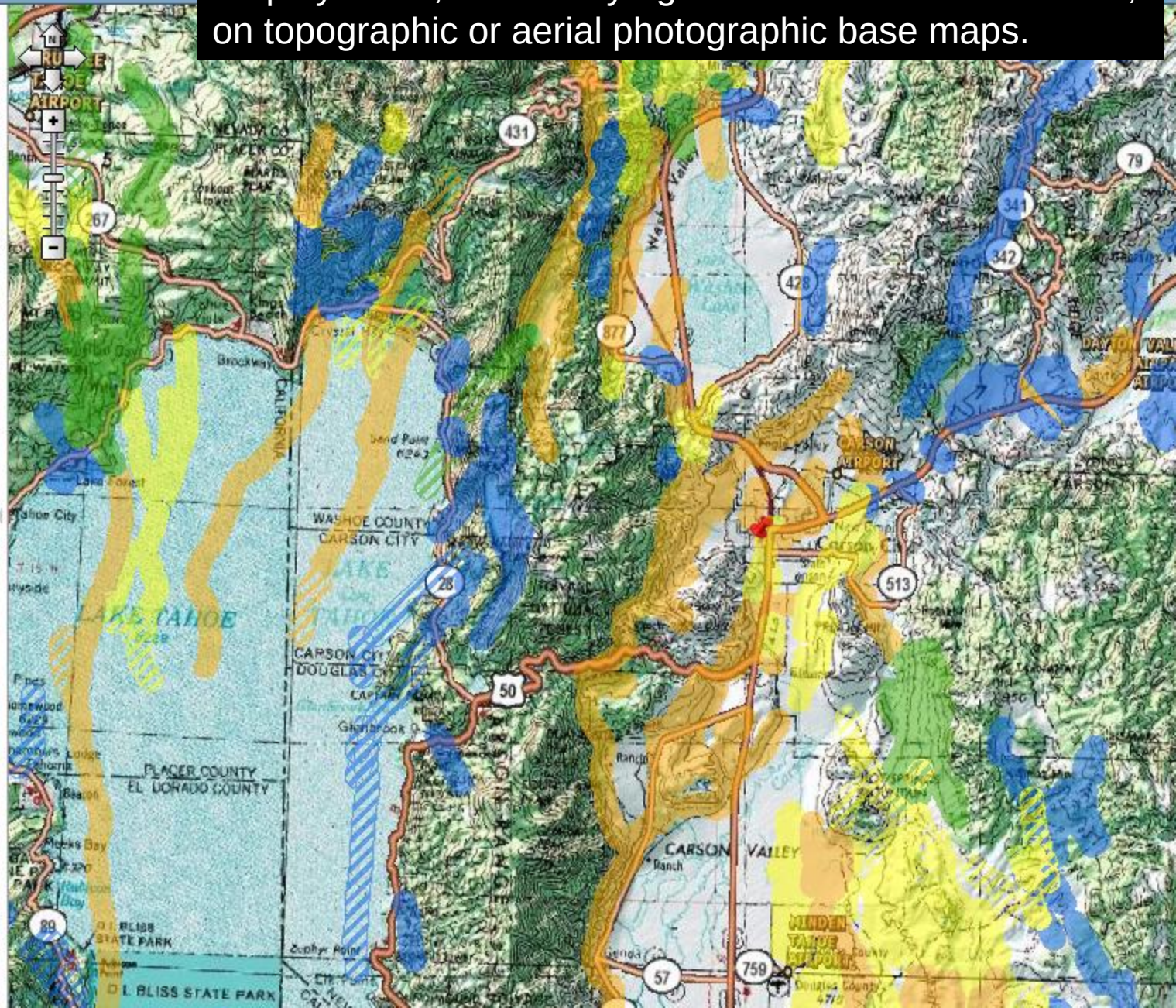
- Quaternary_Faults
  - Legend
  - Base Data
- 9i10glj_TOPO_data
  - Base Data
- USGS_aerial_photographs
  - Base Data

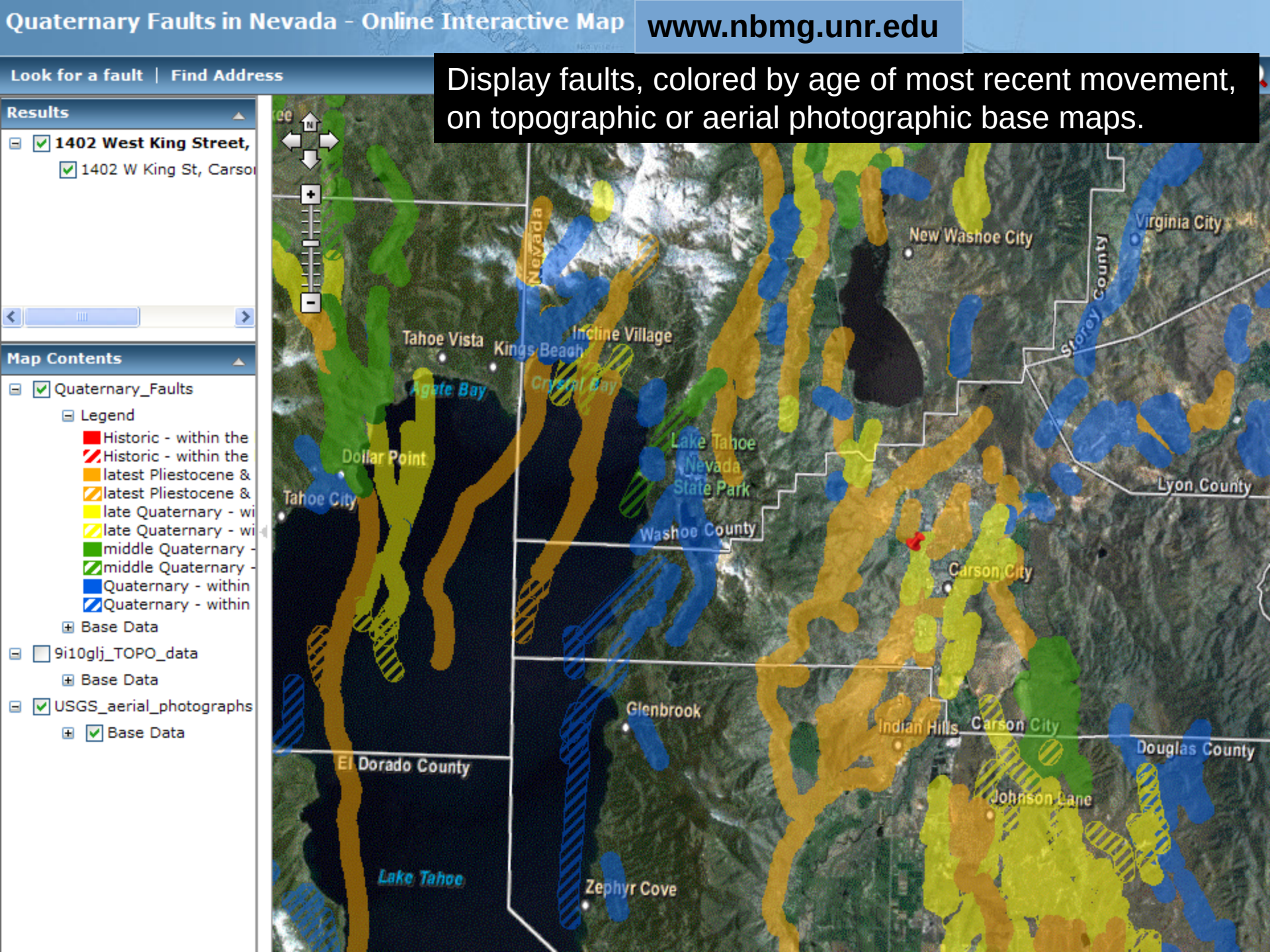
Quaternary Faults in Nevada - Online Interactive Map

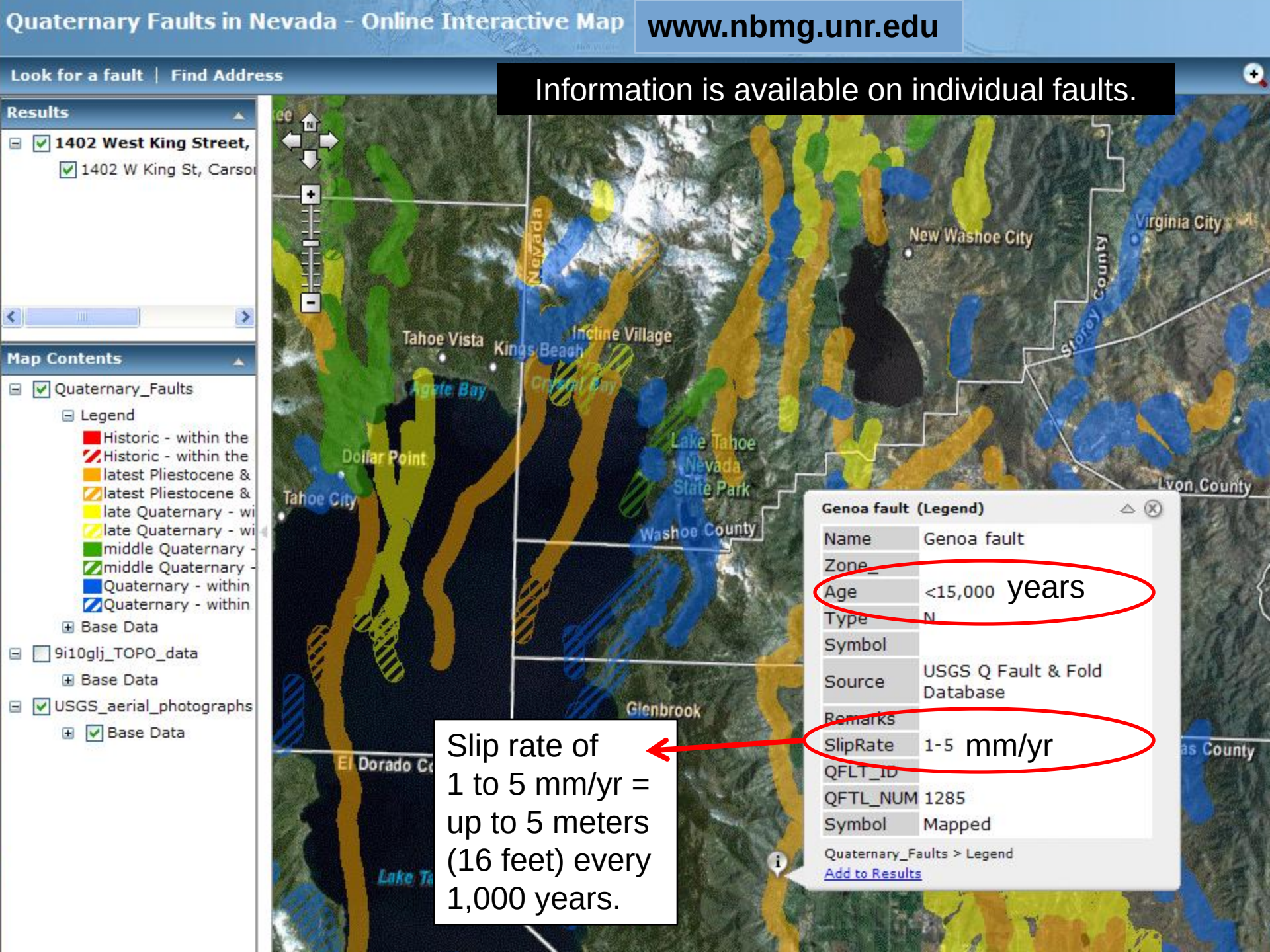
www.nbmg.unr.edu

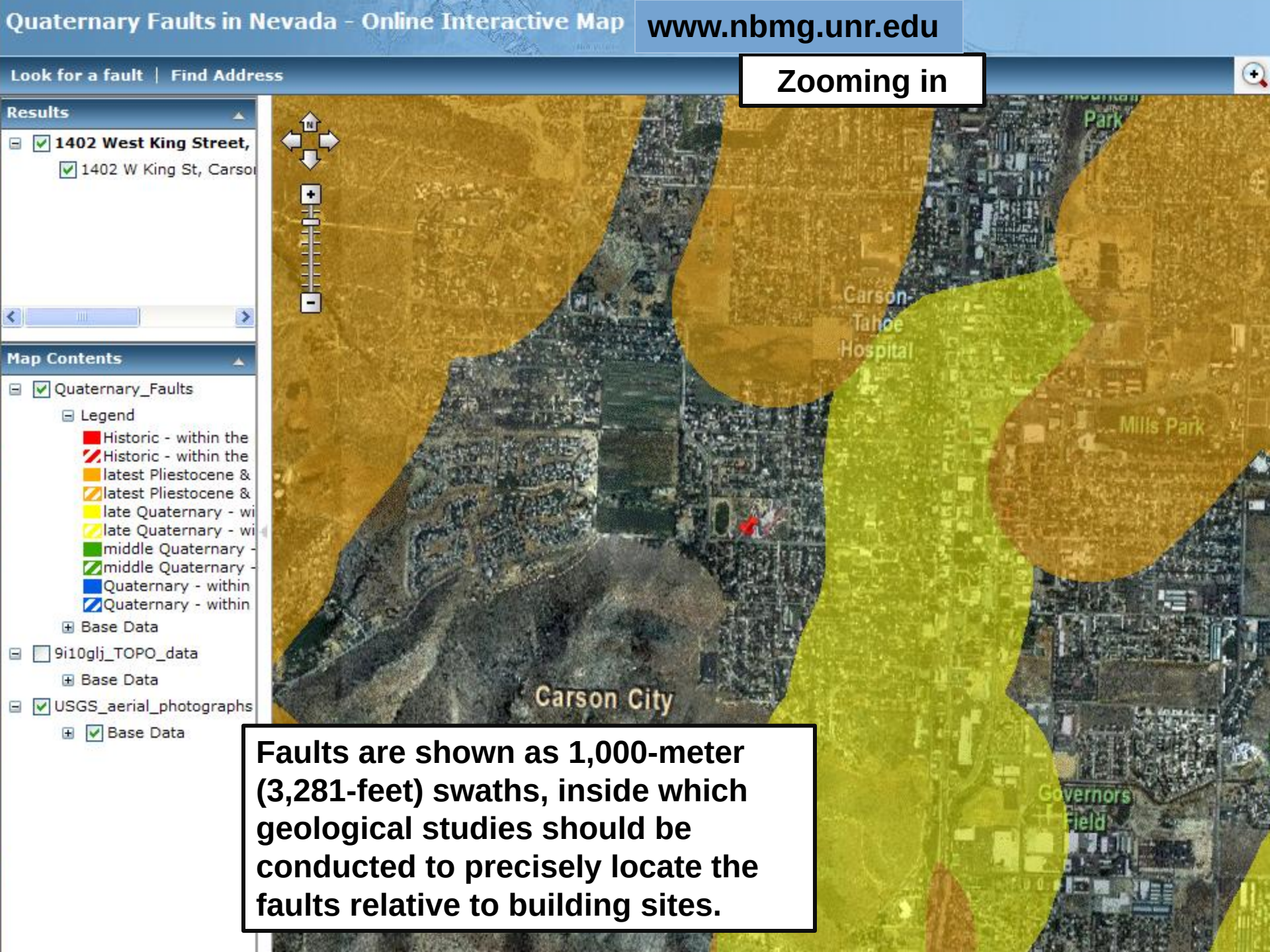
Look for a fault | Find Address

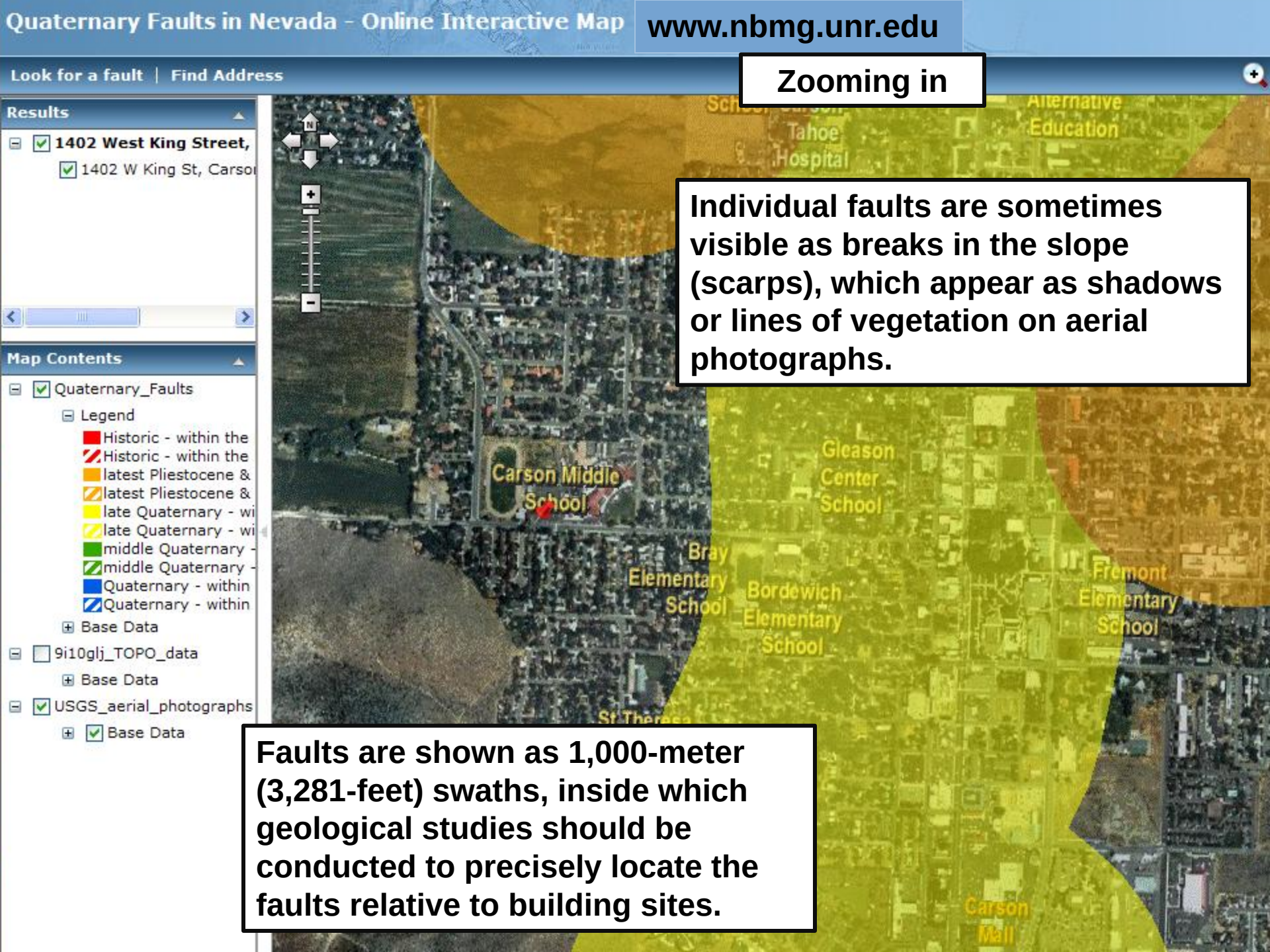
Display faults, colored by age of most recent movement, on topographic or aerial photographic base maps.



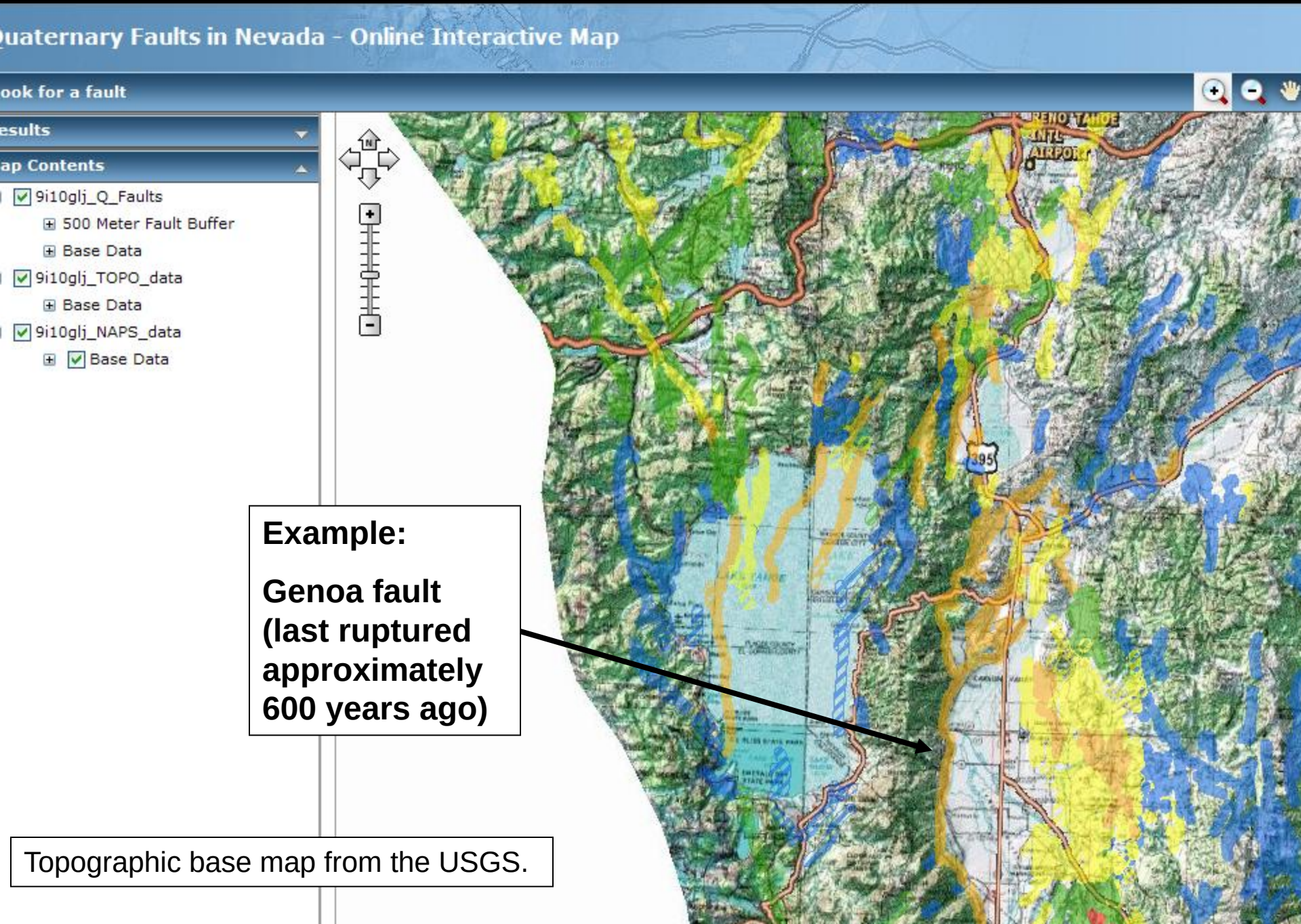

Quaternary Faults in Nevada - Online Interactive Map
www.nbmg.unr.edu
Look for a fault | Find Address
Display faults, colored by age of most recent movement, on topographic or aerial photographic base maps.
Results
1402 West King Street,
1402 W King St, Carso
Map Contents
Quaternary_Faults
Legend
Historic - within the
Historic - within the
latest Pliestocene &
latest Pliestocene &
late Quaternary - wi
late Quaternary - wi
middle Quaternary -
middle Quaternary -
Quaternary - within
Quaternary - within
Base Data
9i10glj_TOPO_data
Base Data
USGS_aerial_photographs
Base Data
Tahoe Vista
Kings Beach
Incline Village
Agate Bay
Crystal Bay
Dollar Point
Tahoe City
Lake Tahoe
Nevada
State Park
Washoe County
New Washoe City
Virginia City
Storey County
Lyon County
Carson City
Glenbrook
Indian Hills
Carson City
Douglas County
Johnson Lane
El Dorado County
Lake Tahoe
Zephyr Cove


Quaternary Faults in Nevada - Online Interactive Map
www.nbmg.unr.edu
Look for a fault | Find Address
Information is available on individual faults.
Results
1402 West King Street,
1402 W King St, Carson
Map Contents
Quaternary_Faults
Legend
Historic - within the
Historic - within the
latest Pliestocene &
latest Pliestocene &
late Quaternary - wi
late Quaternary - wi
middle Quaternary -
middle Quaternary -
Quaternary - within
Quaternary - within
Base Data
9i10glj_TOPO_data
Base Data
USGS_aerial_photographs
Base Data
Tahoe Vista
Kings Beach
Incline Village
Crystal Bay
Agate Bay
Dollar Point
Tahoe City
Lake Tahoe Nevada State Park
Washoe County
New Washoe City
Virginia City
Storey County
Lyon County
Glenbrook
El Dorado Co
Genoa fault (Legend)
Name Genoa fault
Zone
Age <15,000 years
Type N
Symbol
Source USGS Q Fault & Fold Database
Remarks
SlipRate 1-5 mm/yr
QFLT_ID
QFTL_NUM 1285
Symbol Mapped
Quaternary_Faults > Legend
Add to Results
Slip rate of 1 to 5 mm/yr = up to 5 meters (16 feet) every 1,000 years.

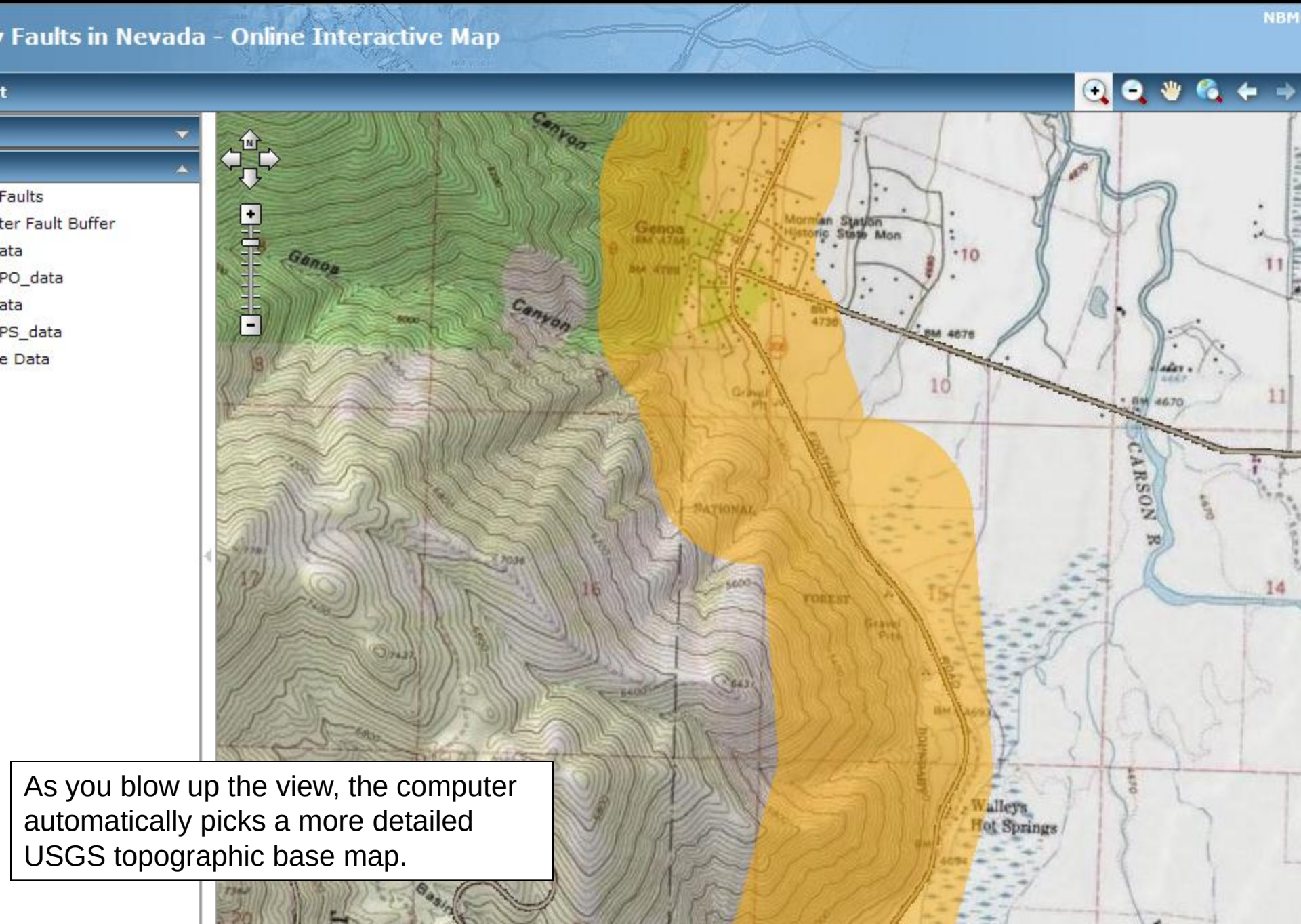

Quaternary Faults in Nevada - Online Interactive Map
www.nbmg.unr.edu
Look for a fault | Find Address
Zooming in
Results
1402 West King Street,
1402 W King St, Carso
Map Contents
Quaternary_Faults
Legend
Historic - within the
Historic - within the
latest Pliestocene &
latest Pliestocene &
late Quaternary - wi
late Quaternary - wi
middle Quaternary -
middle Quaternary -
Quaternary - within
Quaternary - within
Base Data
9i10glj_TOPO_data
Base Data
USGS_aerial_photographs
Base Data
Carson Tahoe Hospital
Mills Park
Carson City
Governors Field
Faults are shown as 1,000-meter (3,281-feet) swaths, inside which geological studies should be conducted to precisely locate the faults relative to building sites.

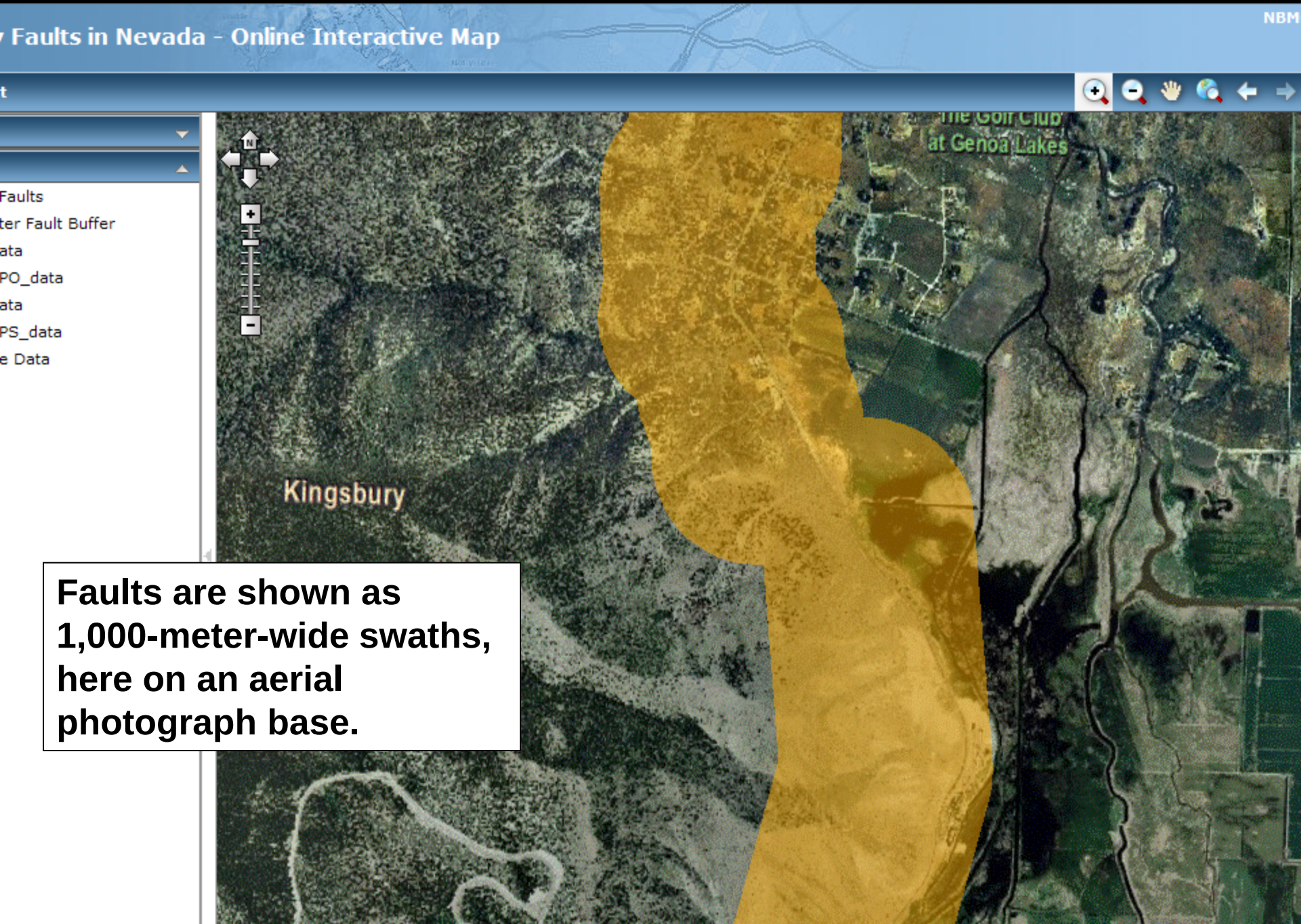

Quaternary Faults in Nevada - Online Interactive Map
www.nbmg.unr.edu
Look for a fault | Find Address
Zooming in
Results
1402 West King Street,
1402 W King St, Carso
Map Contents
Quaternary_Faults
Legend
Historic - within the
Historic - within the
latest Pliestocene &
latest Pliestocene &
late Quaternary - wi
late Quaternary - wi
middle Quaternary -
middle Quaternary -
Quaternary - within
Quaternary - within
Base Data
9i10glj_TOPO_data
Base Data
USGS_aerial_photographs
Base Data
Individual faults are sometimes visible as breaks in the slope (scarps), which appear as shadows or lines of vegetation on aerial photographs.
Faults are shown as 1,000-meter (3,281-feet) swaths, inside which geological studies should be conducted to precisely locate the faults relative to building sites.
Tahoe Hospital
Alternative Education
Carson Middle School
Gleason Center School
Bray Elementary School
Bordewich Elementary School
Fremont Elementary School
Carson Mall

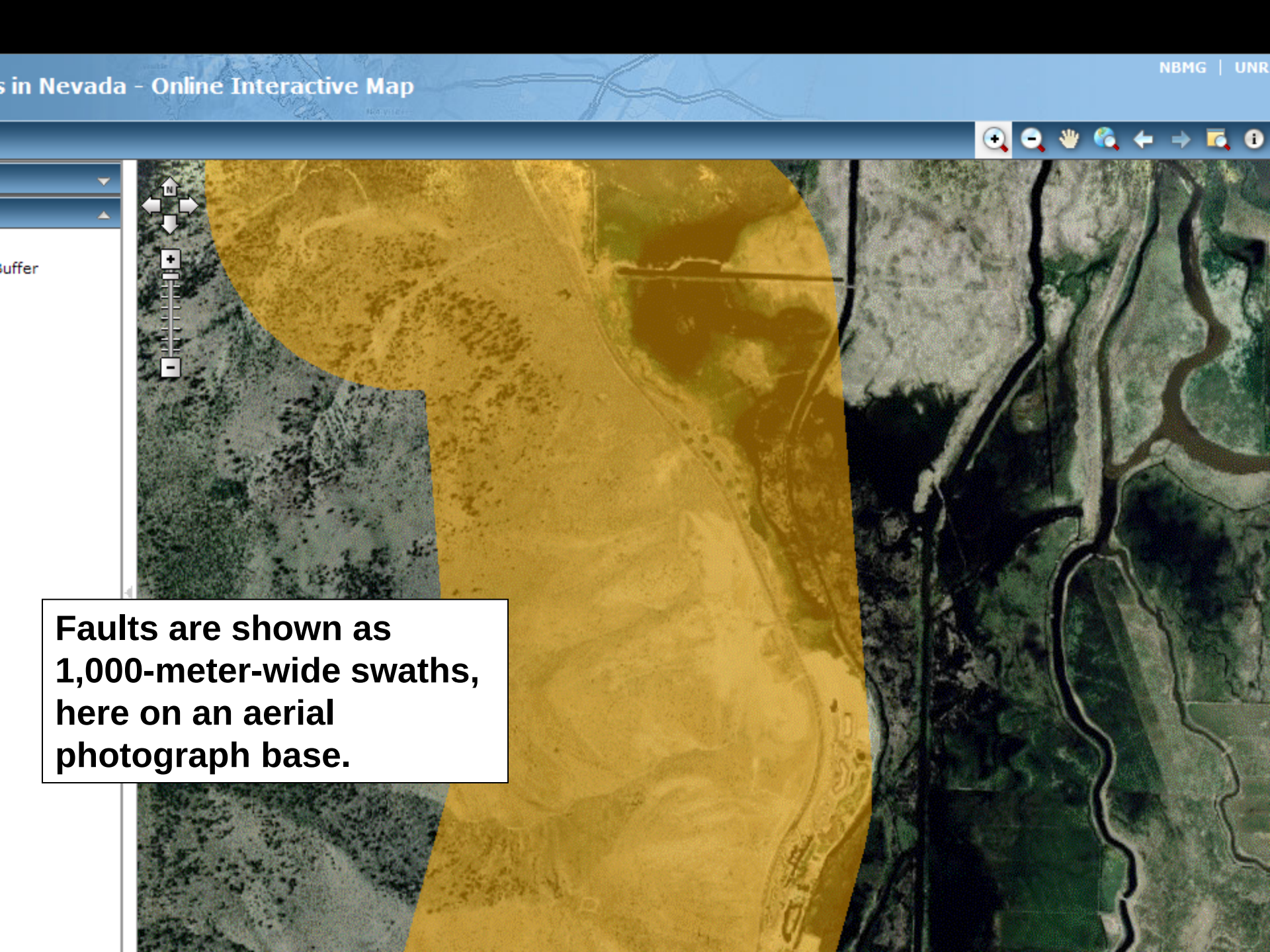
Individual faults are sometimes visible as breaks in the slope (scarps), as along US-395 north of Williams Street.

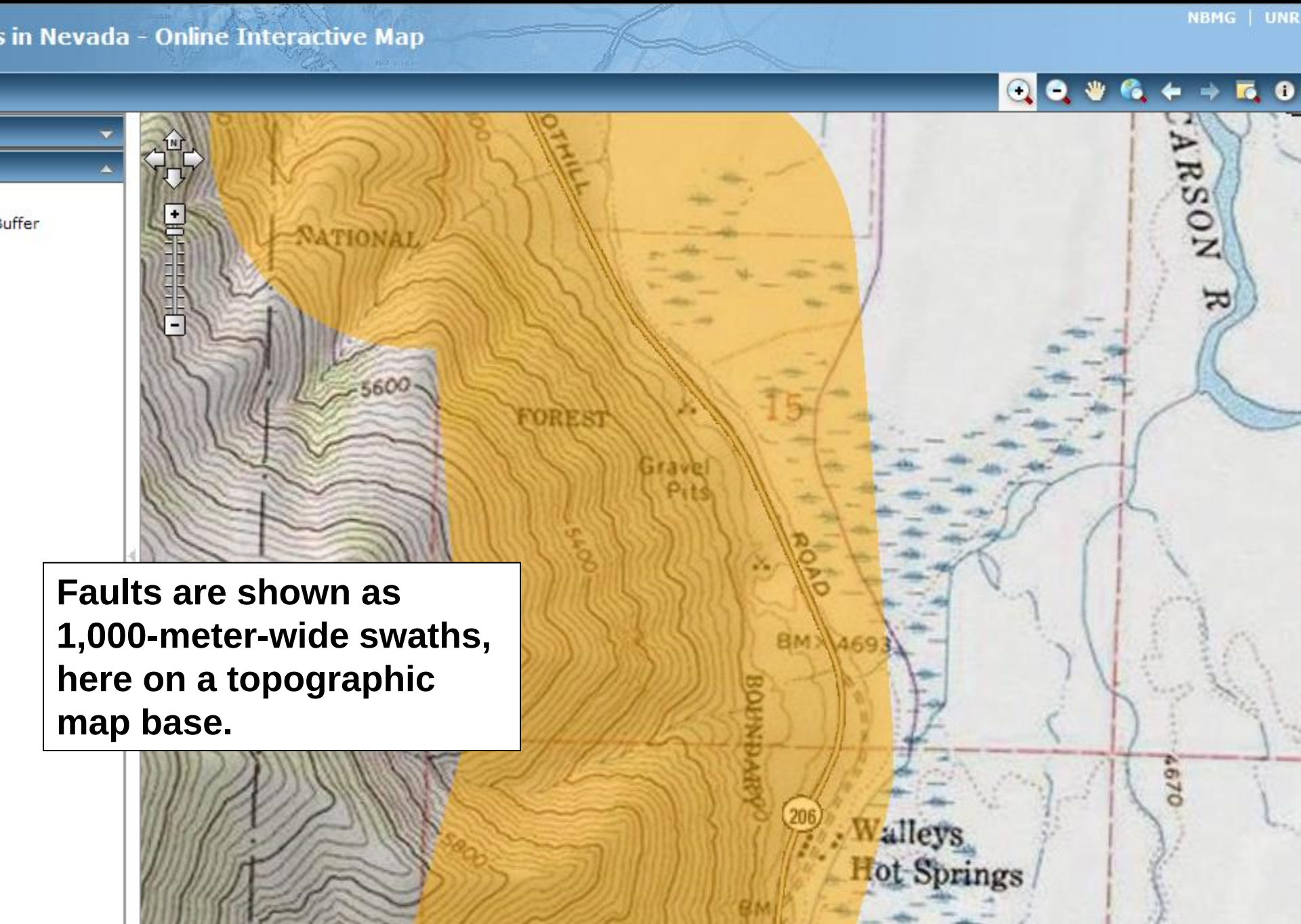

Quaternary Faults in Nevada - Online Interactive Map
ook for a fault
esults
ap Contents
9i10glj_Q_Faults
500 Meter Fault Buffer
Base Data
9i10glj_TOPO_data
Base Data
9i10glj_NAPS_data
Base Data
RENO TAHOE INTL AIRPORT
395
Example:
Genoa fault (last ruptured approximately 600 years ago)
Topographic base map from the USGS.

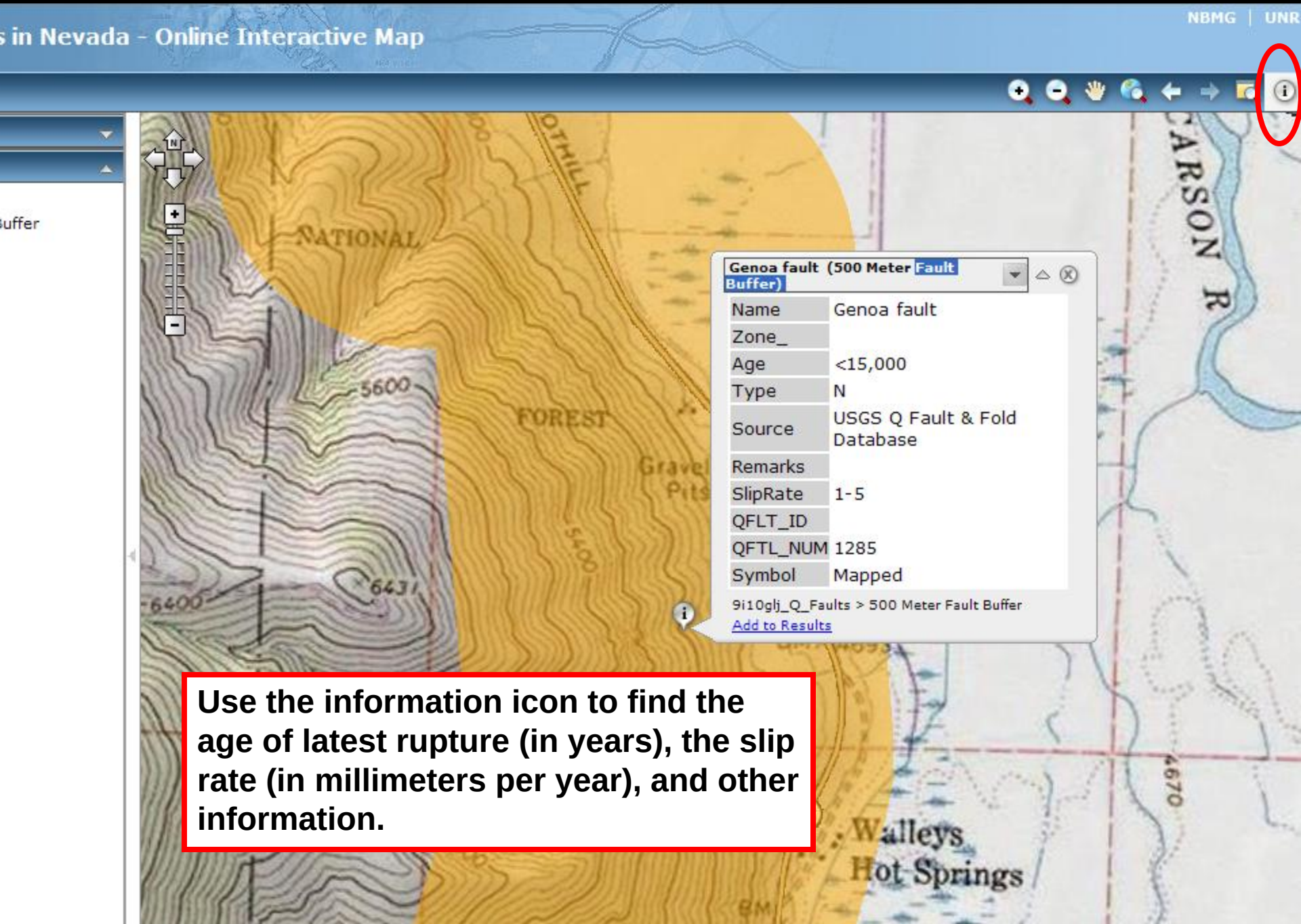
As you blow up the view, the computer automatically picks a more detailed USGS topographic base map.

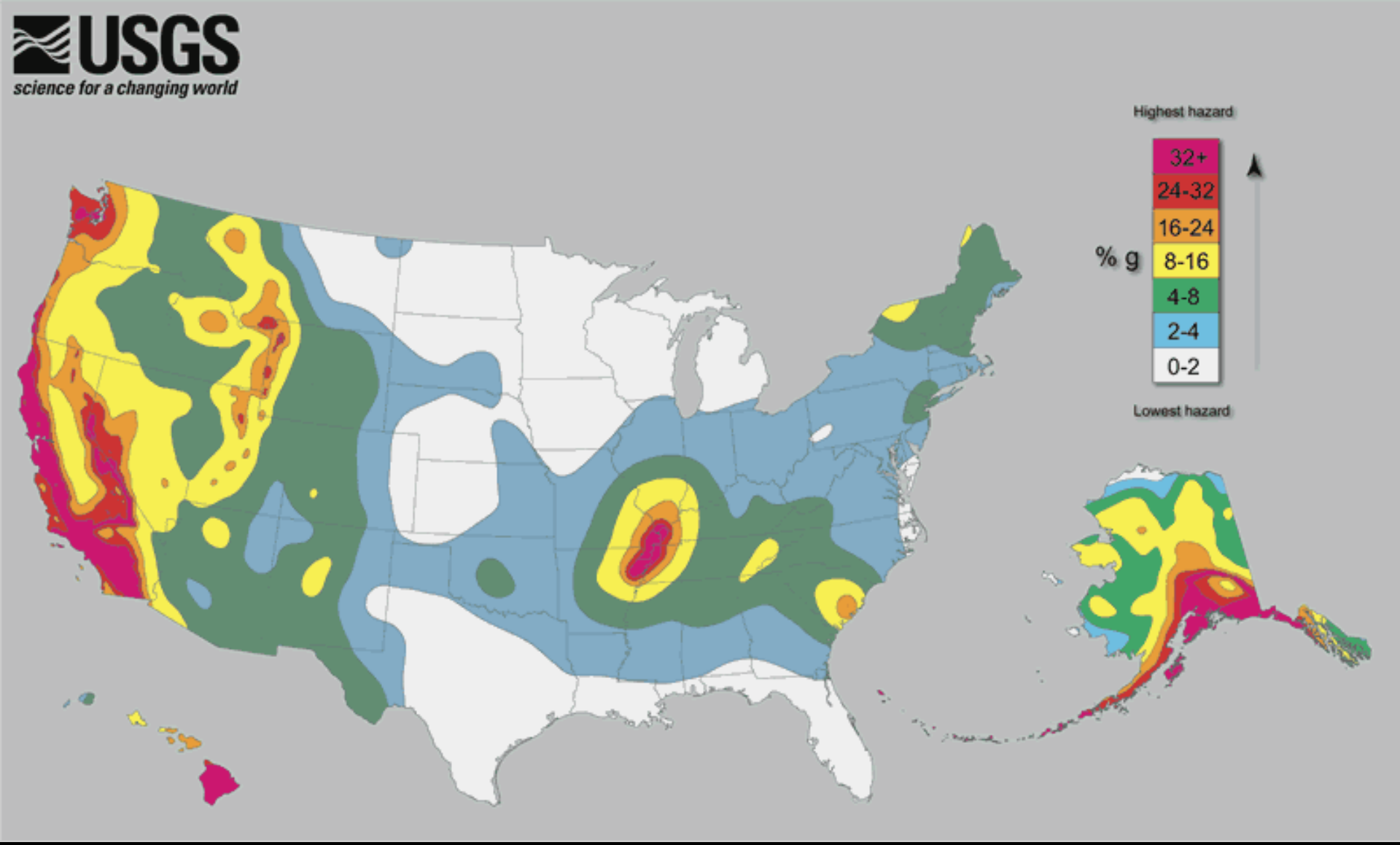

Faults in Nevada - Online Interactive Map
NBM
Faults
ter Fault Buffer
ata
PO_data
ata
PS_data
e Data
Genoa
Canyon
Mormon Station Historic State Mon
CARSON R
Walleys Hot Springs
As you blow up the view, the computer automatically picks a more detailed USGS topographic base map.


Faults in Nevada - Online Interactive Map
NBM
Faults
ter Fault Buffer
ata
PO_data
ata
PS_data
e Data
at Genoa Lakes
Kingsbury
Faults are shown as 1,000-meter-wide swaths, here on an aerial photograph base.

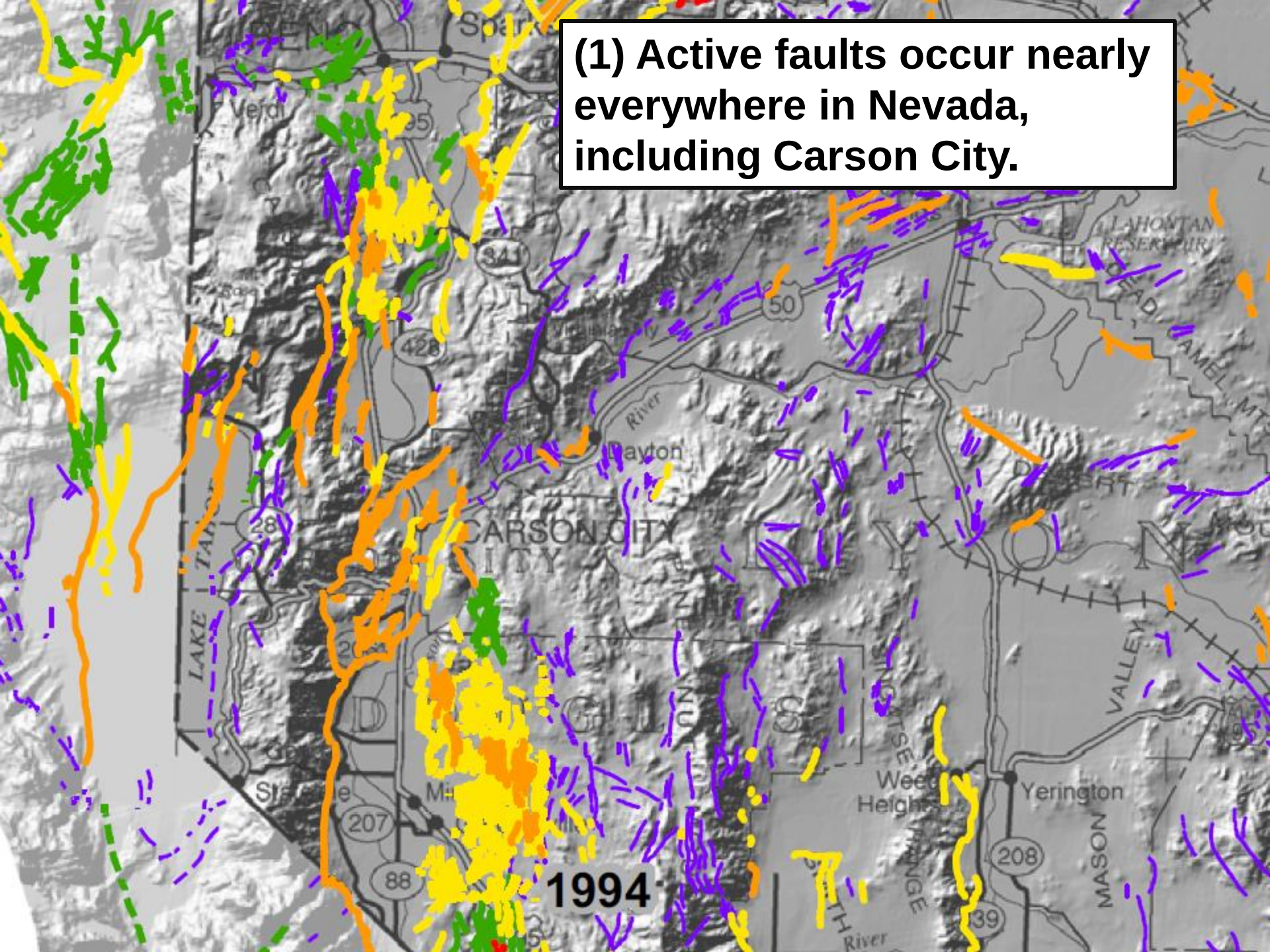

s in Nevada - Online Interactive Map
NBMG | UNR
Buffer
Faults are shown as 1,000-meter-wide swaths, here on an aerial photograph base.

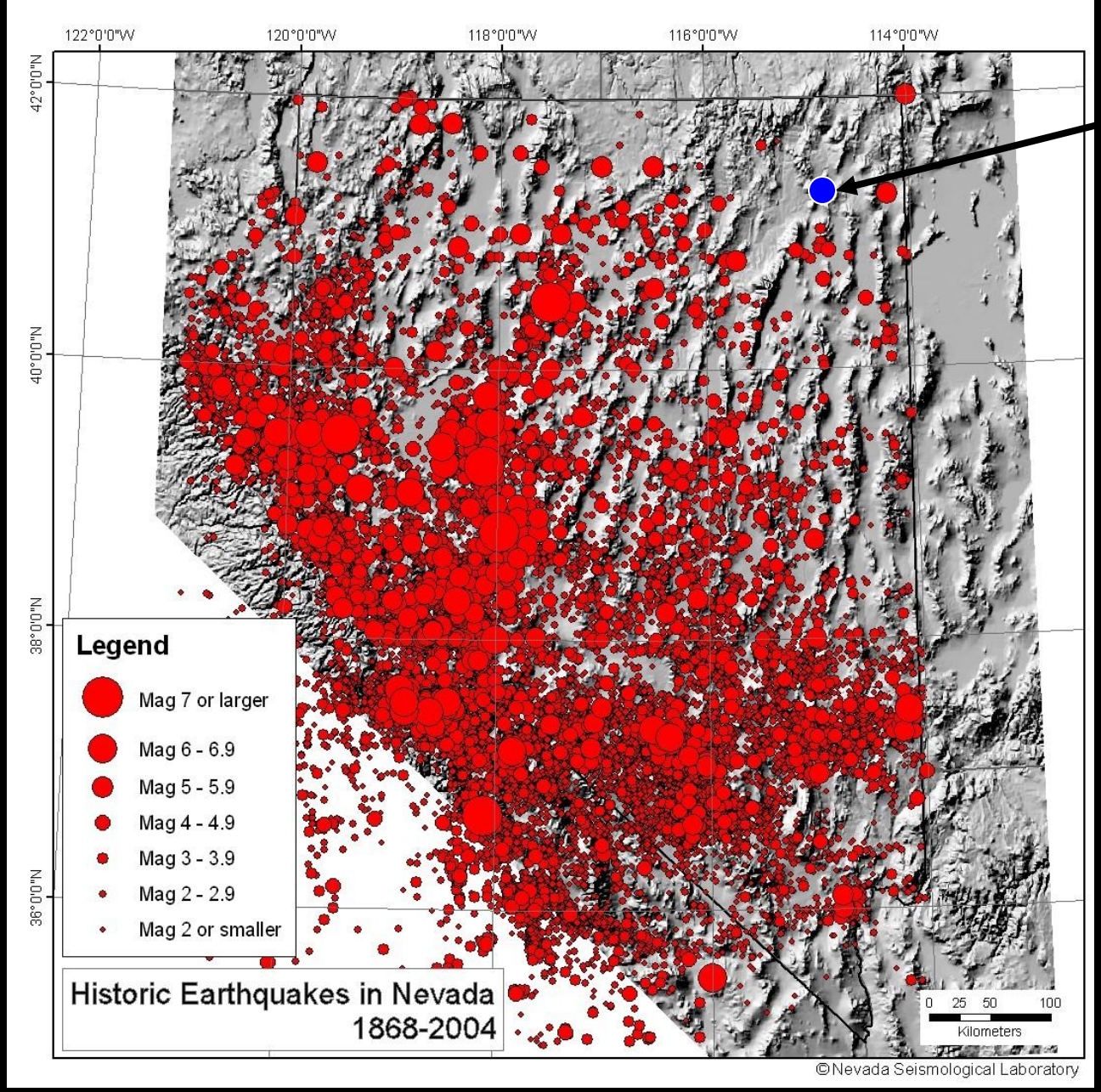

s in Nevada - Online Interactive Map
NBMG | UNR
Buffer
NATIONAL
FOREST
5600
5400
5800
Gravel Pits
15
ROAD
BOUNDARY
BM 4693
206
Walleys Hot Springs
CARSON R
4670
Faults are shown as 1,000-meter-wide swaths, here on a topographic map base.


s in Nevada - Online Interactive Map
NBMG | UNR
Buffer
NATIONAL
FOREST
5600
6400
6431
5400
Gravel Pits
CARSON R
4670
Walleys Hot Springs
Genoa fault (500 Meter Fault Buffer)
Name Genoa fault
Zone_
Age <15,000
Type N
Source USGS Q Fault & Fold Database
Remarks
SlipRate 1-5
QFLT_ID
QFTL_NUM 1285
Symbol Mapped
9i10glj_Q_Faults > 500 Meter Fault Buffer
Add to Results
Use the information icon to find the age of latest rupture (in years), the slip rate (in millimeters per year), and other information.



The USGS integrates (1) fault, (2) earthquake, and (3) geodetic data into its probabilistic seismic hazard analysis.


(1) Active faults occur nearly everywhere in Nevada, including Carson City.
1994
Dayton
CARSON CITY
Yerington
Weed Heights
LAKE
MASON
VALLEY
River
50
341
428
28
207
88
208
39



(2) Earthquakes have occurred throughout Nevada.

A Geodetic Strain Rate Model for the Pacific–North American Plate Boundary, Western United States

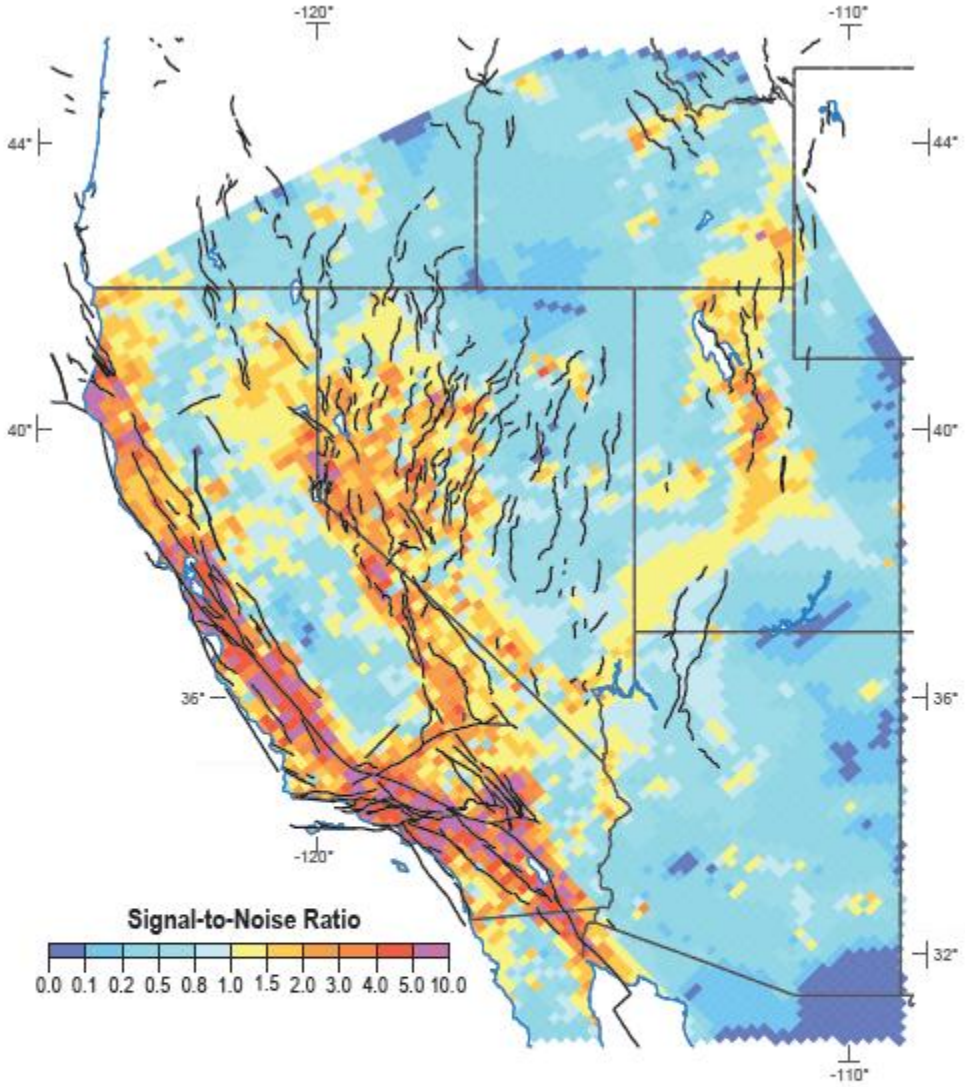
Corné Kreemer[1]
William C. Hammond[1]
Geoffrey Blewitt[1]
Austin A. Holland[2]
Richard A. Bennett[2]

[1]Nevada Bureau of Mines and Geology, University of Nevada Reno
[2]Department of Geological Sciences, University of Arizona

2012

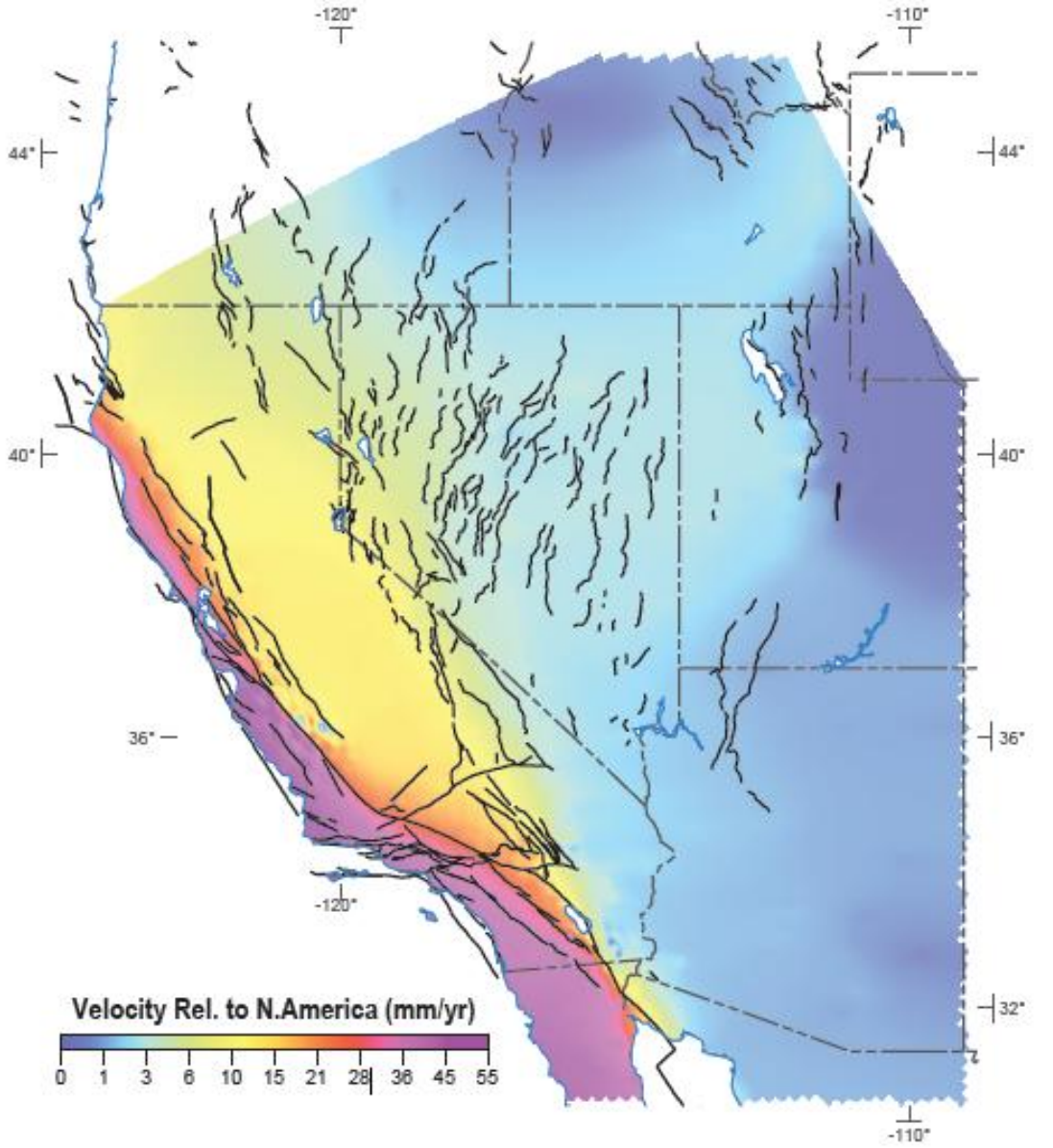
(3) Geodetic data indicate that the Nevada is gaining about 0.2 acre of area per year through crustal extension, and that western Nevada is accommodating ~20% of the North American-Pacific plate interaction.

Kreemer et al. (2012)



Signal-to-noise (SNR) ratio defined as the ratio of second invariant of the strain rate over the a posteriori standard deviation These values are strongly affected by the GPS station density and the precision of velocities. Everywhere where SNR<1 the area could be considered rigid within one standard deviation. Conversely, for areas that the model suggests are nearly rigid and where SNR<1 (e.g., Arizona, eastern Nevada) strain rates may be much more localized (i.e., higher) than the model suggests.

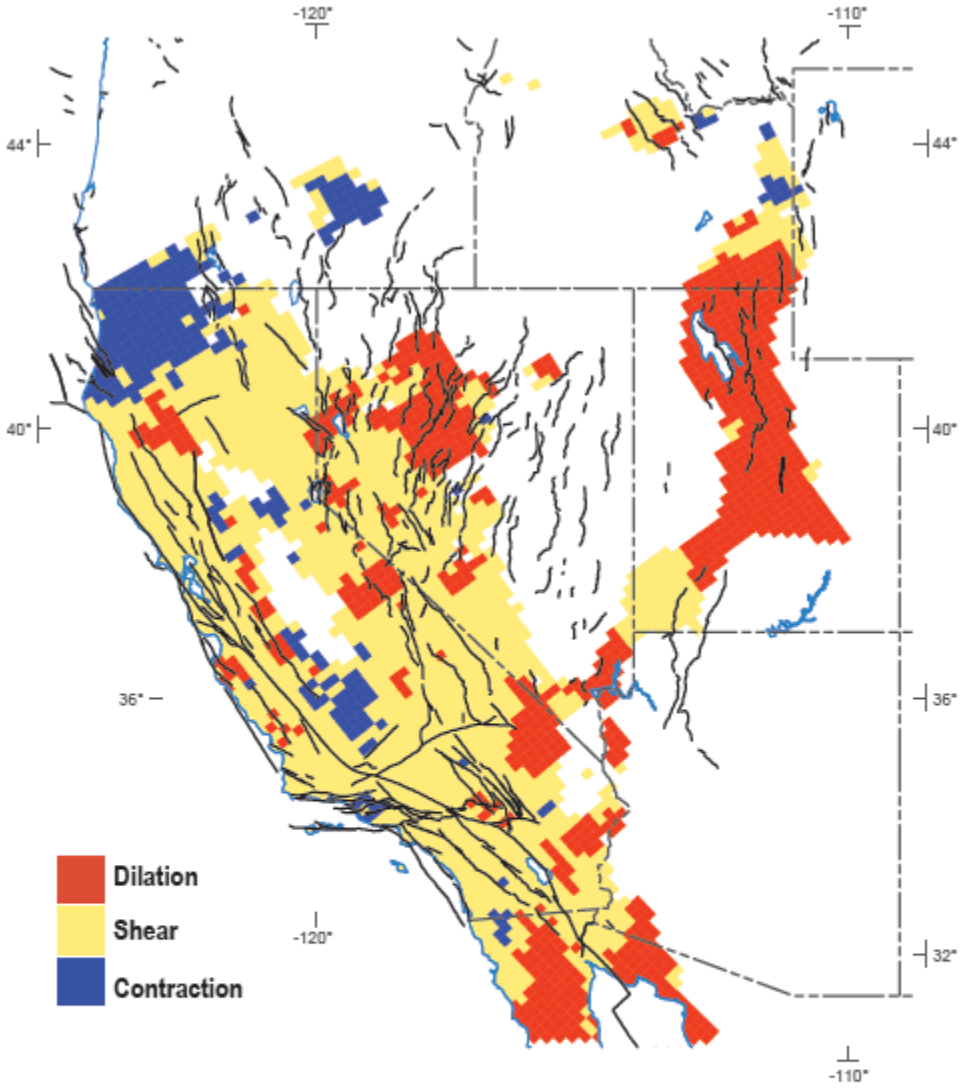
Uncertainty is high in areas with few geodetic GPS data points (areas in blue on this map).



Contour map of the amplitude of interpolated velocities relative to North America. Results are clipped at coast.

West of the San Andreas fault in California, the Pacific Plate is moving northwest relative to the North American Plate.

Kreemer et al. (2012)



General style of deformation for all areas where at least one strain rate principal component is > 6 nanostrain/yr. Results are spatially averaged. We define shear where the largest absolute principal value is less than twice the smallest absolute principal value. If not shear, we define dilatation or contraction when the largest principal value is positive or negative, respectively. Results are clipped at coast.

Western Nevada is accommodating ~20% of the North American-Pacific plate interaction, mostly along right-lateral strike-slip faults and oblique-slip normal faults.

Extension is occurring mostly in western and central Nevada (and along the Wasatch front in Utah) along normal faults.

Kreemer et al. (2012)

State	Surface Growth (acres/yr)
AZ	0.08
CA	-0.96
NV	0.20
UT	0.21

The negative value for California indicates shrinking, not growing.

Nevada and Utah are growing.

Kreemer et al. (2012)

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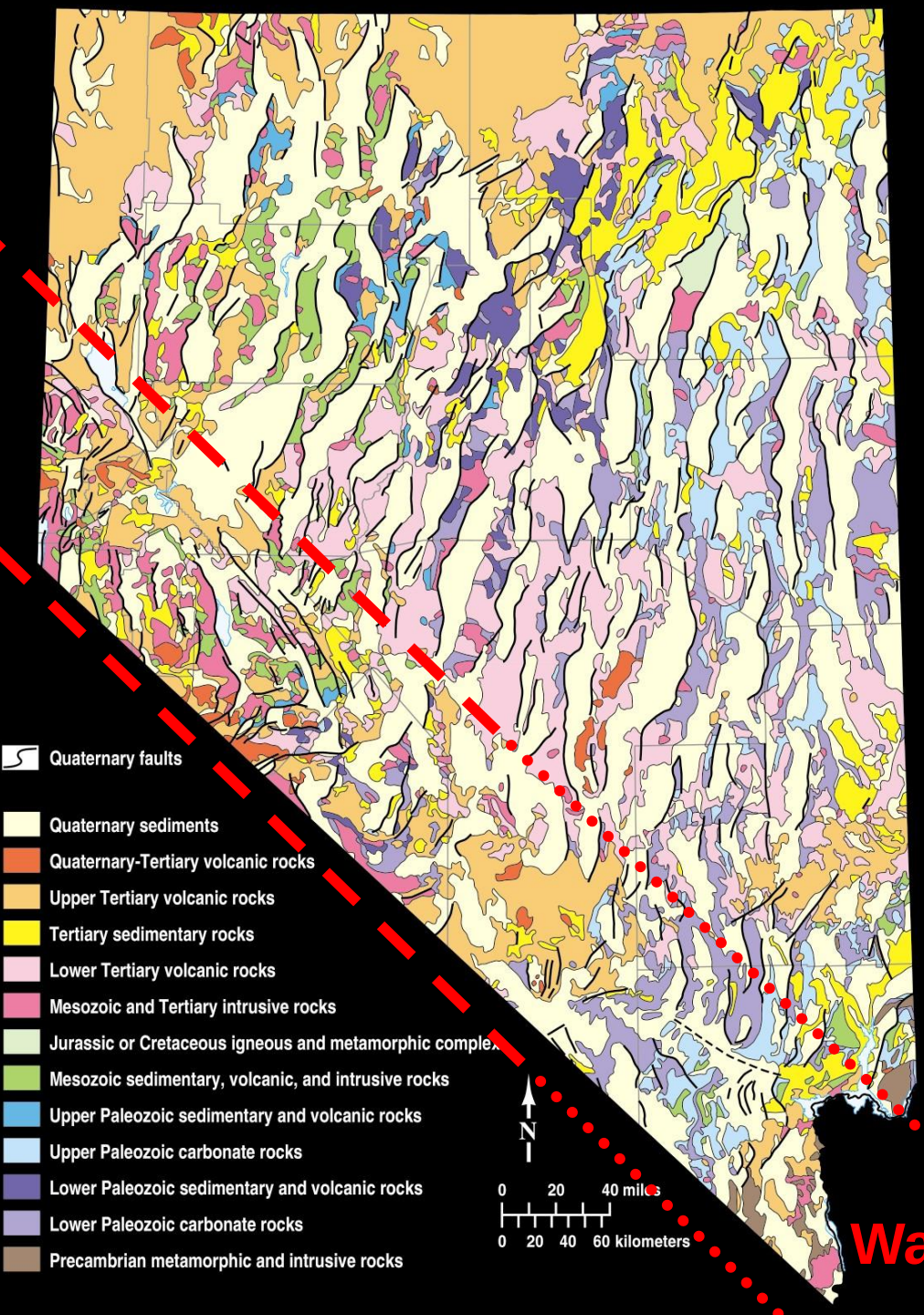
2012

(3) Geodetic data indicate that the Nevada is gaining about 0.2 acre of area per year through crustal extension, and that western Nevada is accommodating ~20% of the North American-Pacific plate interaction.

Kreemer et al. (2012)



In Nevada, much of the right-lateral shear between the North American and Pacific plates occurs along northwest-striking strike-slip faults of the Walker Lane.

Extension largely is accommodated along N- to NE-striking, basin-bounding normal faults.

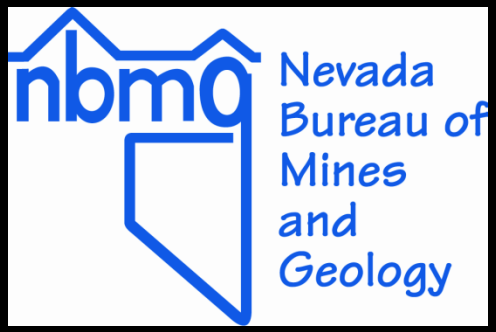
The hazard: expressed in terms of probability of an earthquake of a given magnitude occurring within 50 years and within 50 km of the community.

	% Probability of magnitude greater than or equal to magnitude				
Community	5.0	5.5	6.0	6.5	7.0
Dayton	>90	~80	70-75	50-55	12-15
Carson City	>90	~80	70	50-55	12-15
Reno	>90	~80	67	50	12-15
Incline Village	>90	~80	60-70	40-50	10-12
Stateline	>90	~80	60-70	40-50	10
Fallon	80-90	~60	35	20-25	6-8
Las Vegas	40-50	~30	12	4-5	<0.5
Elko	30-40	~25	10-15	6-8	0.5-1
Wells	30-40	~20	9	6	0.5-1
Laughlin	10-20	~5	2-3	0.5-1	<0.5

Data are from the USGS at http://eqint.cr.usgs.gov/eqprob/2002/index.php .
Values for magnitude 5.5 are extrapolated between 5.0 and 6.0.

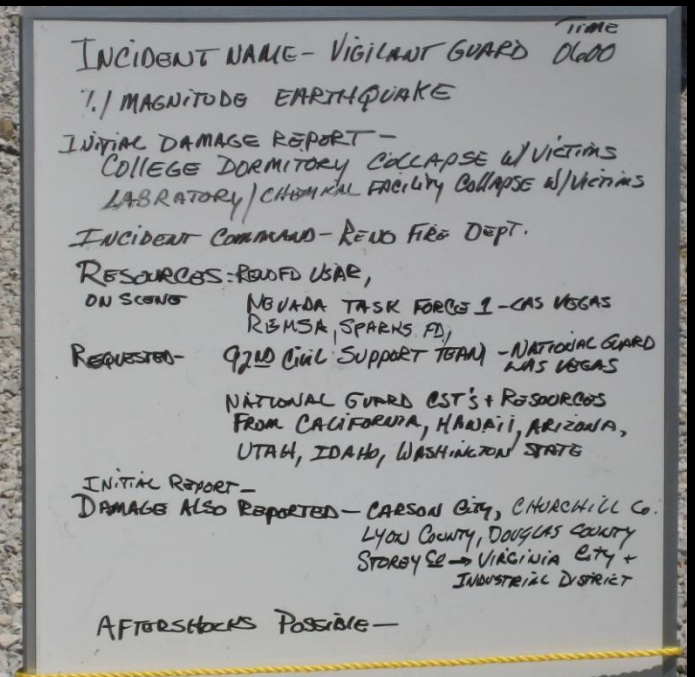
Earthquake faults occur throughout Nevada, and potential losses from earthquakes are high for many communities.

NBMG Open-File Report 09-8, *Estimated Losses from Earthquakes near Nevada Communities*, demonstrates that the consequences of earthquakes can be huge in Nevada, particularly if individuals are not prepared.



Earthquake risks in Nevada are assessed by the Nevada Bureau of Mines and Geology using the Federal Emergency Management Agency's loss-estimation model, HAZUS-MH, and the U.S. Geological Survey's probabilistic seismic hazard analysis.

These loss estimates are useful in hazard-mitigation planning, in building scenarios for emergency response and recovery exercises, and in helping emergency managers and the Governor make decisions on official disaster declarations after an actual earthquake.



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NBMG Open-File Report 09-8, *Estimated Losses from Earthquakes near Nevada Communities*, contains HAZUS scenarios for magnitude 5.0, 5.5, 6.0, 6.5, and 7.0 earthquakes near 38 communities in Nevada.

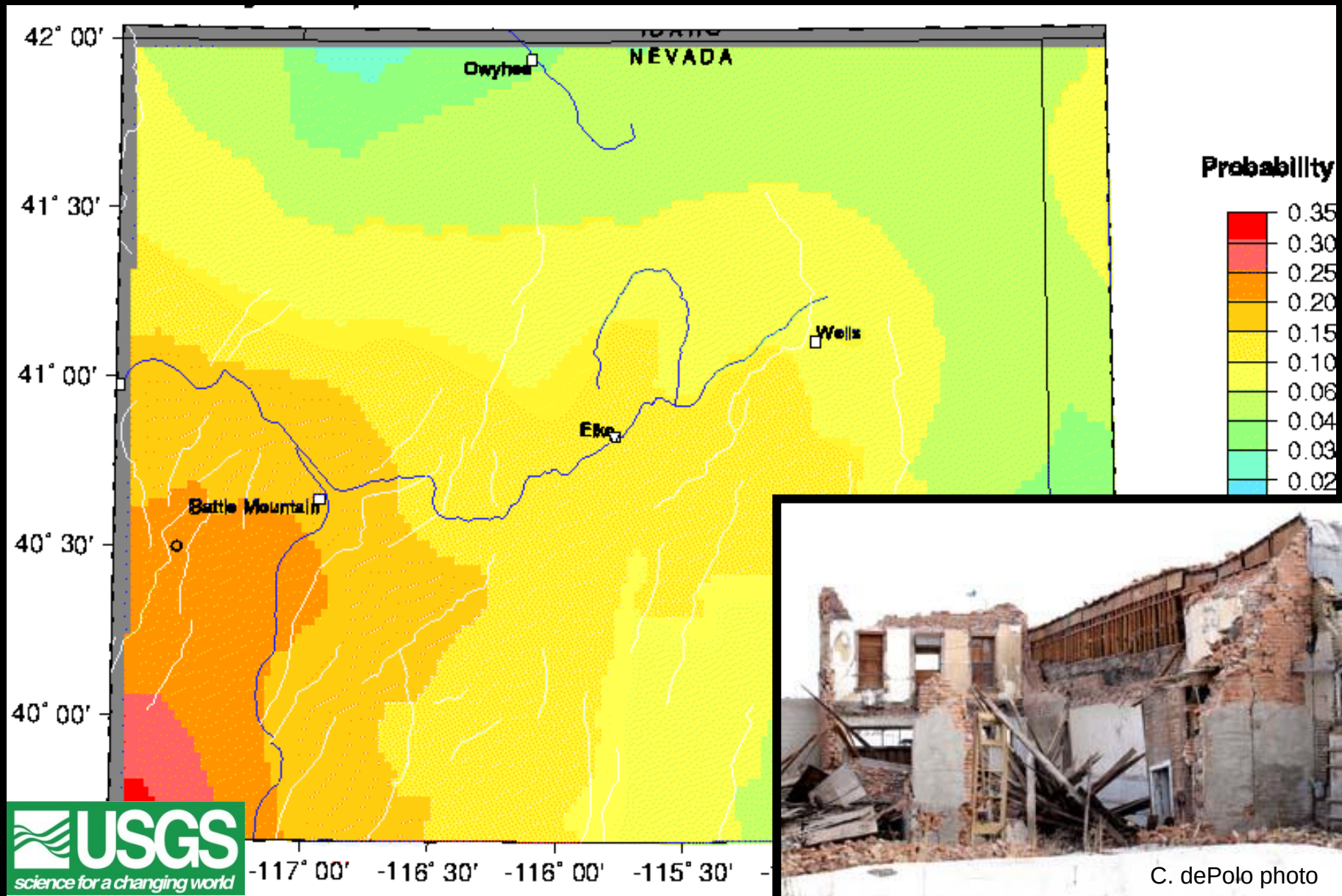
Uncertainties in the location of epicenters, depths, and magnitude, when combined with changing population and uncertainties in local effects (soil and rock types, assumptions about attenuation, basin geometry, liquefaction potential, and directivity), make loss estimates generally consistent within one order of magnitude (a factor of 10), although experience with urban earthquakes in the US has generally yielded numbers within a factor of 2 or 3 of the actual damages.

HAZUS estimates for total economic loss from a magnitude 6.0 earthquake and probability of an earthquake of this magnitude or greater occurring within 50 years and within 50 km of the community.

Community	Total Economic Loss	Probability in 50 years within 50 km
Las Vegas	$7.2 billion	12%
Reno	$1.9 billion	67%
Carson City	$650 million	70%
Elko	$160 million	10 to 15%
Fallon	$110 million	35%
Wells	$30 million	9%

Total economic loss is from HAZUS. Probabilities are from the USGS at http://eqint.cr.usgs.gov/eqprob/2002/index.php .

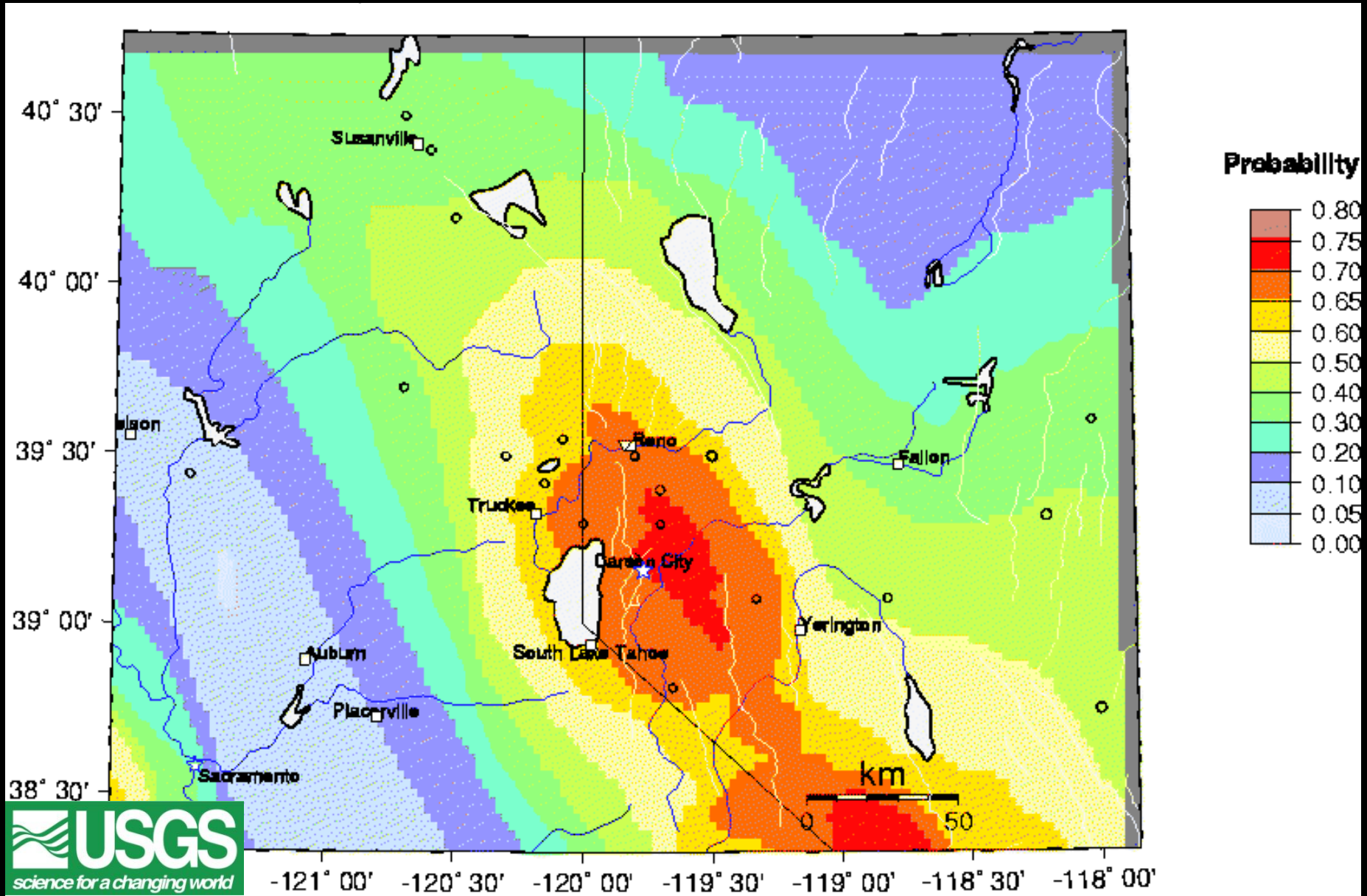
The probability of a magnitude 6.0 earthquake occurring within 50 km of Wells, Nevada within the next 50 years is approximately 9%.
It happened on 21 February 2008.



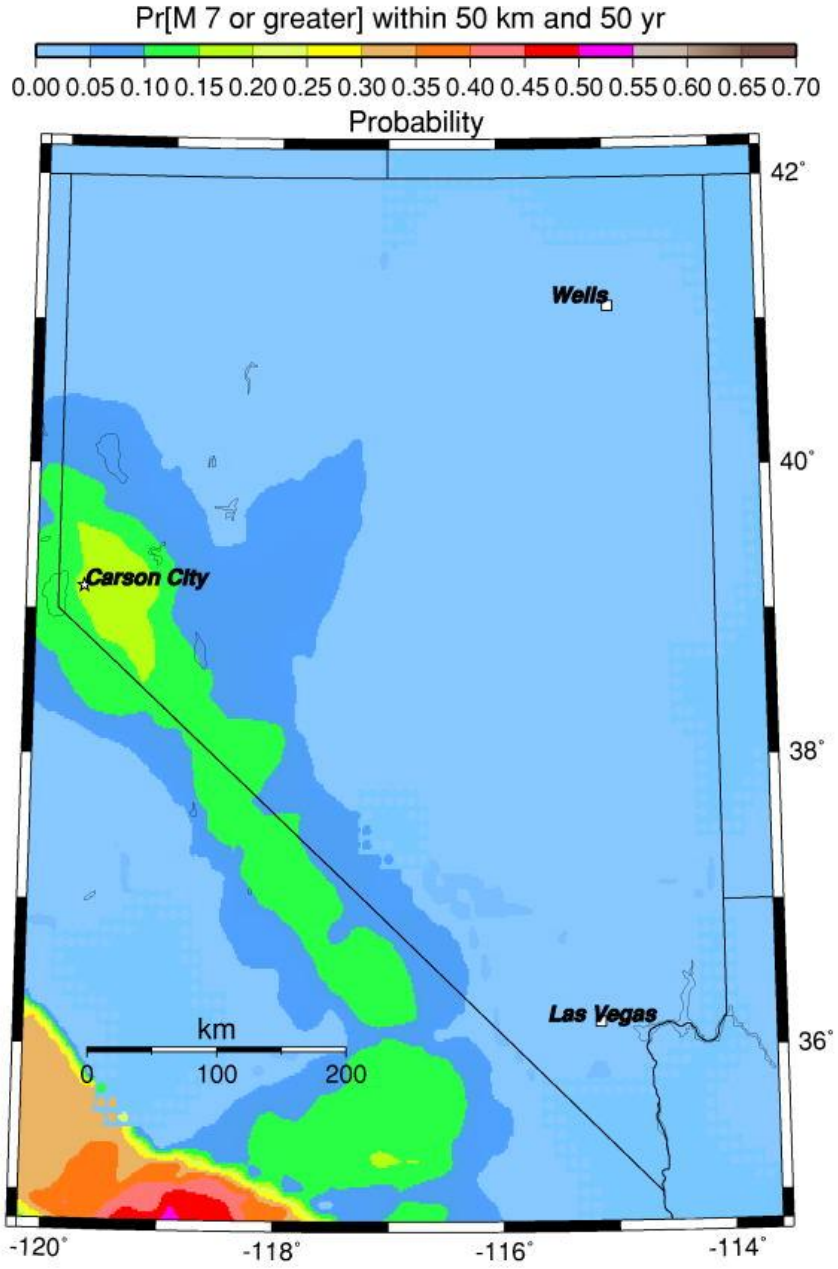
C. dePolo photo

USGS science for a changing world

The probability of a magnitude 6.0 earthquake occurring within 50 km of Carson City within the next 50 years is approximately 70%, 7.8 times higher than for Wells.



USGS science for a changing world


Pr[M 7 or greater] within 50 km and 50 yr
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70
Probability
Wells
Carson City
Las Vegas
km
0
100
200
42˚
40˚
38˚
36˚
-120˚
-118˚
-116˚
-114˚

Earthquake faults occur throughout Nevada, and potential losses from earthquakes are high for many communities.

The consequences of earthquakes can be huge in Nevada, particularly if individuals are not prepared.

A. Be prepared to respond.

B. Mitigate structural risks, largely through building codes and avoiding faults and areas of liquefaction.

C. Mitigate nonstructural risks.

Unreinforced masonry building (URM) that collapsed during the Wells earthquake on 21 February 2008

View from back, 20 May 2009

View from front, 20 May 2009

Definition of potential unreinforced masonry (URM) buildings in Nevada:

buildings listed by County Assessors or State Public Works as built before 1974 with brick, stone, or block masonry structure.

Caution: This is a preliminary study based on data provided by the County Assessors and the State of Nevada. We know there are errors in the database:

- **URMs missed - not recorded as masonry structures**
- **URMs missed – ones on federal or Indian lands**
- **URMs counted due to wrong building type in the database**
- **Wrong locations due to poor address coding**
- **Misidentifications due to lack of construction date**
- **Buildings that may have been seismically retrofitted**
- **Buildings that have been removed.**

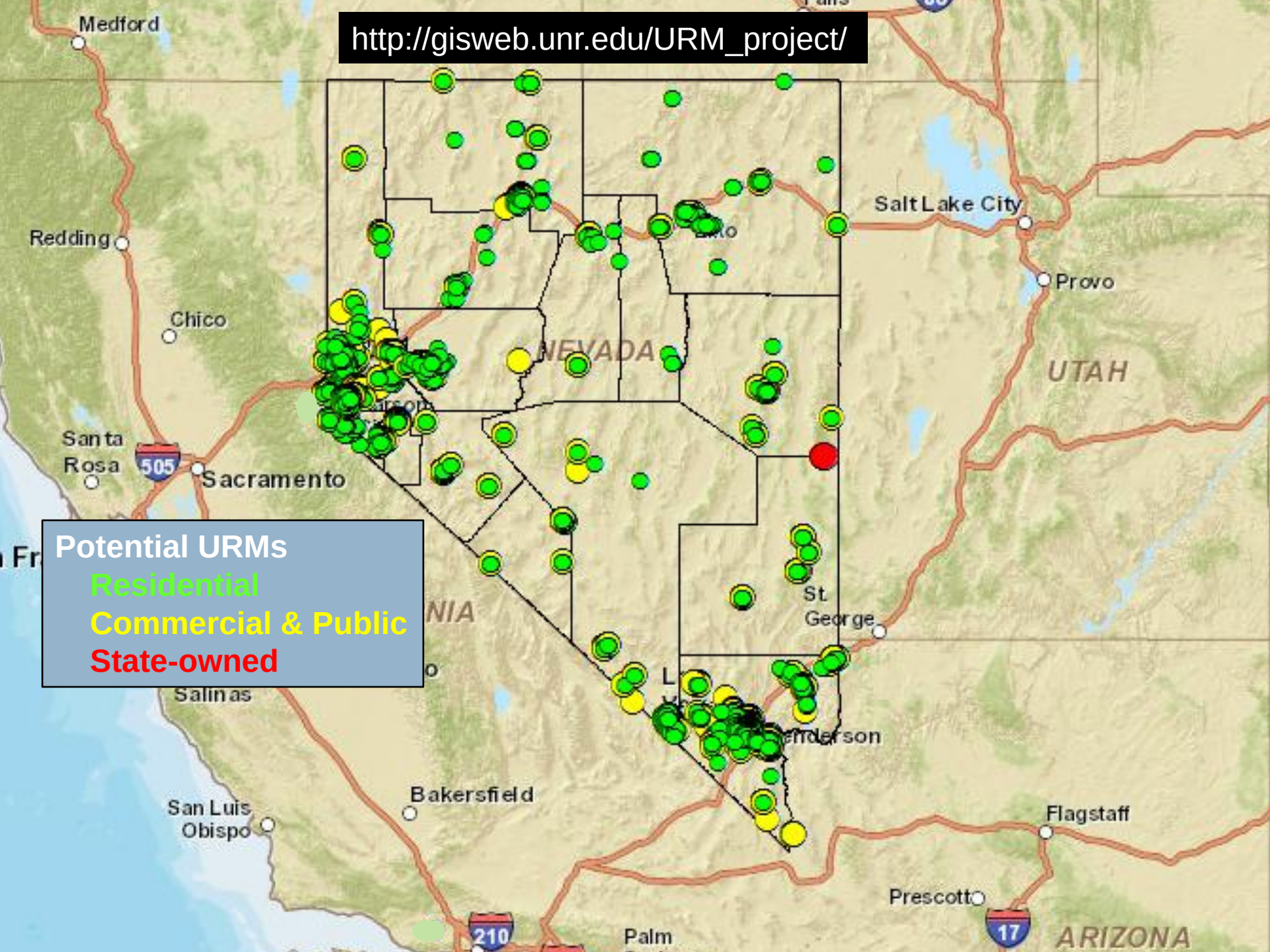
Recommendation 1 (draft): Jurisdictions (cities, counties, state) should use this County Assessors' data to follow up with on-the-ground inspections and checks of building plans. Individuals should determine if their buildings are URMs.

Potential URMs in Nevada – totals*

7,354	Residential
16,145	Commercial & Public (city and county)
98	State-owned
23,597	TOTAL*

* The total does not include buildings owned by the federal government.

http://gisweb.unr.edu/URM_project/

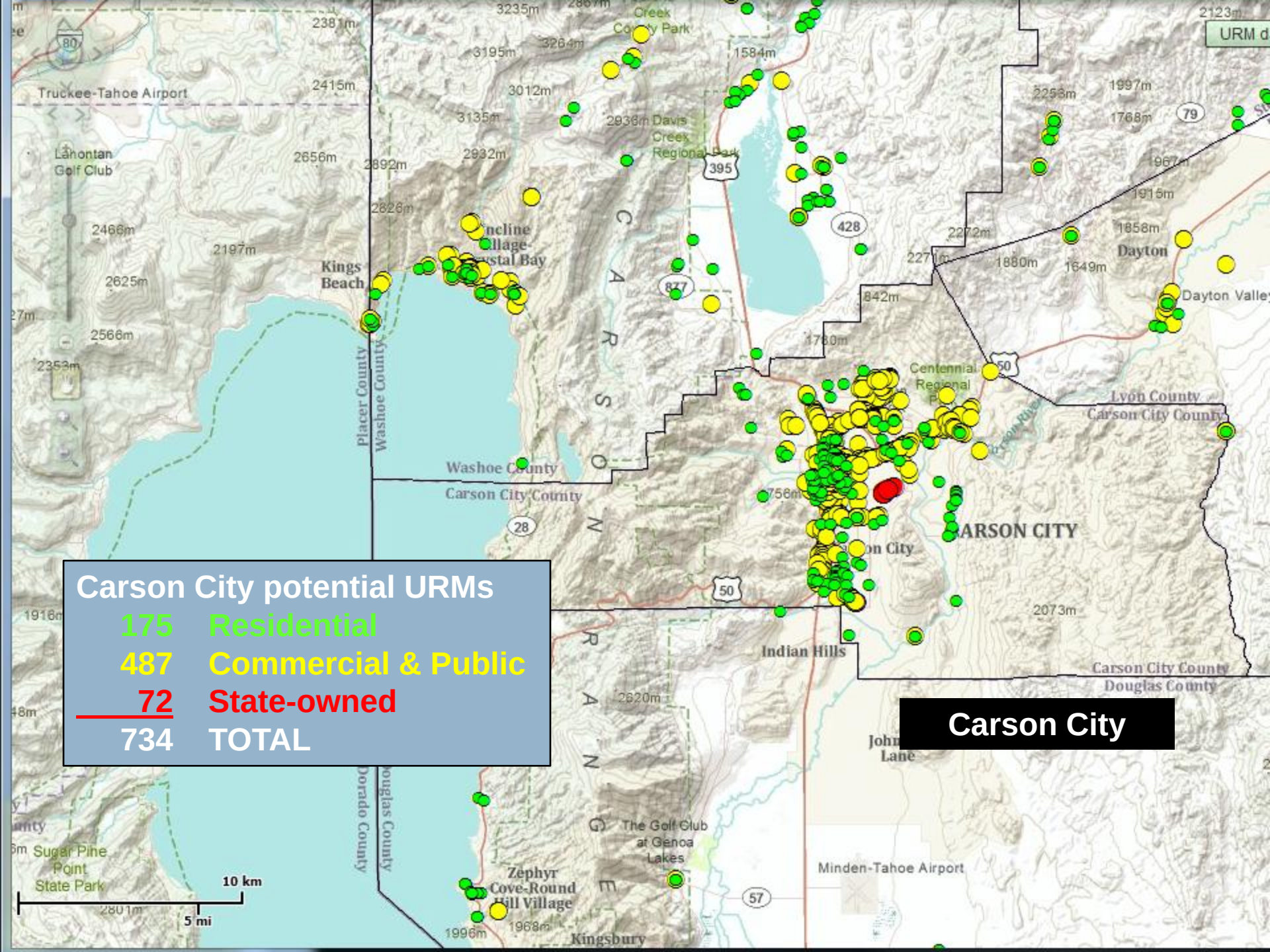

http://gisweb.unr.edu/URM_project/
Potential URMs
Residential
Commercial & Public
State-owned
Medford
Redding
Chico
Santa Rosa
505
Sacramento
Salinas
San Luis Obispo
Bakersfield
Salt Lake City
Provo
NEVADA
UTAH
St. George
Flagstaff
Prescott
ARIZONA
210
17
Palm

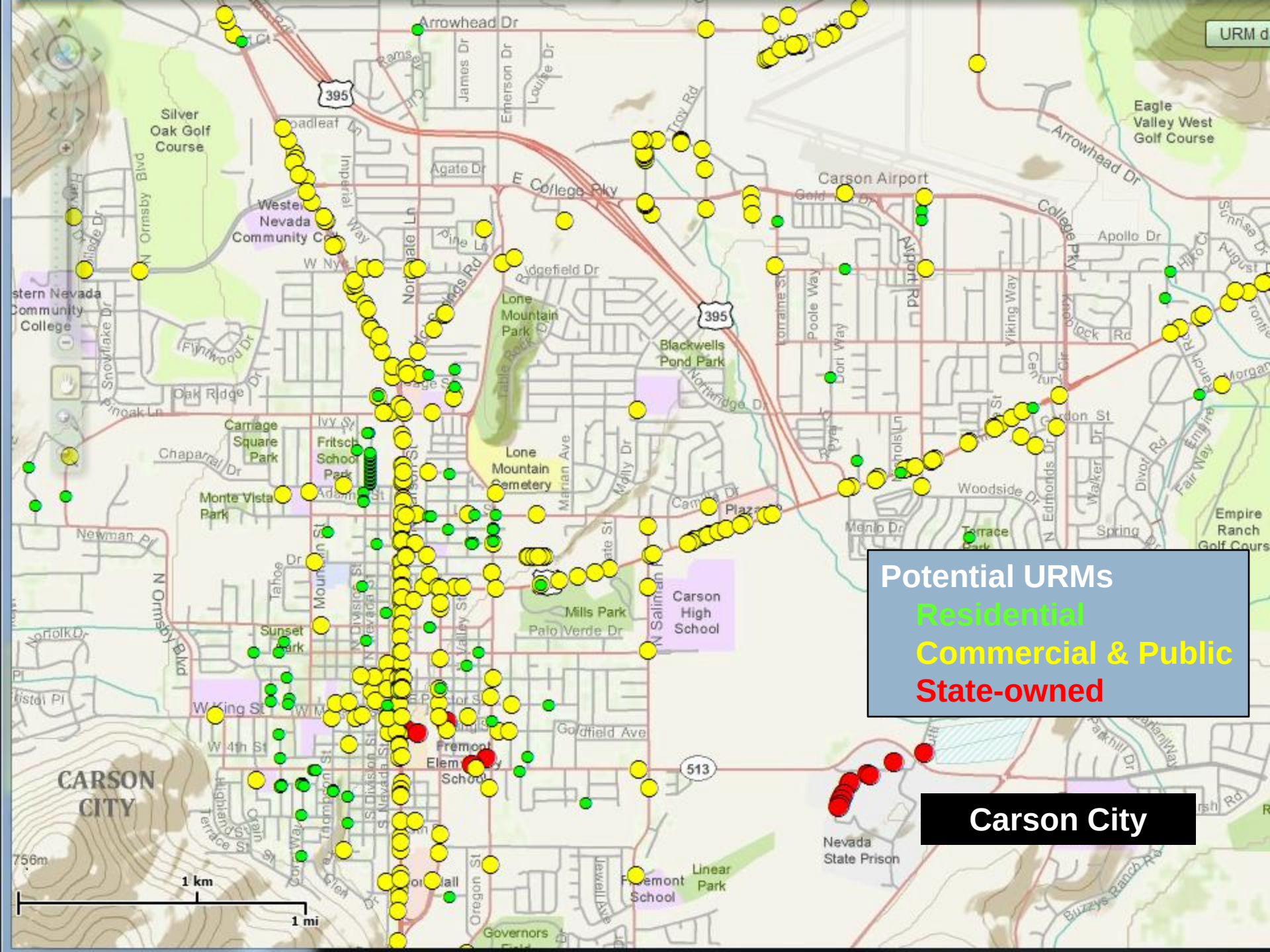
Observations:

Because URMs are mostly 50+ years old, many have deteriorated and need maintenance. Some may have been damaged from shaking during previous distant or small earthquakes.

BAR
306
302
RENO

BEAUJOLAIS
STUDIOS & APTS


Carson City potential URMs
175 Residential
487 Commercial & Public
72 State-owned
734 TOTAL
Carson City
Truckee-Tahoe Airport
Lahontan Golf Club
Kings Beach
Incline Village-Crystal Bay
Placer County
Washoe County
Carson City County
Douglas County
Lyon County
Dayton
Dayton Valley
Centennial Regional Park
CARSON CITY
Indian Hills
Carson City County Douglas County
Minden-Tahoe Airport
The Golf Club at Genoa Lakes
Zephyr Cove-Round Hill Village
Kingsbury
Sugar Pine Point State Park
Davis Creek Regional Park
10 km
5 mi


Potential URMs
Residential
Commercial & Public
State-owned
Carson City
CARSON CITY
Arrowhead Dr
395
Silver Oak Golf Course
Eagle Valley West Golf Course
Carson Airport
E College Pky
Lone Mountain Park
Blackwells Pond Park
Lone Mountain Cemetery
Carriage Square Park
Fritsch School Park
Monte Vista Park
Sunset Park
Mills Park
Carson High School
Fremont Elementary School
Fremont School
Linear Park
Nevada State Prison
Western Nevada Community College
513
1 km
1 mi

Nonstructural damage often can be easily prevented.

Earthquake-secure bookshelves in the office of the State Geologist

Secured computers at the
Clark County Building Department

Thank you!

And thanks to Craig dePolo, Gary Johnson, Christine Ballard, Heather Armeno, Irene Seeley, Linda D. Goar, and Jordan T. Hastings for their work on the open-file reports (OF 09-8 and 09-9), which are available as online documents at www.nbmg.unr.edu.

From there, go to online documents at http://www.nbmg.unr.edu/dox/dox.htm, then scroll down to OF 09-8 or 09-9. Link to the fault map from OF 09-9.

nbmg Nevada Bureau of Mines and Geology

University of Nevada, Reno
Statewide • Worldwide

FEMA

U.S. Department of Homeland Security

Nevada Department of Public Safety
Division of Emergency Management

Nevada Earthquake Safety Council

USGS
science for a changing world

NEVADA Seismological Laboratory

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