Geology of Nevada
(with an emphasis on Southern Nevada)

Jonathan G. Price
State Geologist and Director

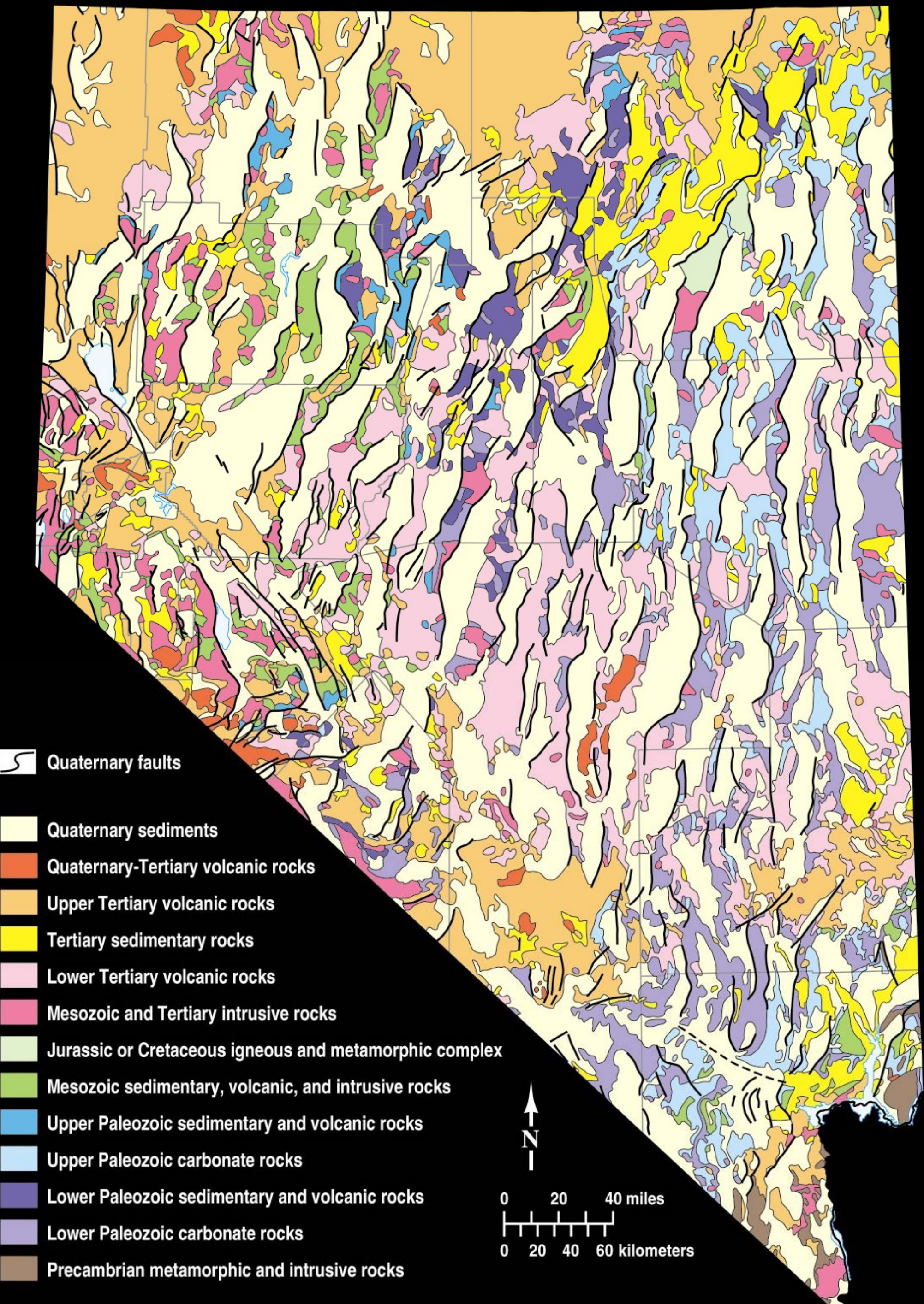
Nevada Bureau of Mines and Geology
(www.nbmg.unr.edu)

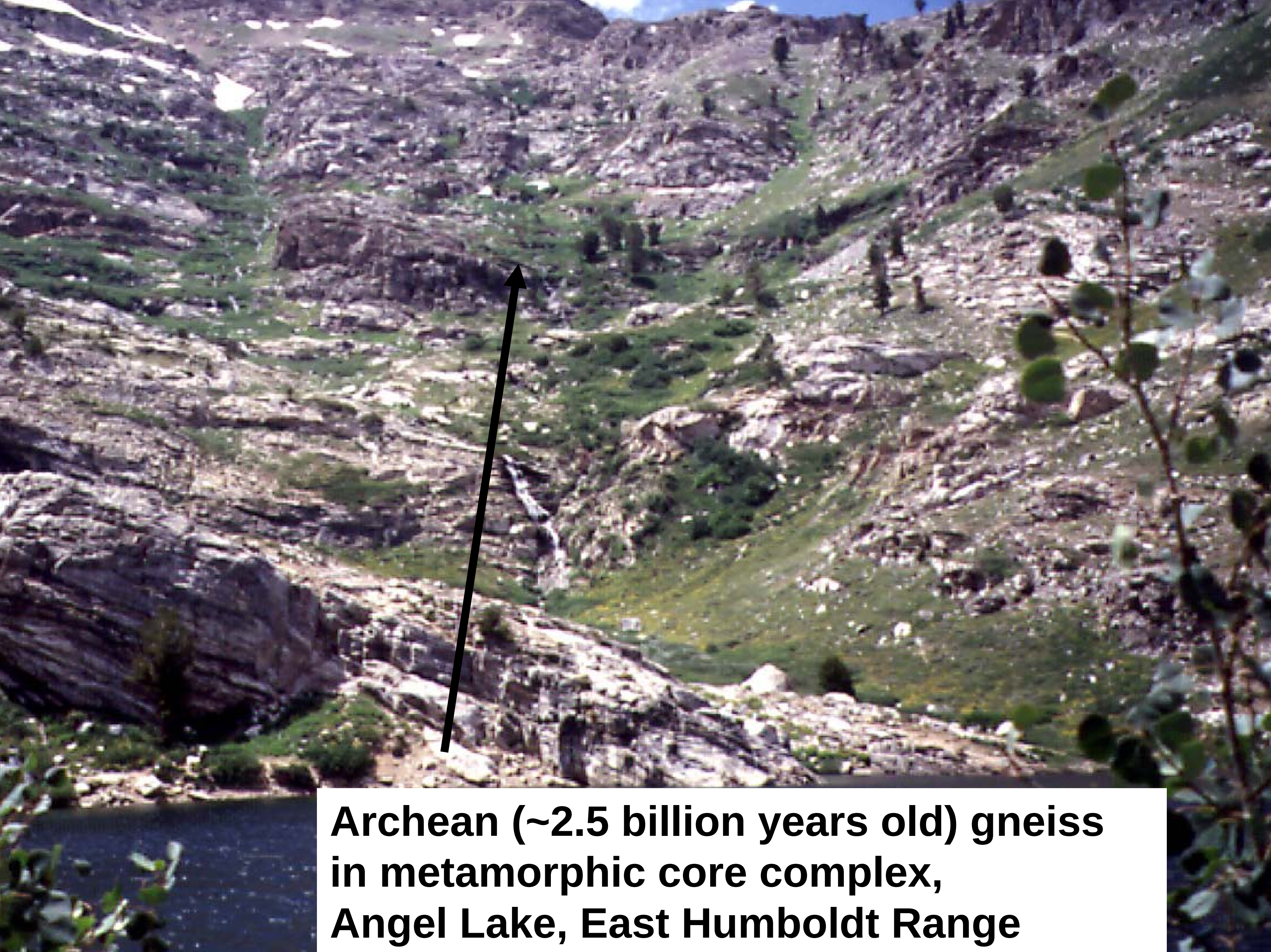
Main Point:

Geology (including rocks types and how the rocks formed) is the key to understanding our mineral, energy, and water resources; our history; and our future as we face the challenges of natural hazards and growth.

Quick Review of Nevada Geologic History

Precambrian events (before 540 million years ago) – thrusting, folding, metamorphism, intrusions, sediments.





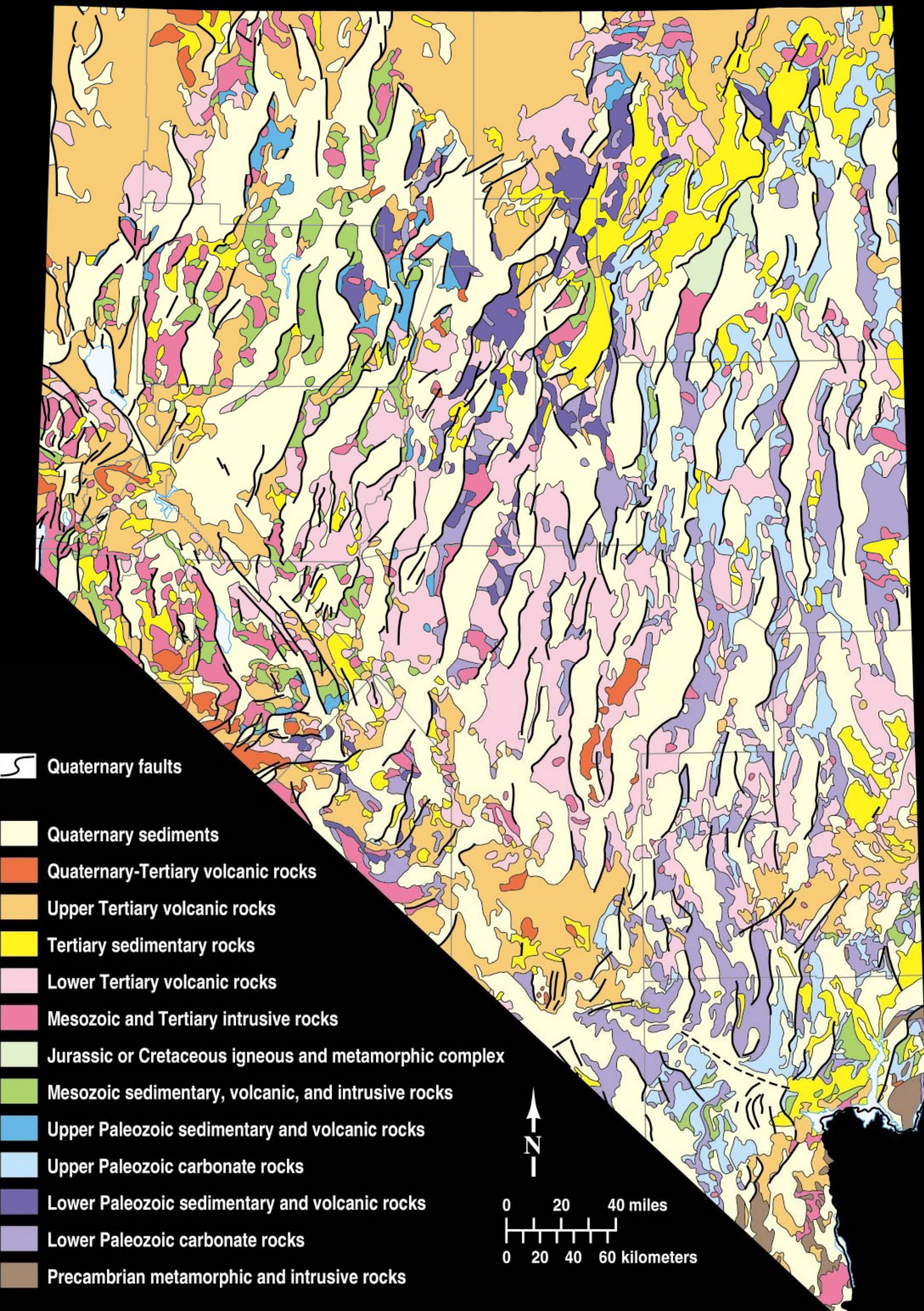
Archean (~2.5 billion years old) gneiss
in metamorphic core complex,
Angel Lake, East Humboldt Range

Clark County geology:

Precambrian rocks are in brown. These are mostly metamorphic and intrusive igneous rocks.

Miner’s shack in Proterozoic (~ 1.7 billion years old) gneiss in the Virgin Mountains

gneiss house



Quick Review of Nevada Geologic History

Precambrian events – thrusting, folding, metamorphism, intrusions, sediments.

Paleozoic (from 540 to 248 million years ago) — thrusting, folding, oceanic crust and sediments.

Refolded folds in gneiss
in the Ruby Mountains

Clark County geology:

Paleozoic rocks are in blue and purple. These are mostly sedimentary rocks.

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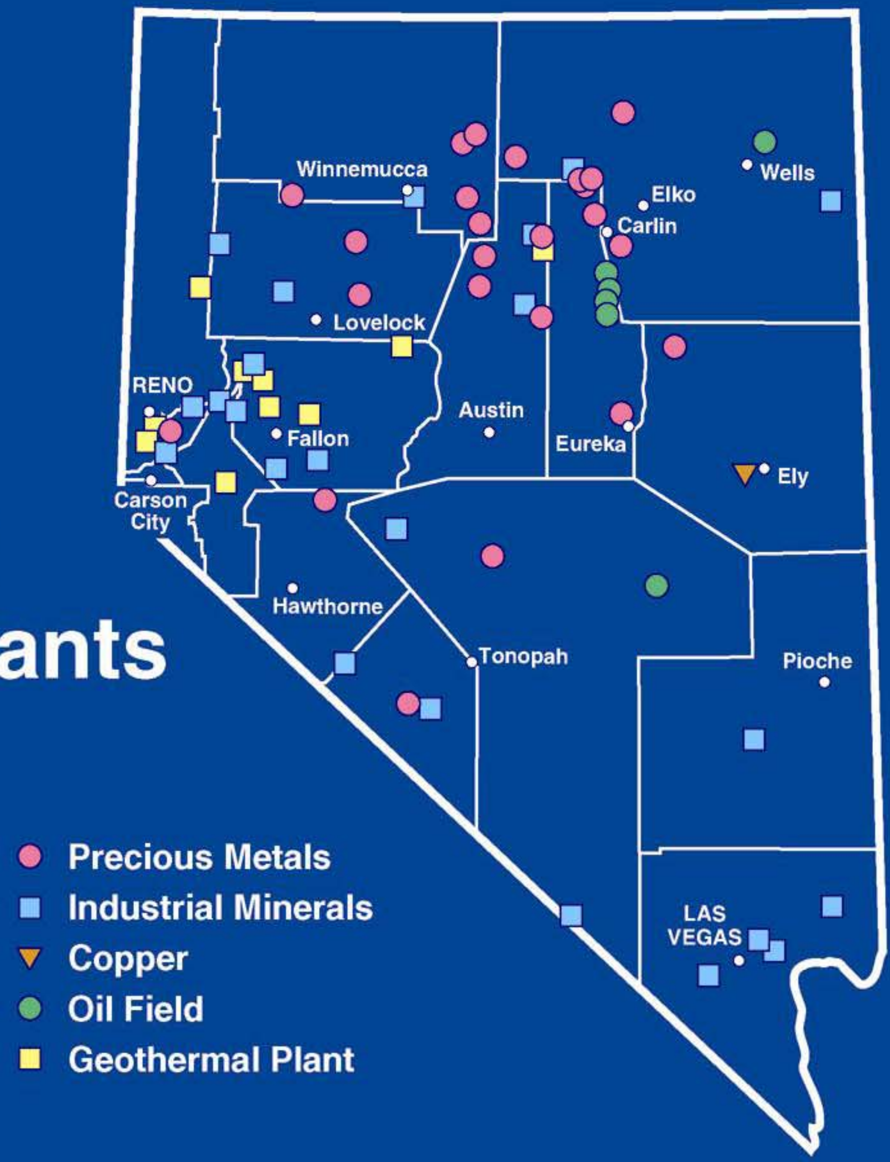
The rocks exposed on Frenchman Mountain (Sunrise Mountain) were tilted and slid into place from an area to the east, near the Grand Canyon.

Major Mines, Oil Fields, and Geothermal Plants

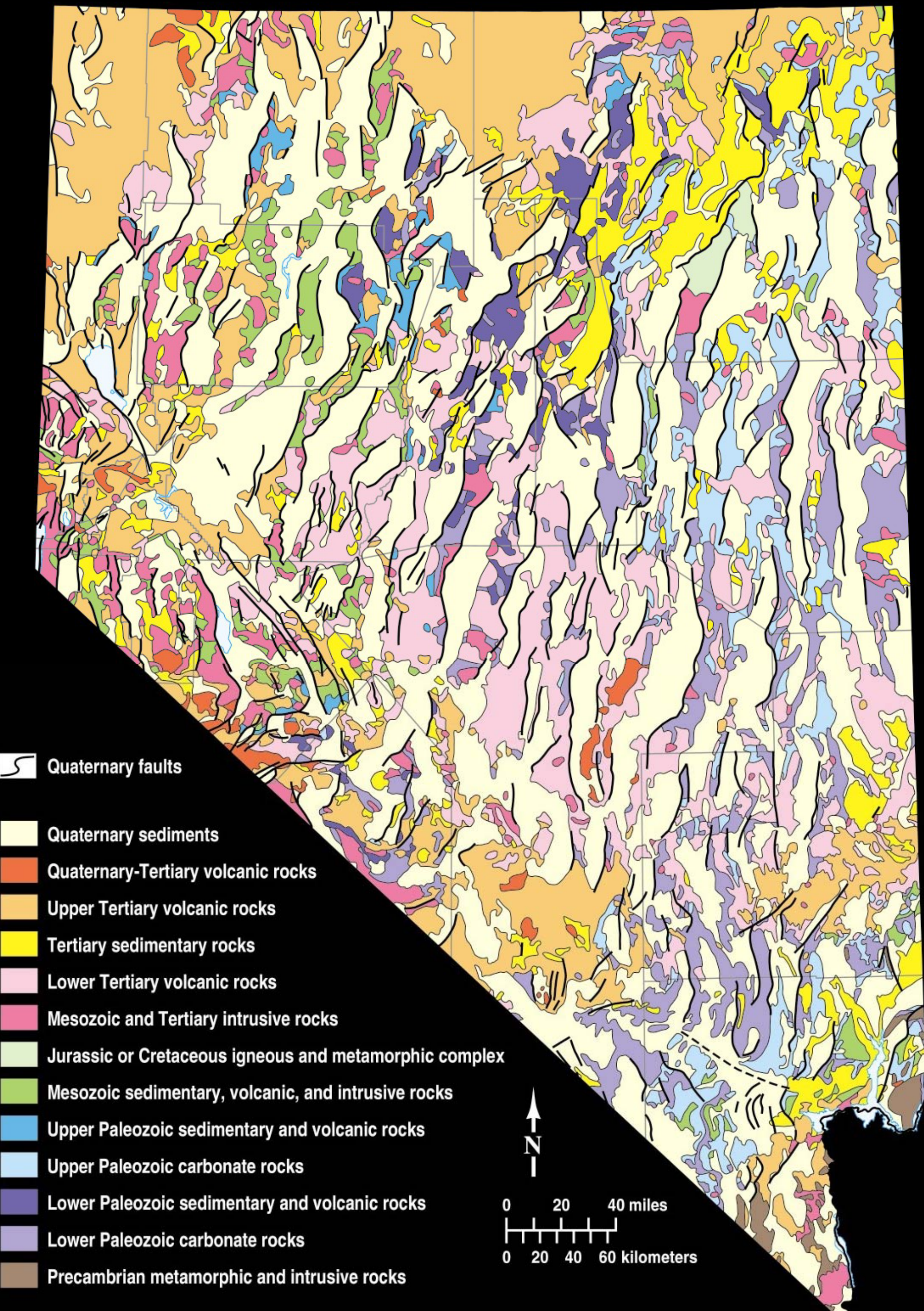


Paleozoic rocks as industrial minerals in Southern Nevada:

Limestone for lime and aggregate.

Gypsum for wallboard.

Lime kiln at Apex – lime (CaO) made from limestone ($CaCO_3$)



Quick Review of Nevada Geologic History

Precambrian events – thrusting, folding, metamorphism, intrusions, sediments.

Paleozoic thrusting, folding, oceanic crust and sediments.

Mesozoic (from 248 to 65 million years ago) — thrusting, folding, intrusion and volcanism.

Clark County geology:

Mesozoic rocks are in green. These are mostly sedimentary rocks as well.

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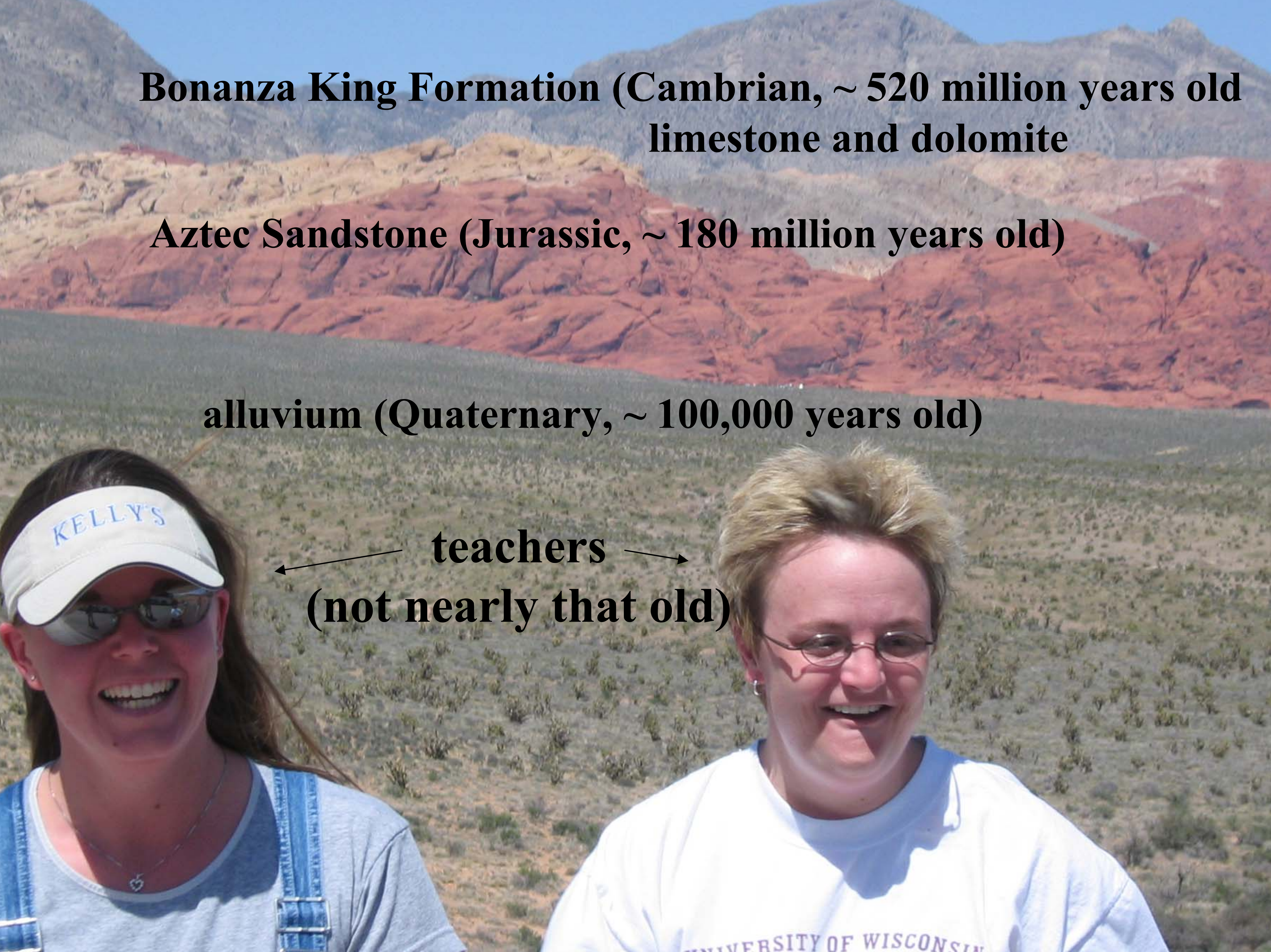
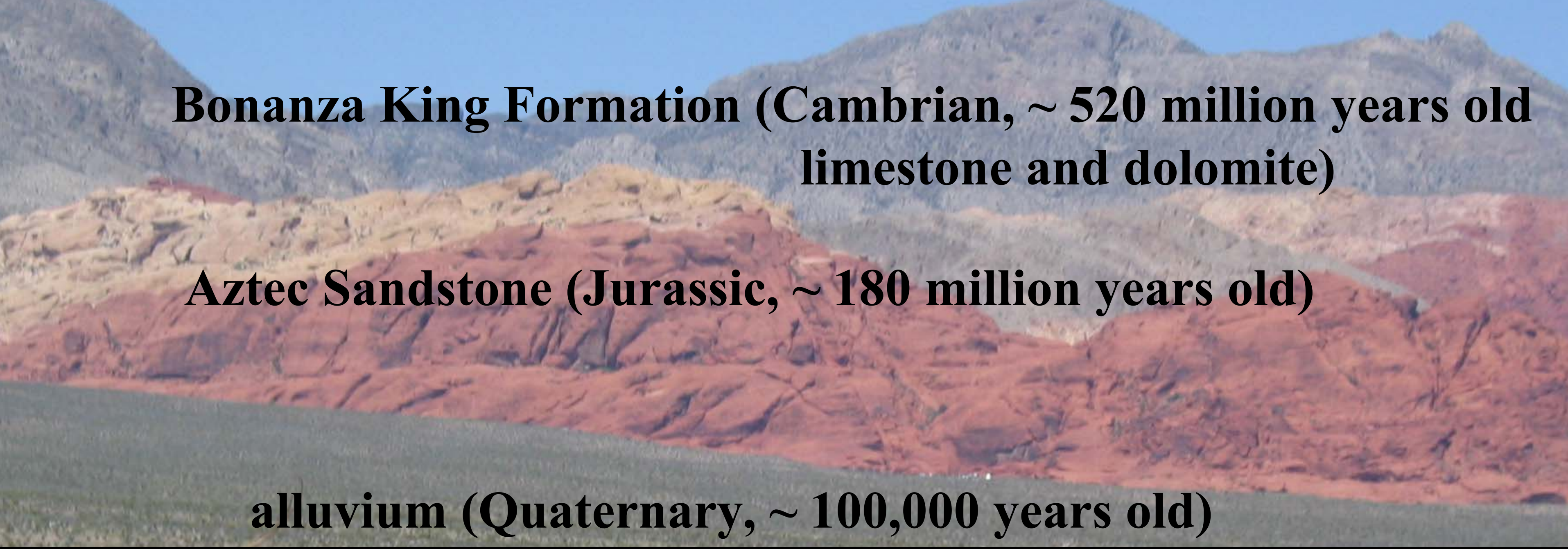
Valley of Fire and Red Rock Canyon are two of the most spectacular areas of Mesozoic rocks in Southern Nevada.


Red Rock Canyon National Conservation Area (BLM)
KELLY'S


Bonanza King Formation (Cambrian, ~ 520 million years old
limestone and dolomite
Aztec Sandstone (Jurassic, ~ 180 million years old)
alluvium (Quaternary, ~ 100,000 years old)
KELLY'S
UNIVERSITY OF WISCONSIN


Bonanza King Formation (Cambrian, ~ 520 million years old
limestone and dolomite
Aztec Sandstone (Jurassic, ~ 180 million years old)
alluvium (Quaternary, ~ 100,000 years old)
teachers
(not nearly that old)
KELLY'S
UNIVERSITY OF WISCONSIN

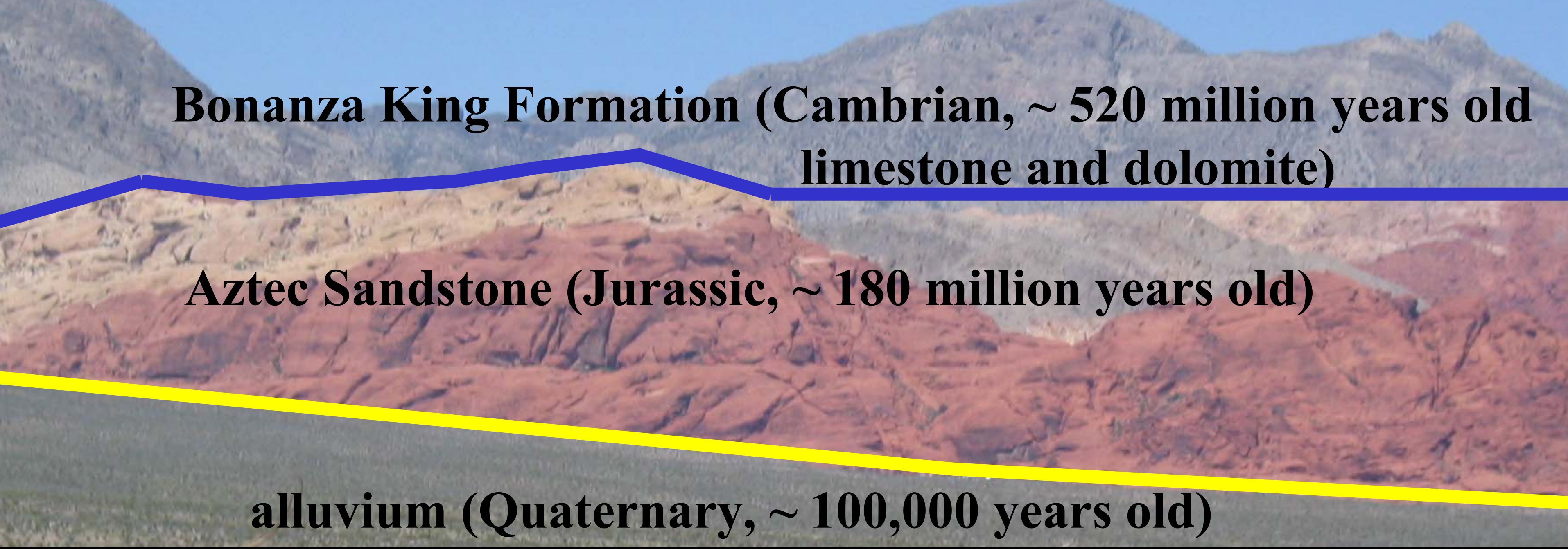


Normal strata:

Youngest sediments are deposited on the top.

Sediments stack up like filling a bucket with sand.

Oldest sediments are deposited on the bottom.



But here we see the reverse at Red Rock Canyon:

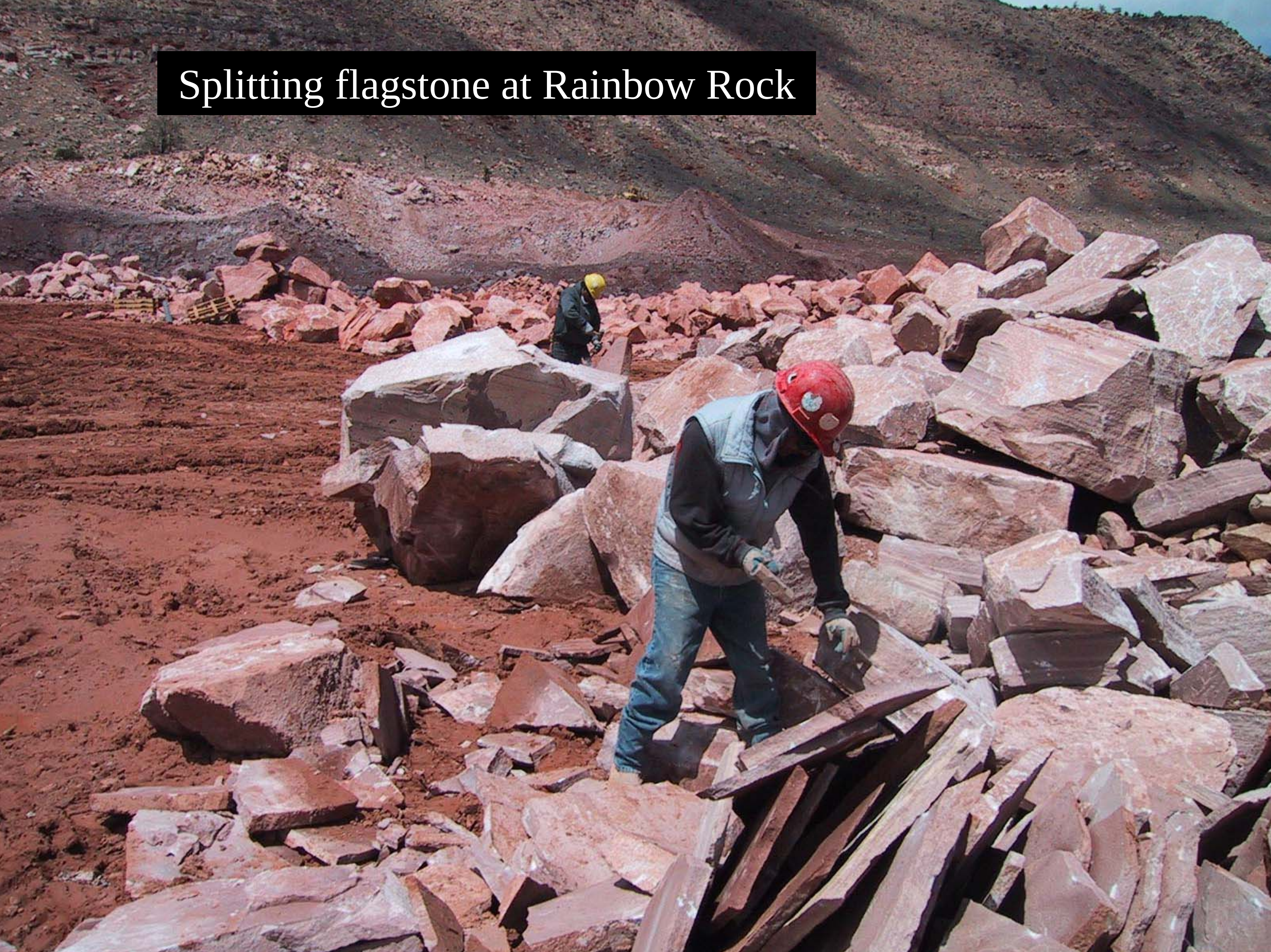
Oldest sedimentary rocks were thrust on top of

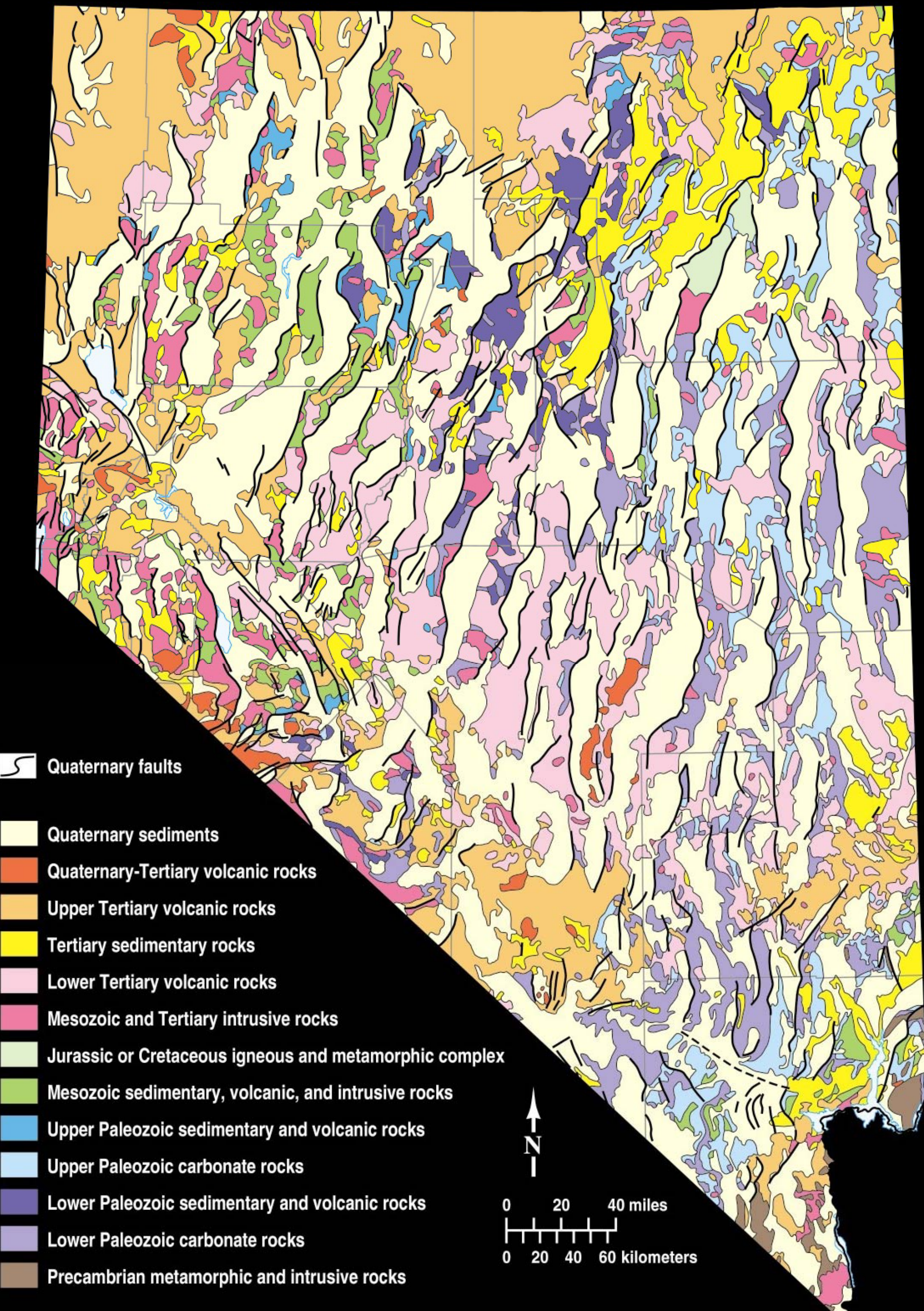
younger sedimentary rocks.

Youngest sediments fill valleys and alluvial fans.

Mesozoic rocks as industrial minerals in Southern Nevada:

Sandstone for making glass (bottles), building stone, and architectural aggregate.


Splitting flagstone at Rainbow Rock



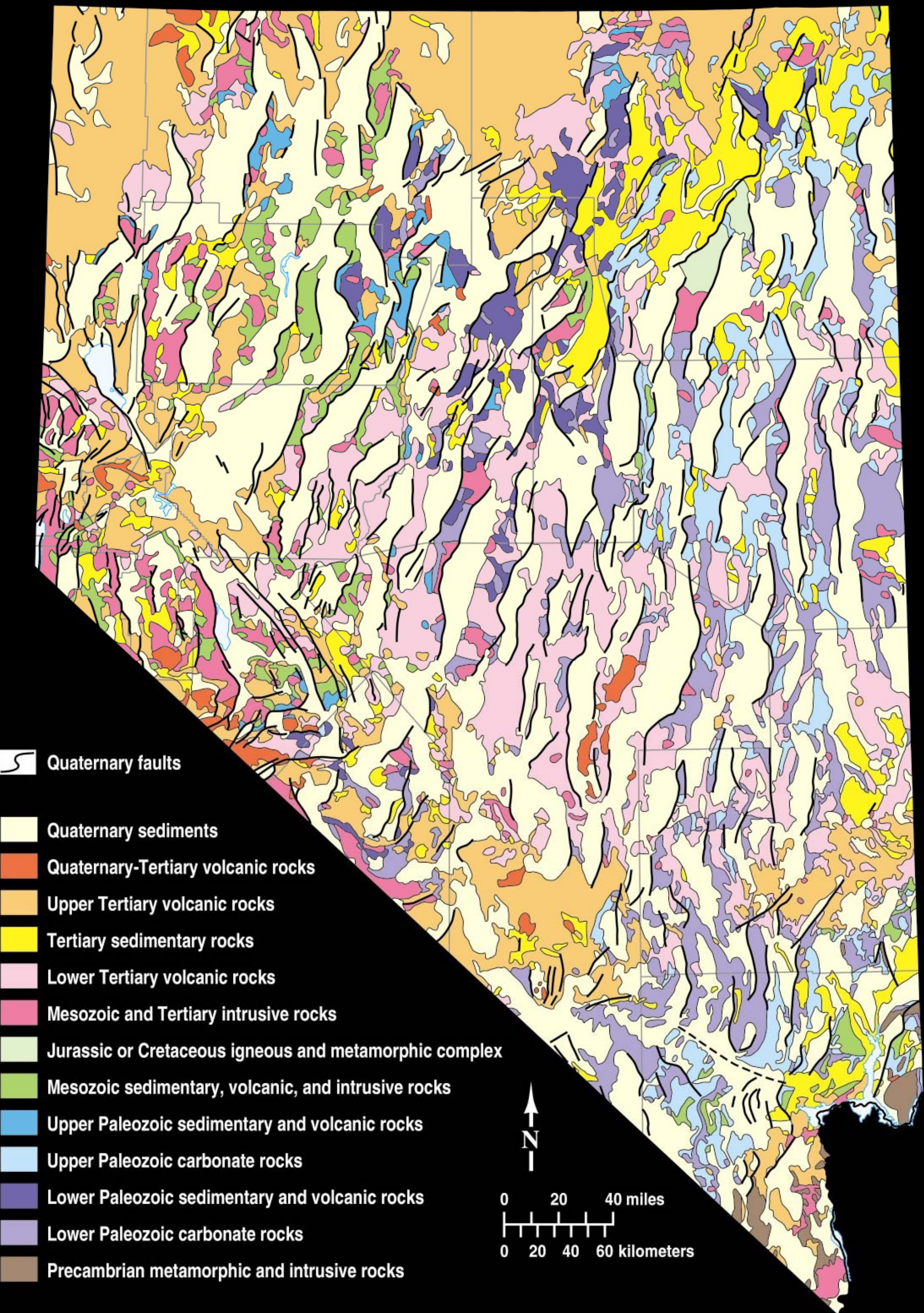
Quick Review of Nevada Geologic History

Precambrian events – thrusting, folding, metamorphism, intrusions, sediments.

Paleozoic thrusting, folding, oceanic crust and sediments.

Mesozoic thrusting, folding, intrusion and volcanism.

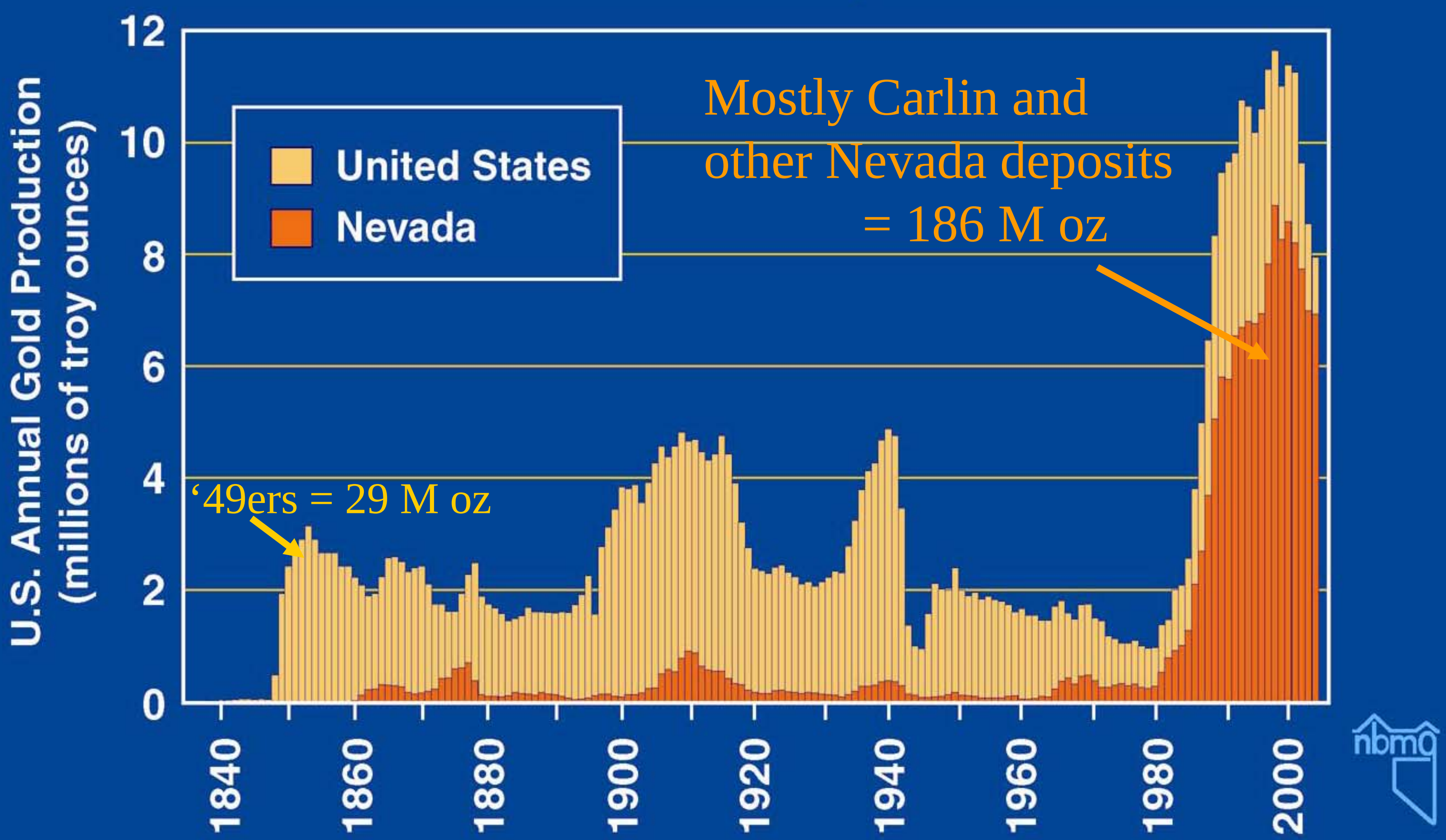
Cenozoic (<65 million years old) — volcanism and intrusion, compression followed by crustal extension, faulting, including right-lateral strike-slip faulting.



Everything pink, red, and orange on the map is igneous.

There are ore deposits associated with many of the Mesozoic and Cenozoic intrusions.

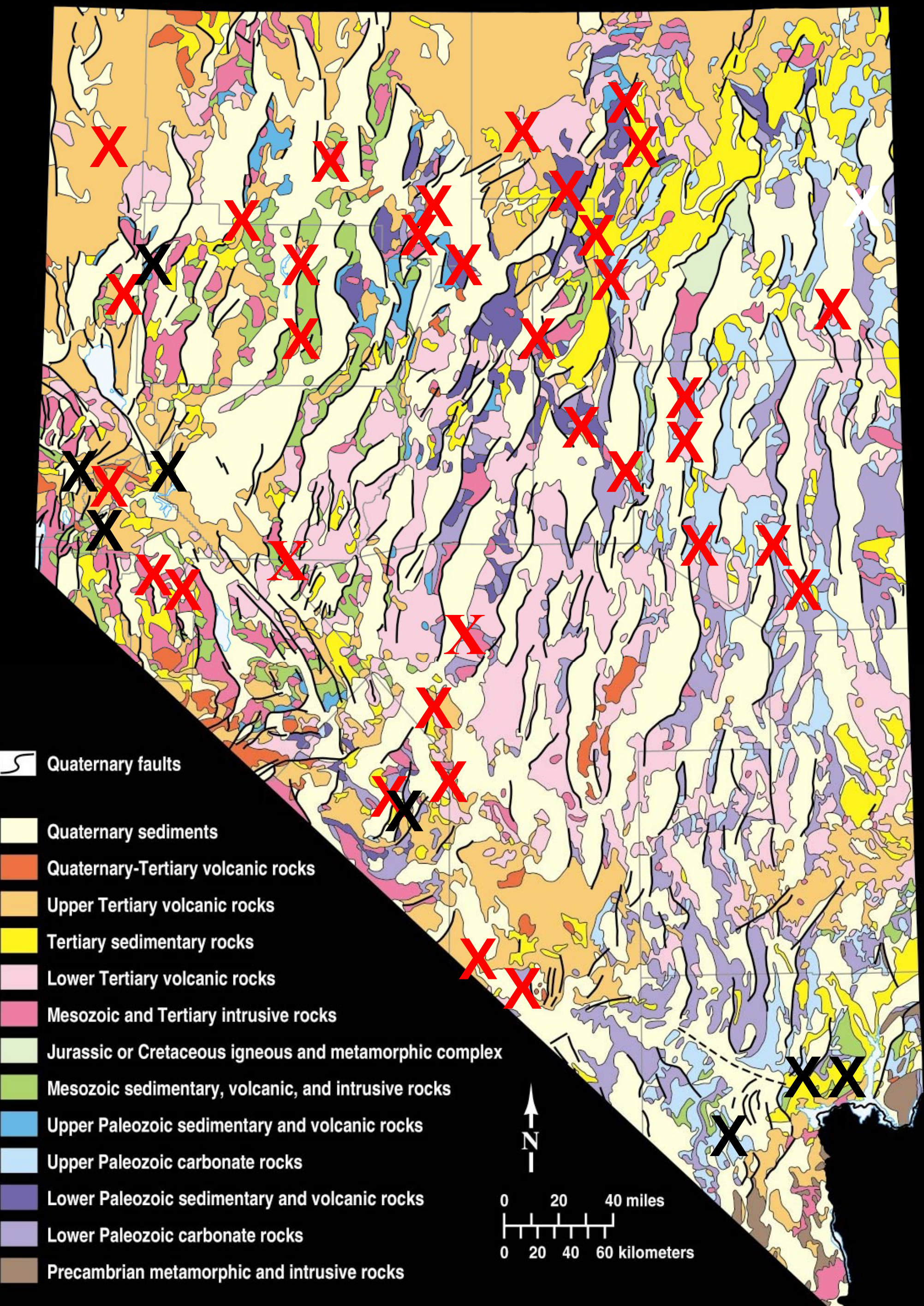
Gold Production, 1835–2004

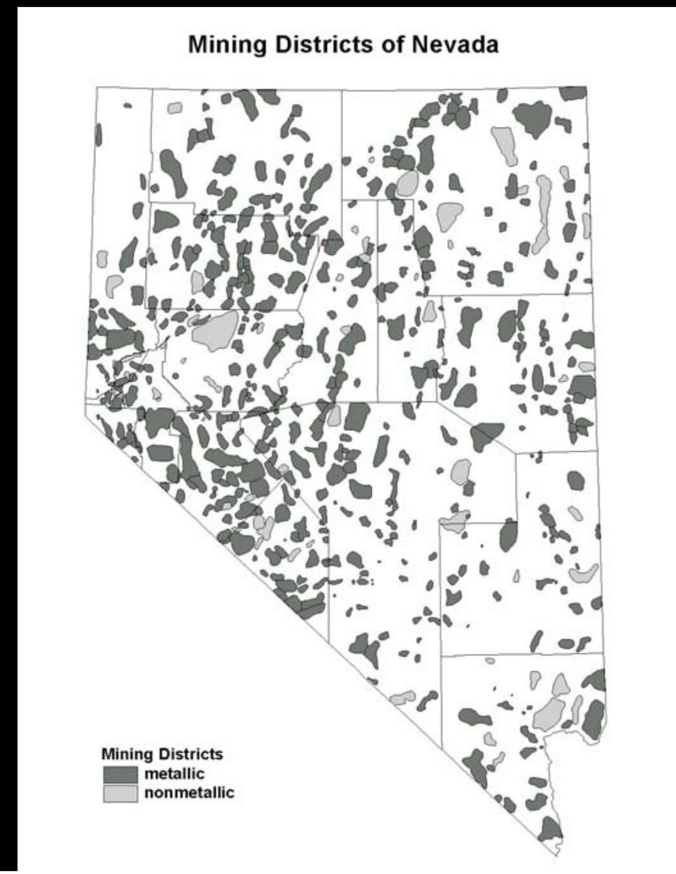


We are in the midst of the biggest gold boom in American history.

Mineral Deposits

– nearly everywhere





Major Active Mines

X Metals (mostly Au, Cu, Ag)

X Industrial minerals

Cenozoic rocks as industrial minerals in Southern Nevada:

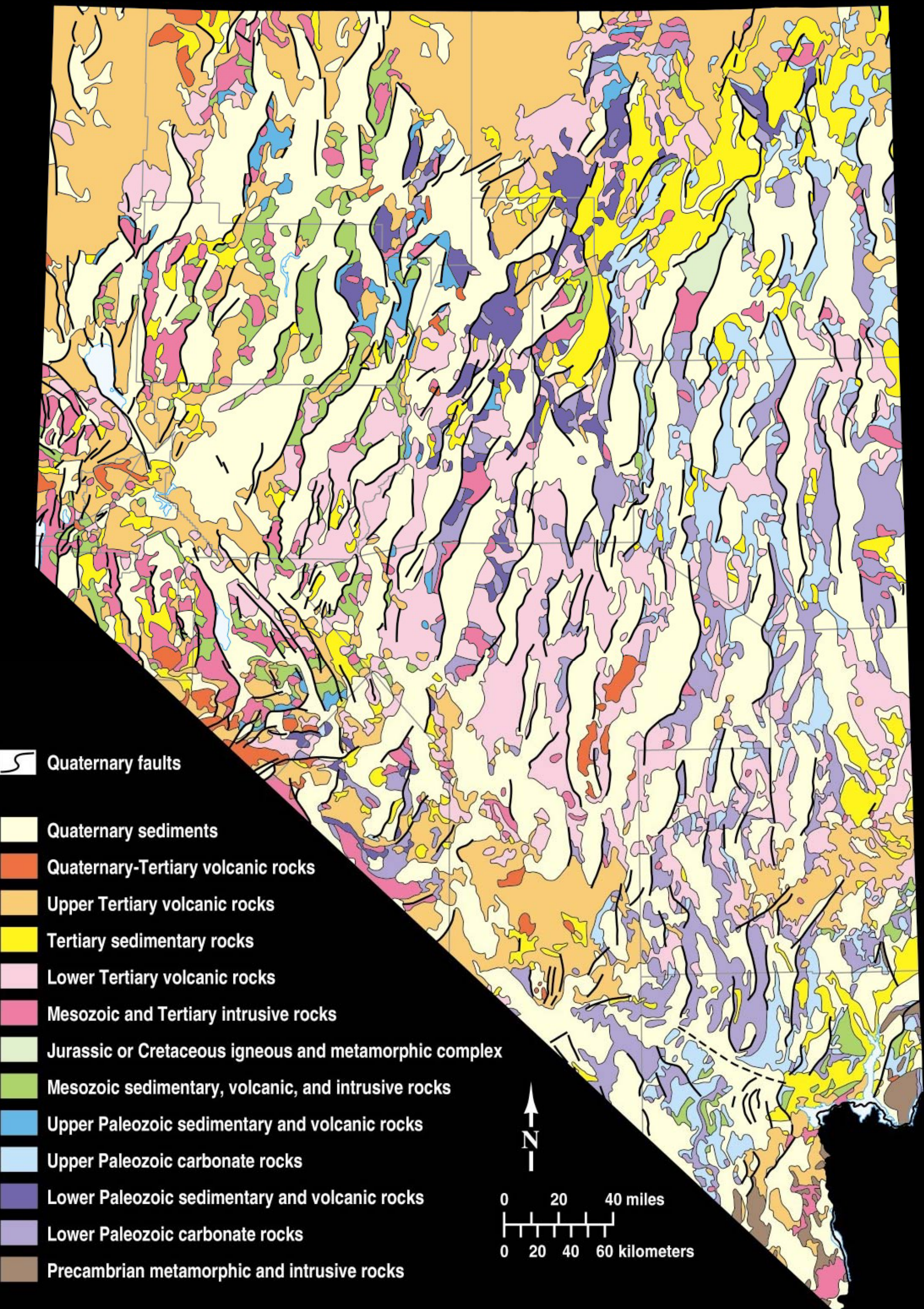
Gypsum for wallboard.

Alluvial gravels for aggregate.

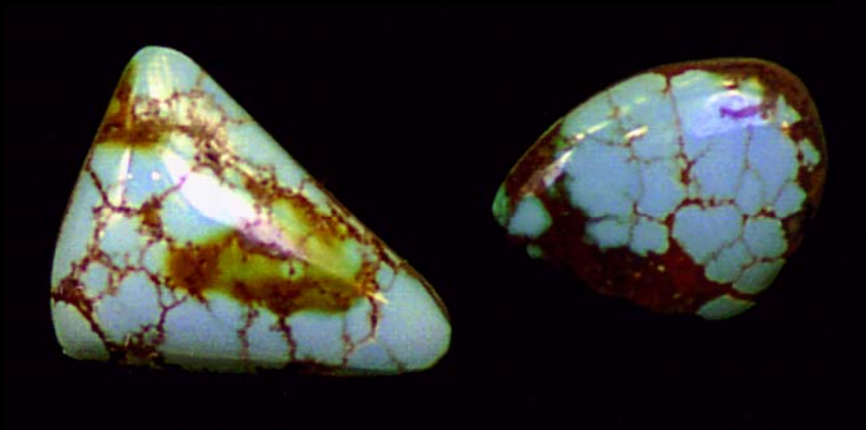
Cenozoic and Mesozoic ores of gold, silver, lead, and zinc were mined in the past.

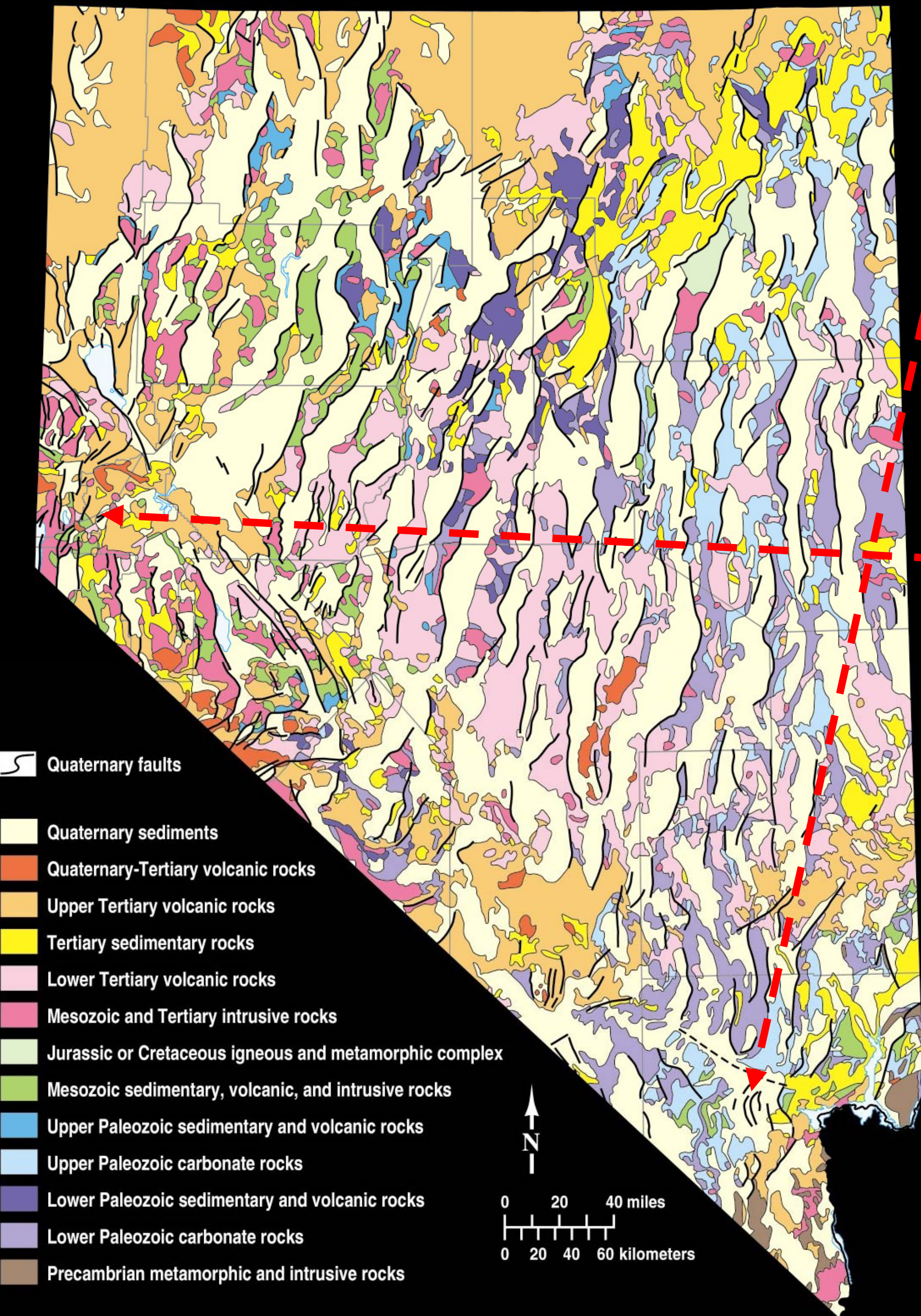
Gypsum in Miocene (~15 million years old) sediments east of Frenchman Mountain.

A blast on a Nevada Mining Association teachers’ workshop



Native American mining –
obsidian, opal, chert for tools
salt for flavoring and
preserving food
turquoise for ornaments





European/American History

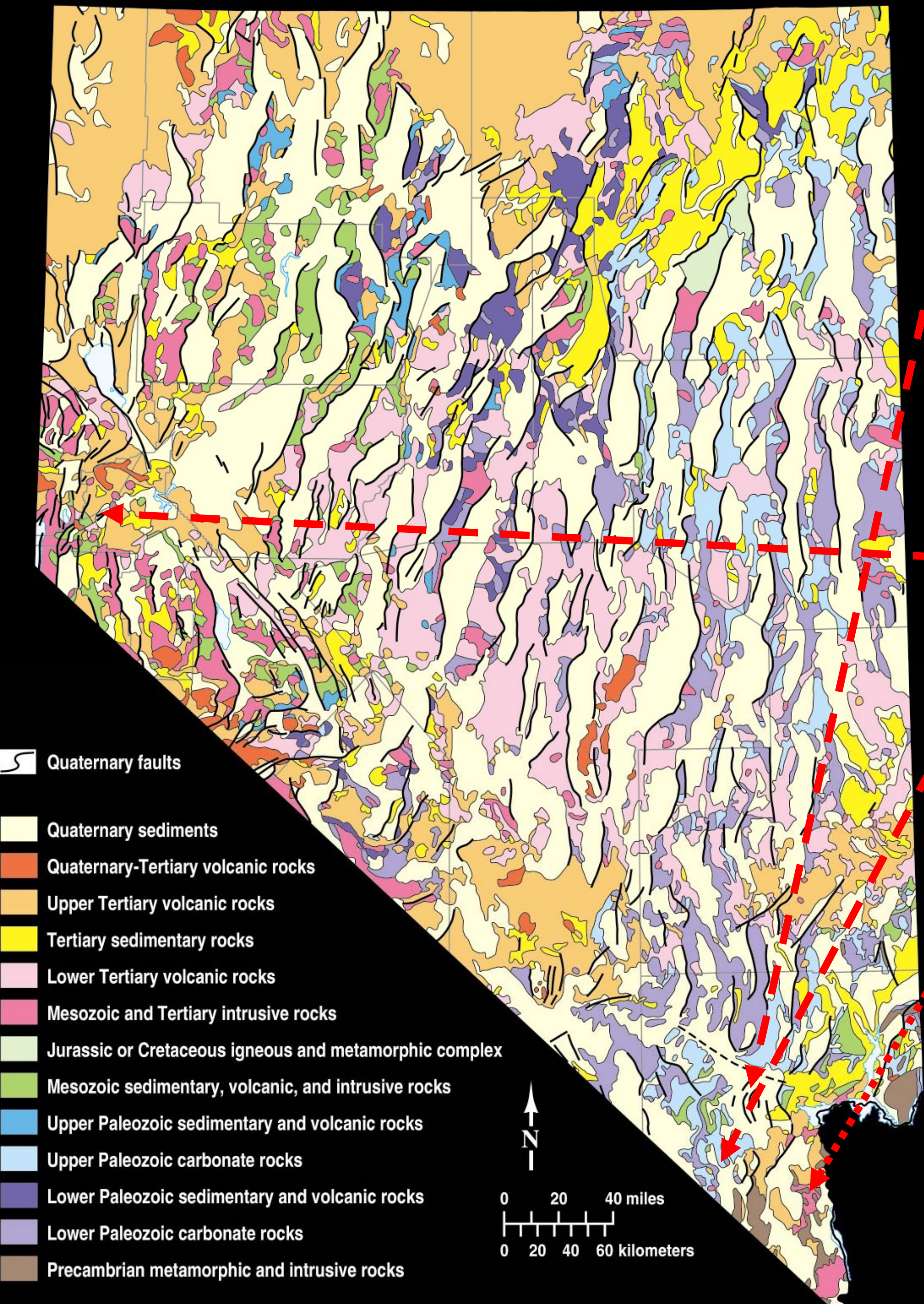
1776: Francisco Carces – Spanish monks in southern Nevada – LA to Santa Fe

1848: Treaty with Mexico – Nevada becomes part of USA

1849: Gold discovered near Dayton by Mormon settlers

Paleozoic carbonates thrust over Mesozoic sandstones near Las Vegas: not much ore where there aren't any igneous rocks.

European/American History



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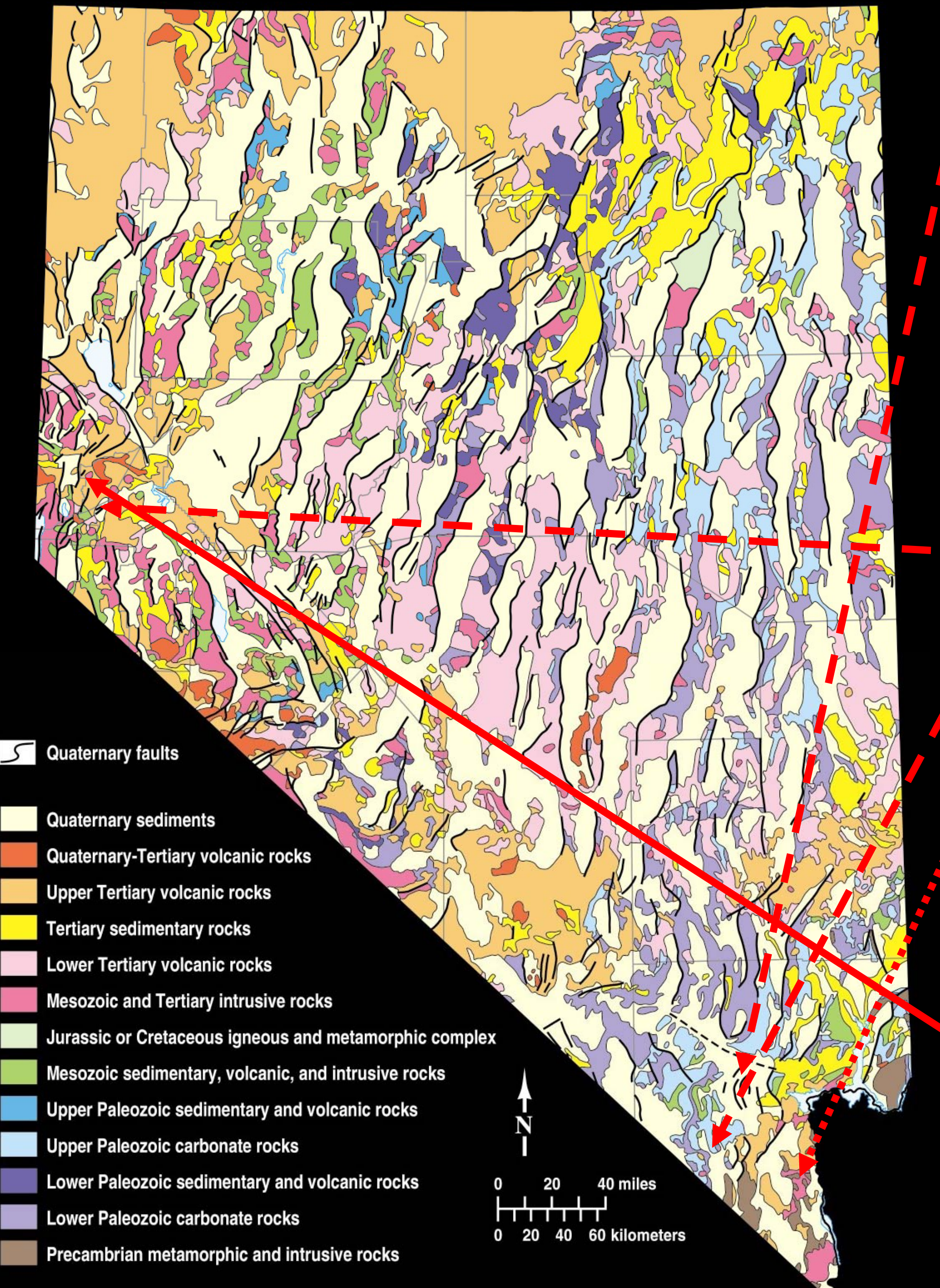
1849: Gold discovered near Dayton by Mormon settlers

1855: Potosi Mine – Zn-Pb-Ag-Au, Goodsprings district discovered by Mormons

1857: Nelson – Ag-Au



European/American History

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1849: Gold discovered near Dayton by Mormon settlers

1855: Potosi Mine – Zn-Pb-Ag-Au, Goodsprings district discovered by Mormons

1857: Nelson – Ag-Au

1859: Discovery of the Comstock Lode – Ag-Au, Virginia City

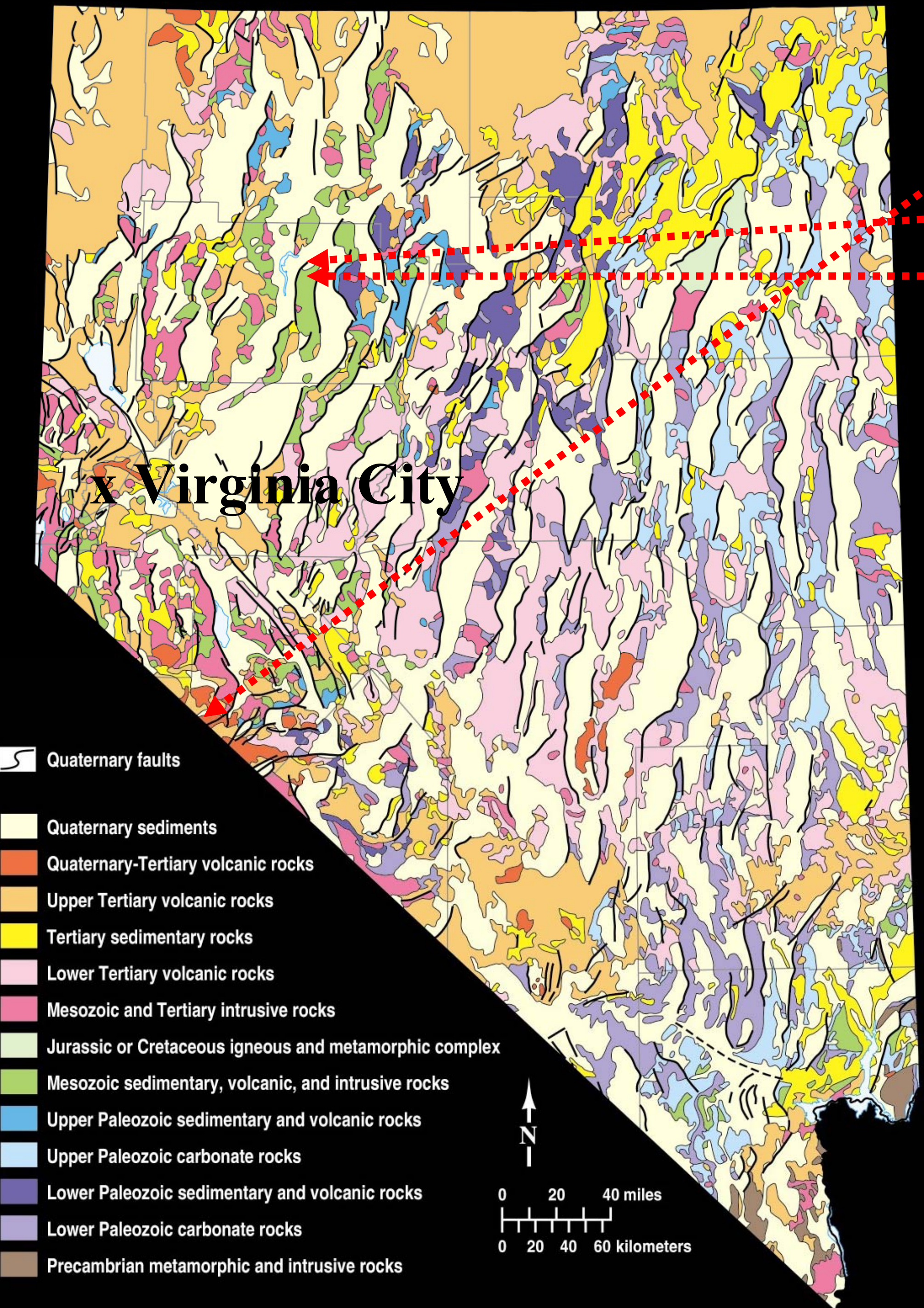
1864: Statehood – Battle Born and the Silver State

The '49ers spread out across the west:

Aurora (1860)

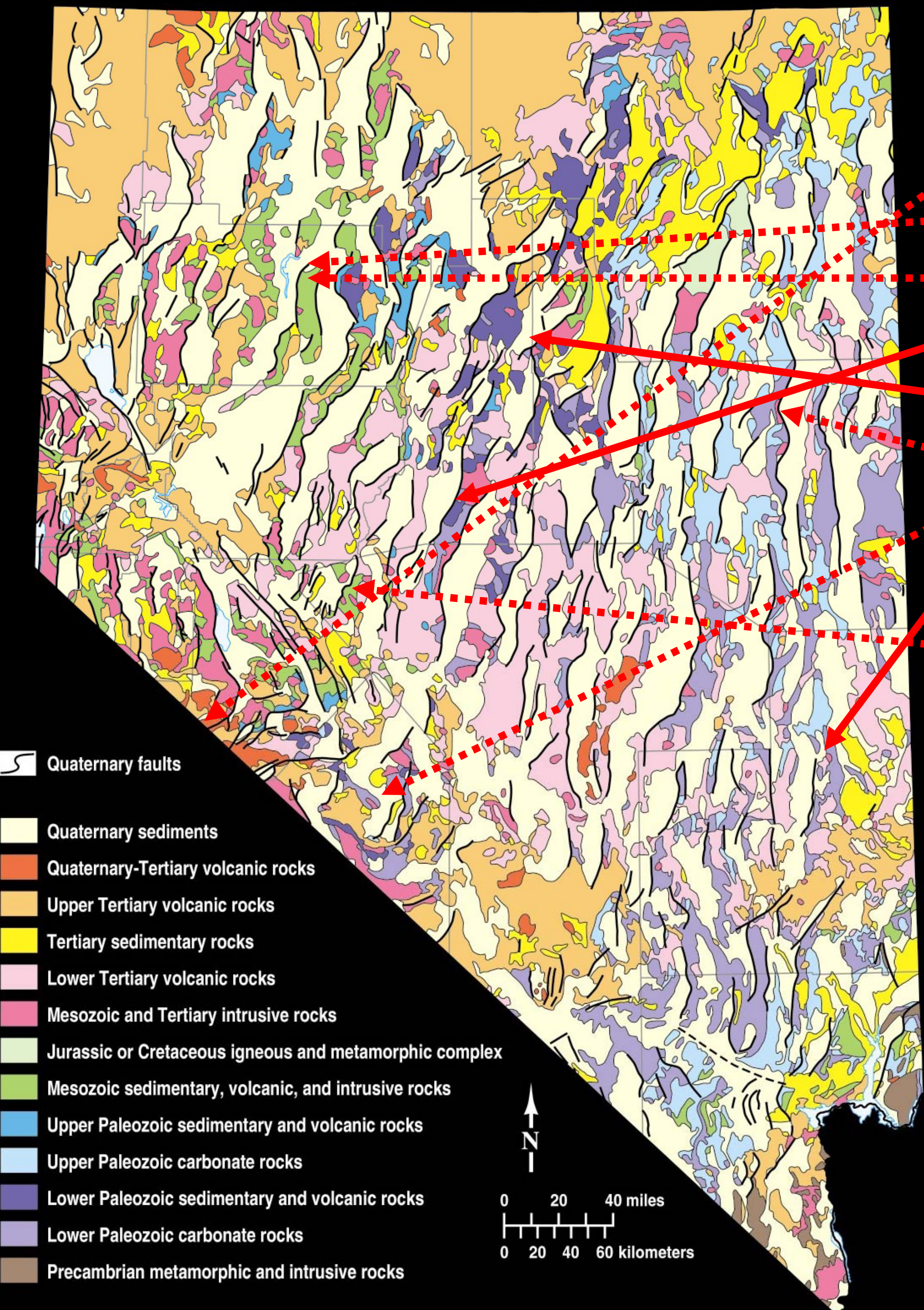
Humboldt district (1860)

Star and Buena Vista districts (1861)



The ’49ers spread out across the west:

Aurora (1860)
Humboldt district (1860)
Star and Buena Vista districts (1861)
Reese River district – Austin (1862)
Cortez (1863)
Cherry Creek district (1863)
Silver Peak (1863)
Pioche (1863)
Union district – Ione (1863)



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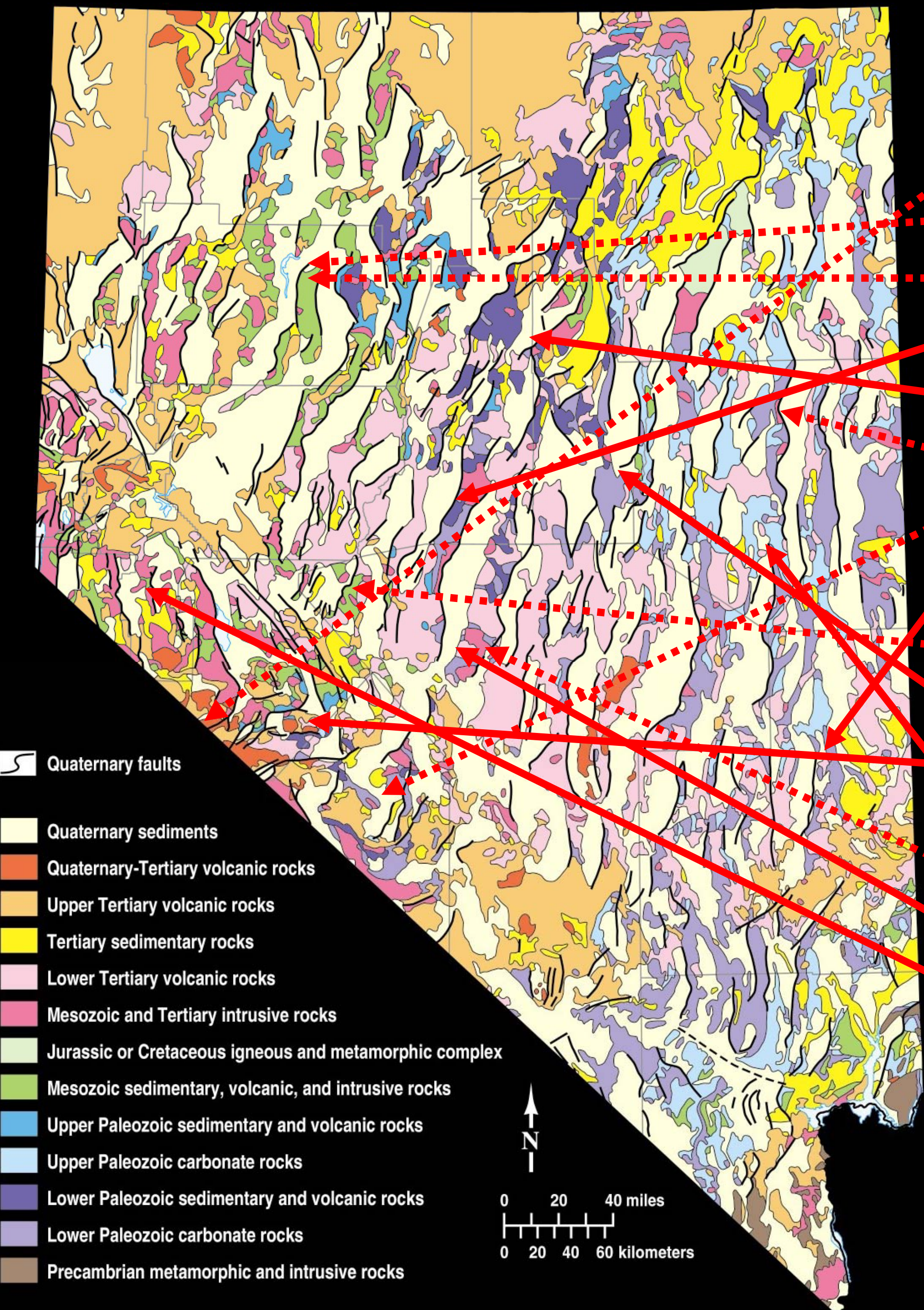
Eureka (1864)
Candelaria (1864)
White Pine district – Ely (1865)
Belmont (1865)
Round Mountain (1865)
Yerington (1865)



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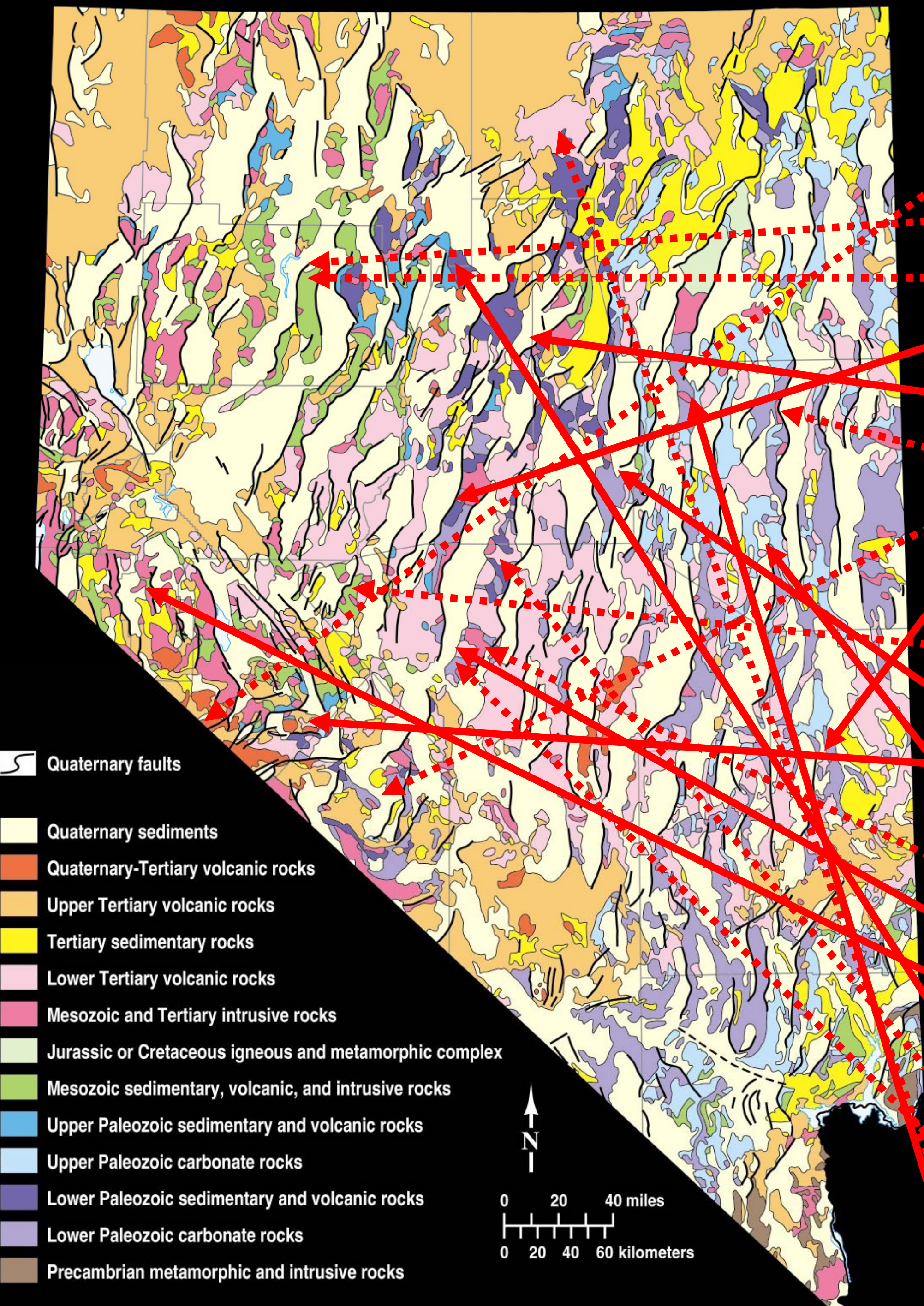

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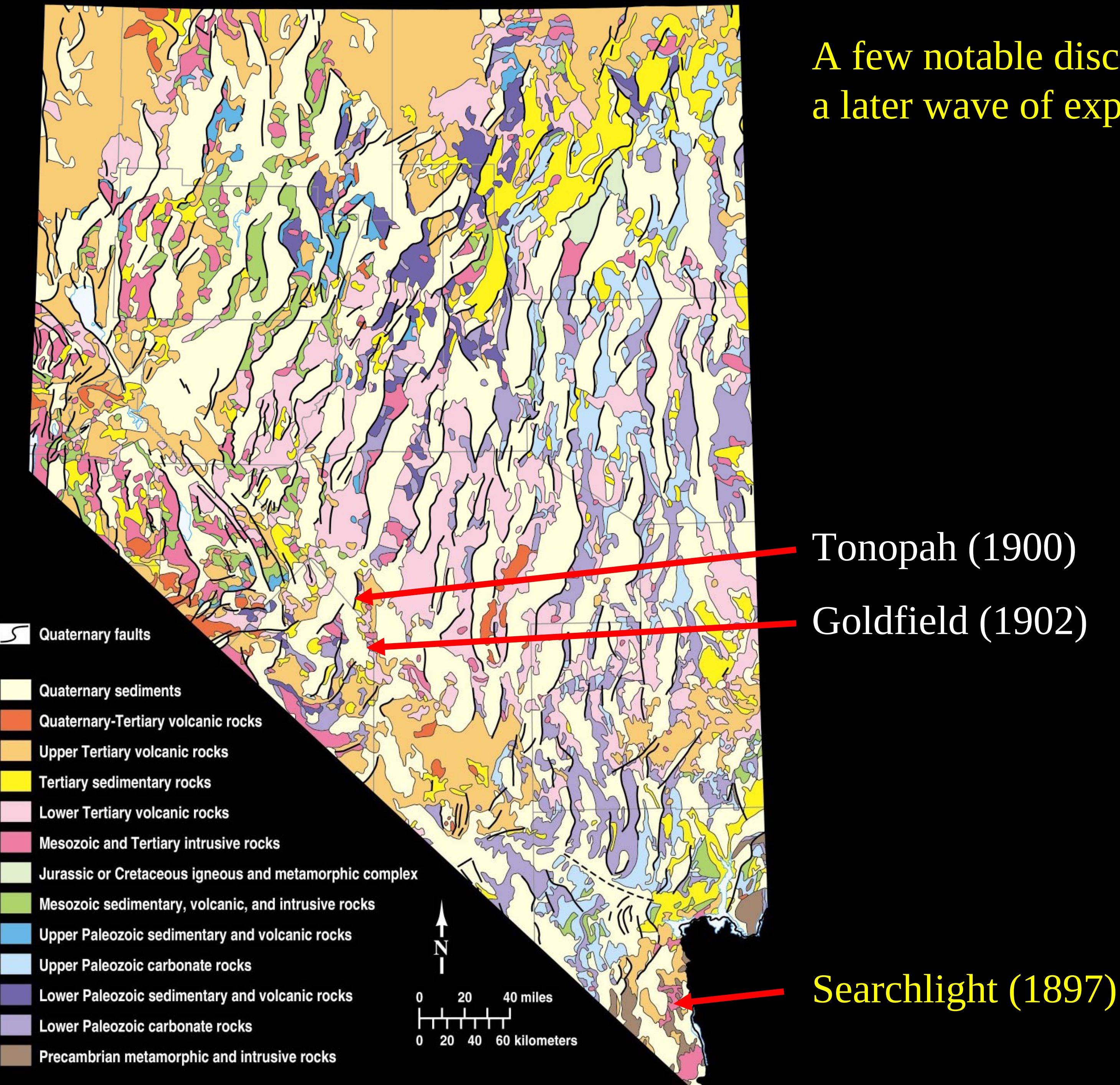
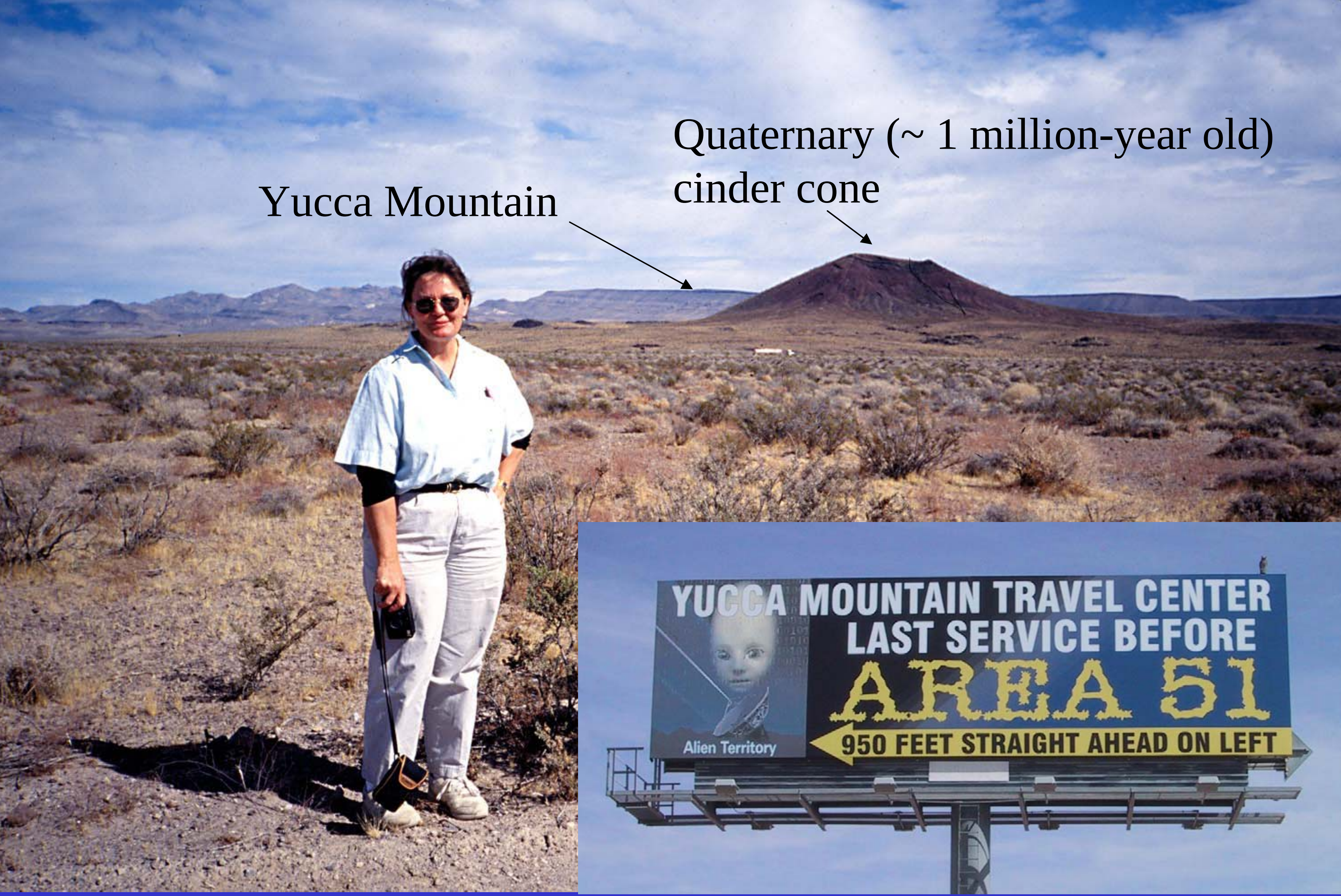
Round Mountain (1865)
Yerington (1865)
Battle Mountain (1866)
Northumberland (1866)
Manhattan (1866)
Tuscarora (1867)
Bald Mountain (1869)

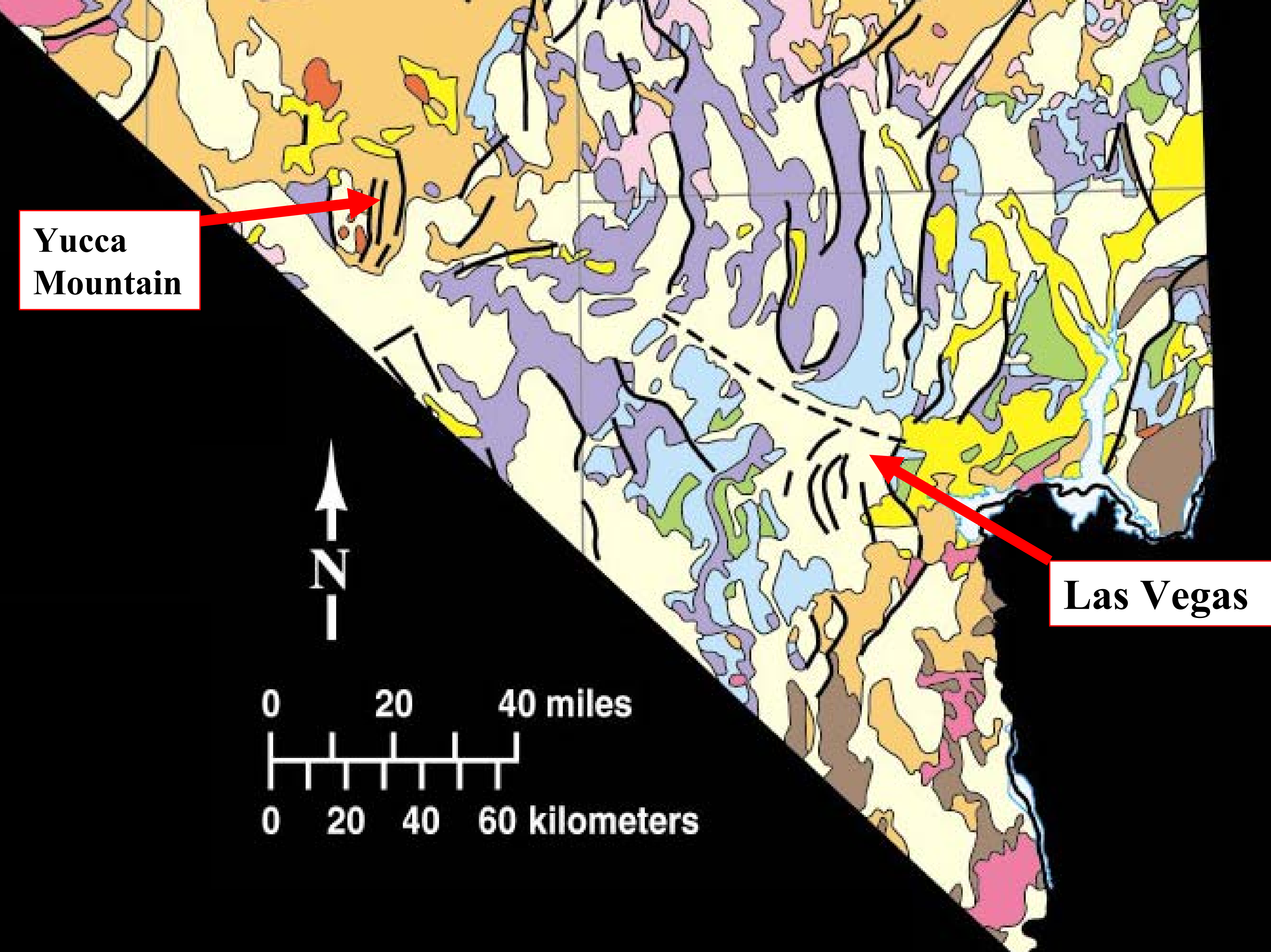
A few notable discoveries were made in a later wave of exploration.



Cenozoic (<65 million years old) volcanic rocks are in beige; intrusive igneous rocks are in pink; mostly Miocene (24 to 5 million-year old) sedimentary rocks are in bright yellow; Quaternary (<1.8 million- year old) alluvial sediments in pale yellow fill the upper parts of valleys.

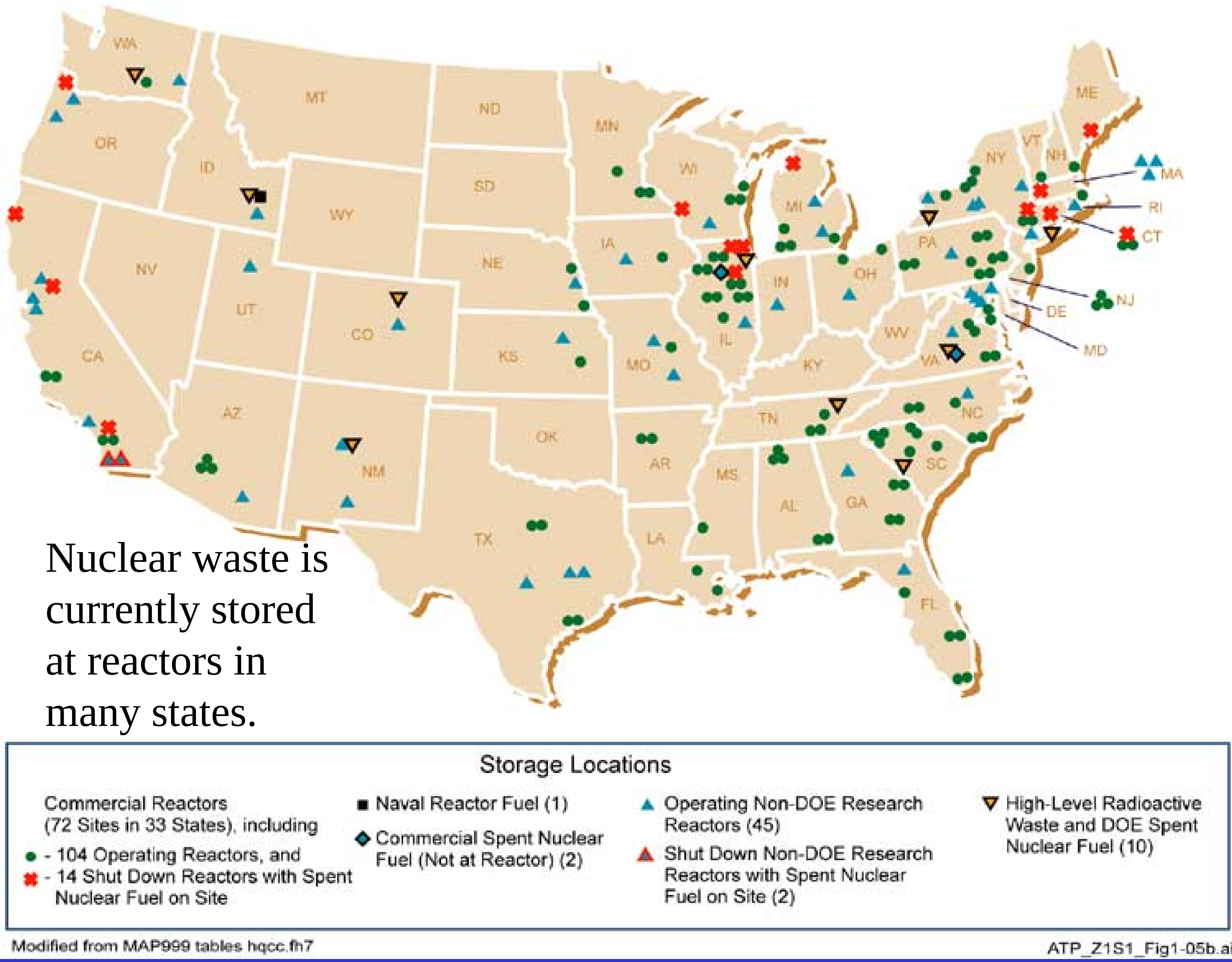


Black Cone in Crater Flat, Yucca Mountain in background to the east



Yucca Mountain
Las Vegas
N
0 20 40 miles
0 20 40 60 kilometers

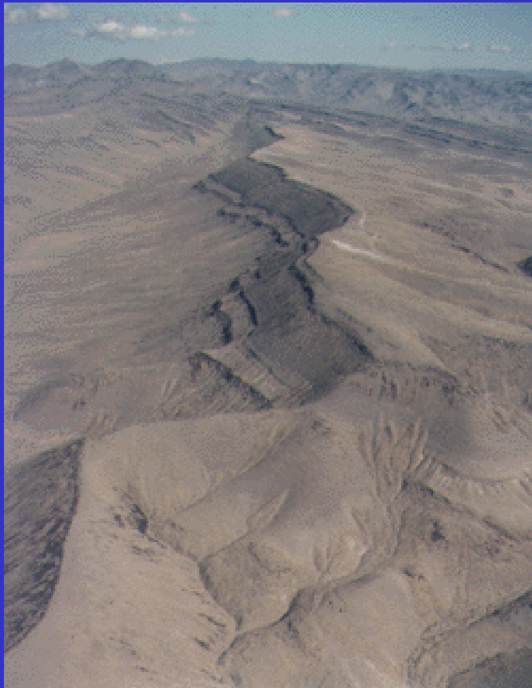
Nuclear waste is currently stored at reactors in many states.



Issues at Yucca Mountain (human health over a <u>one-million-year</u> time period):

Earthquake hazards (shaking, faulting and fracturing)

Fluid flow (fractures, flow paths to springs, saturated and unsaturated flow)

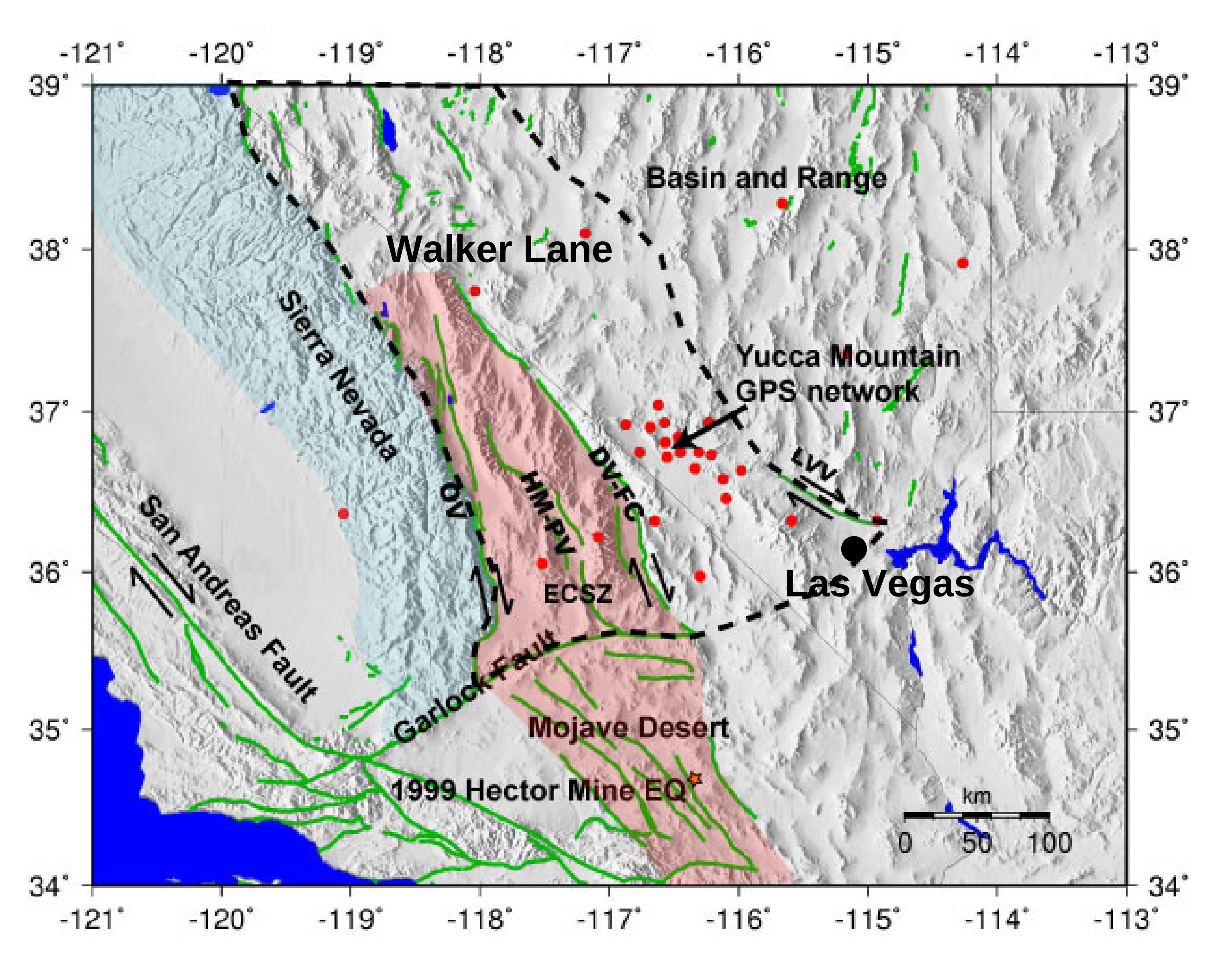


Corrosion of containers

Volcanism

Transportation

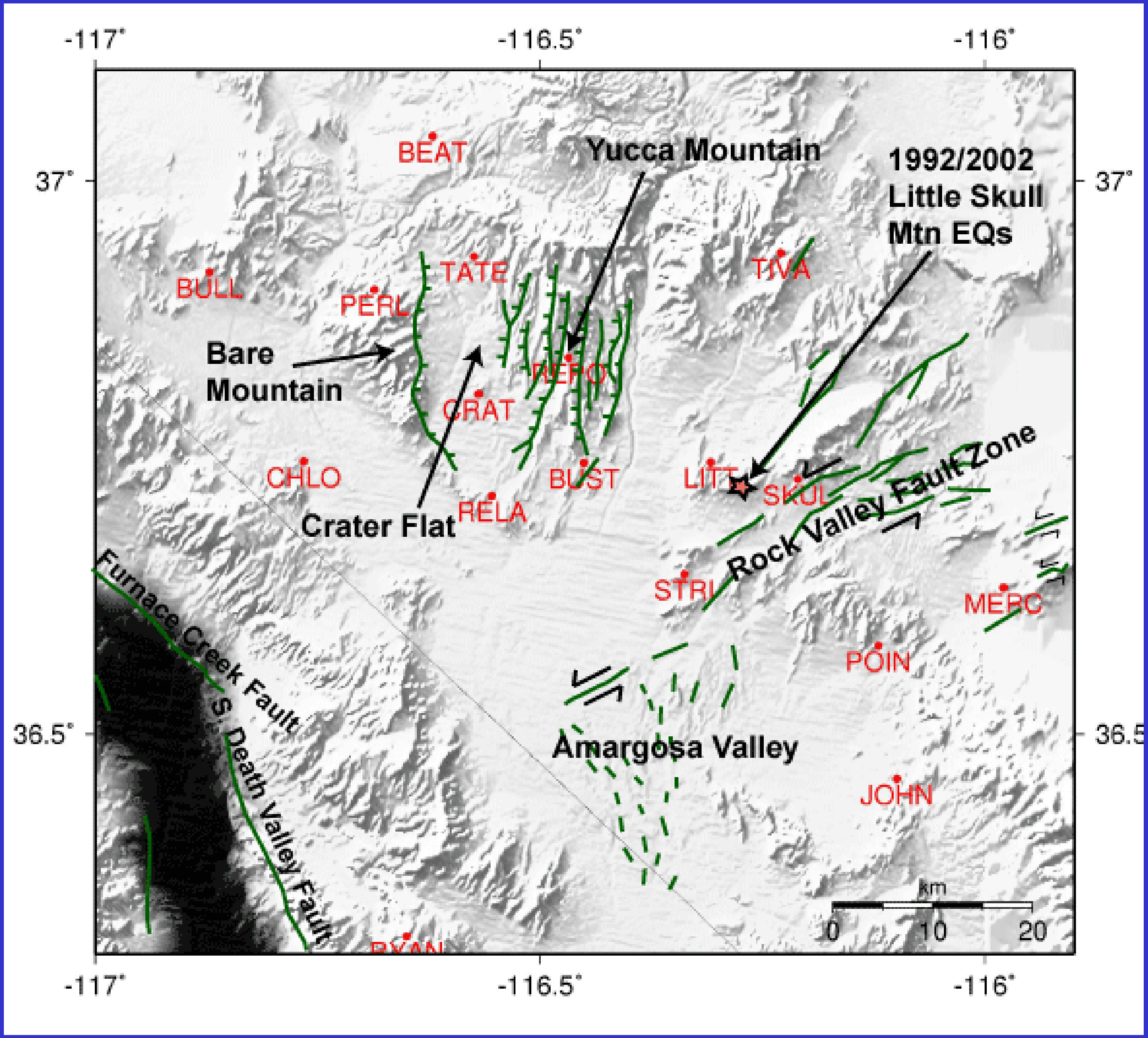
Earthquake Hazards - Regional Tectonic Setting



- Red dots; BARGEN stations
- Green lines; Quaternary faults (Jennings, 1975; Dohrenwend et al., 1996)

slide courtesy of Emma Hill

Earthquake Hazards - Local Tectonic Setting

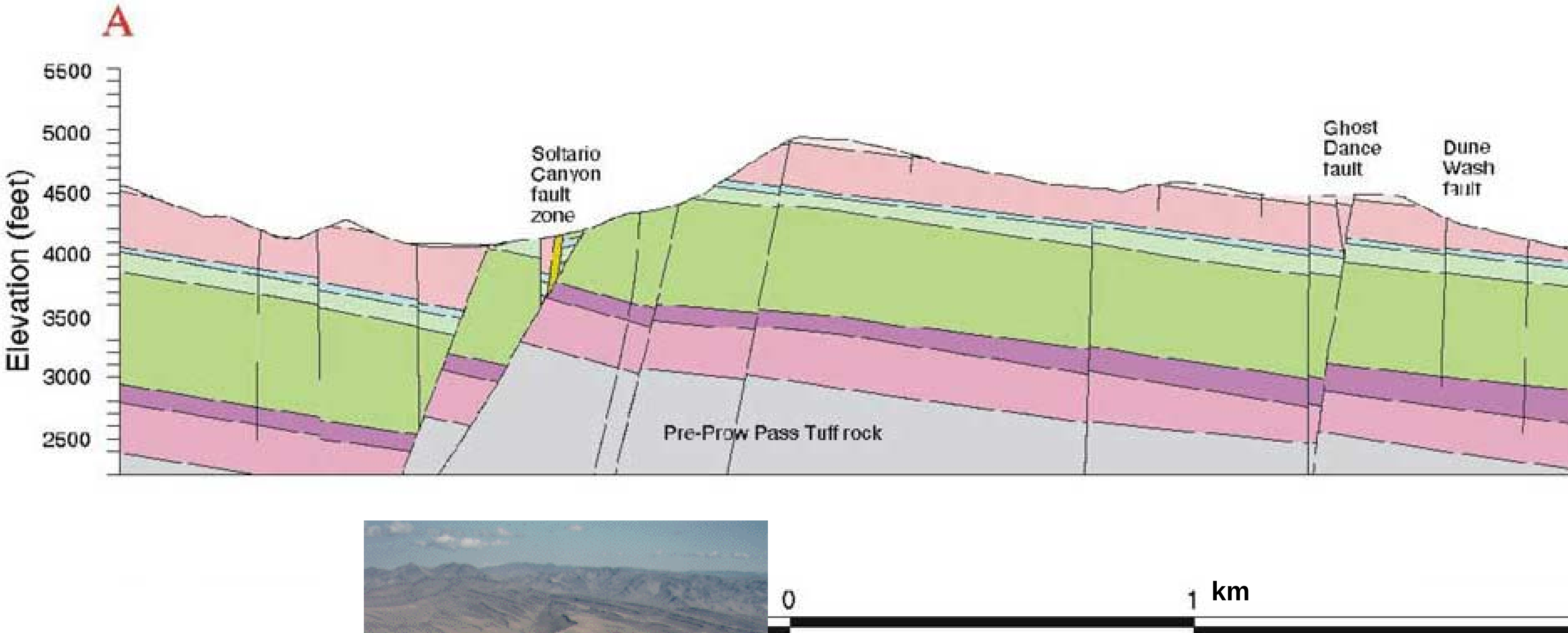


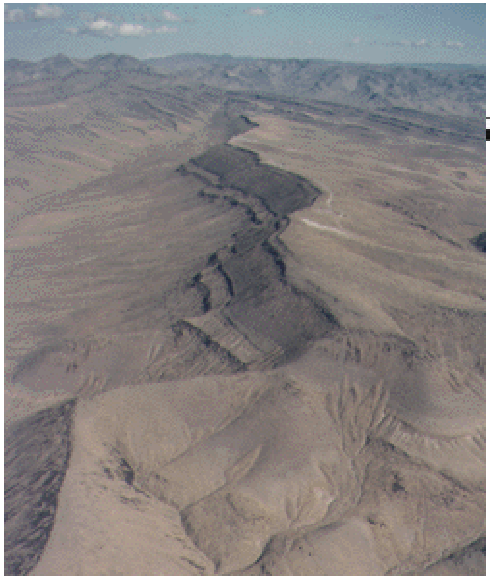
The Yucca Mountain faults have very low geologic slip rates, 0.01 – 0.02 mm/yr (Simonds et al., 1995)

slide courtesy of Emma Hill

Simplified Cross Section of Yucca Mountain

looking north

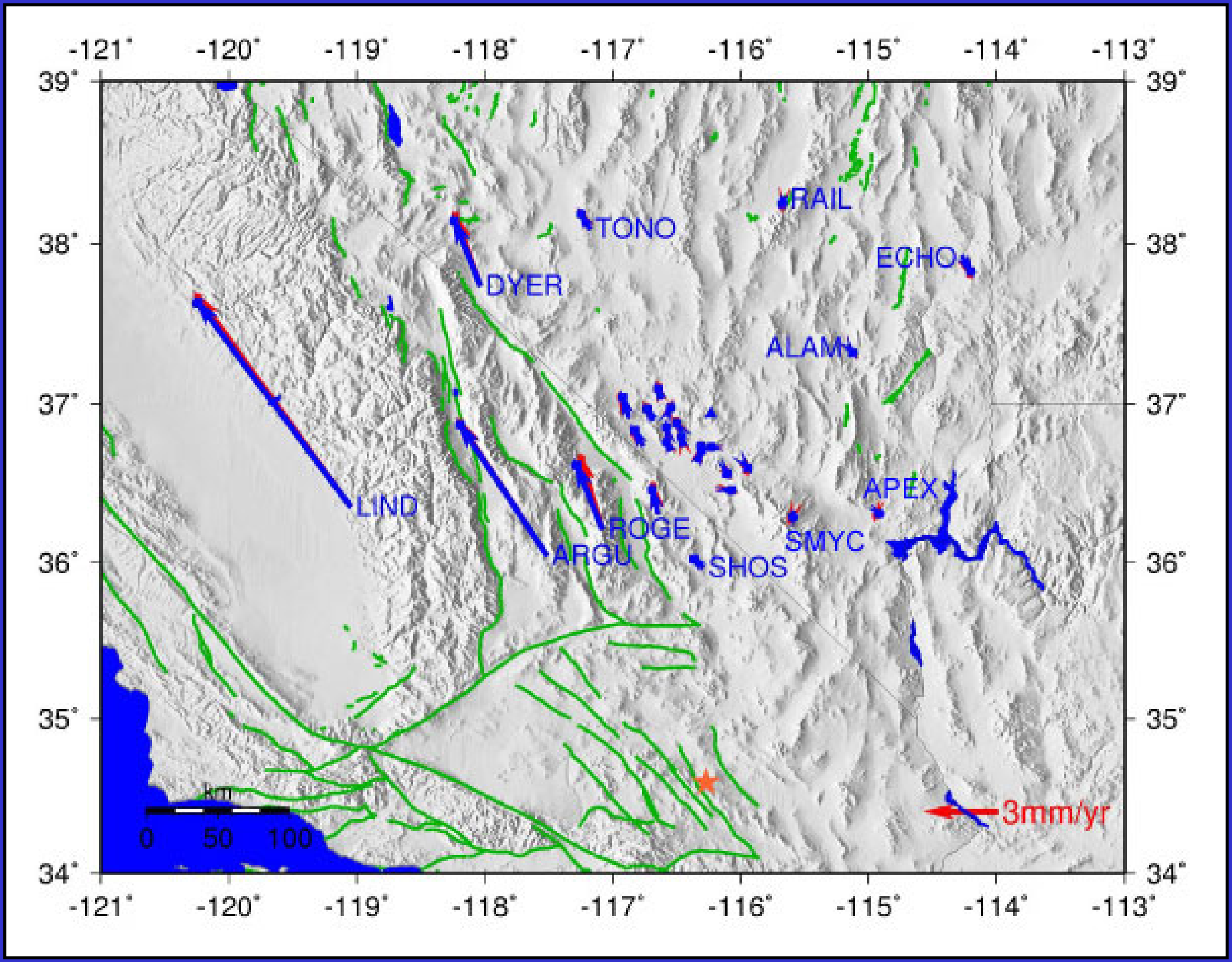


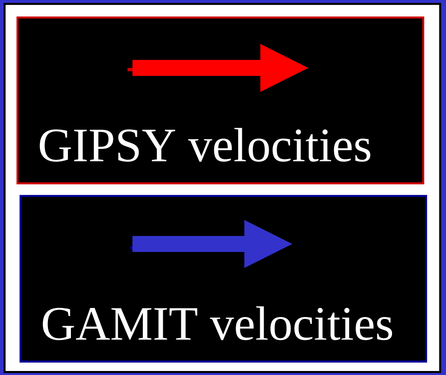


How active are the faults – from geologic, seismic, and geodetic perspectives?


looking north from the crest of Yucca Mountain
GPS antenna

Comparison of GIPSY and GAMIT results

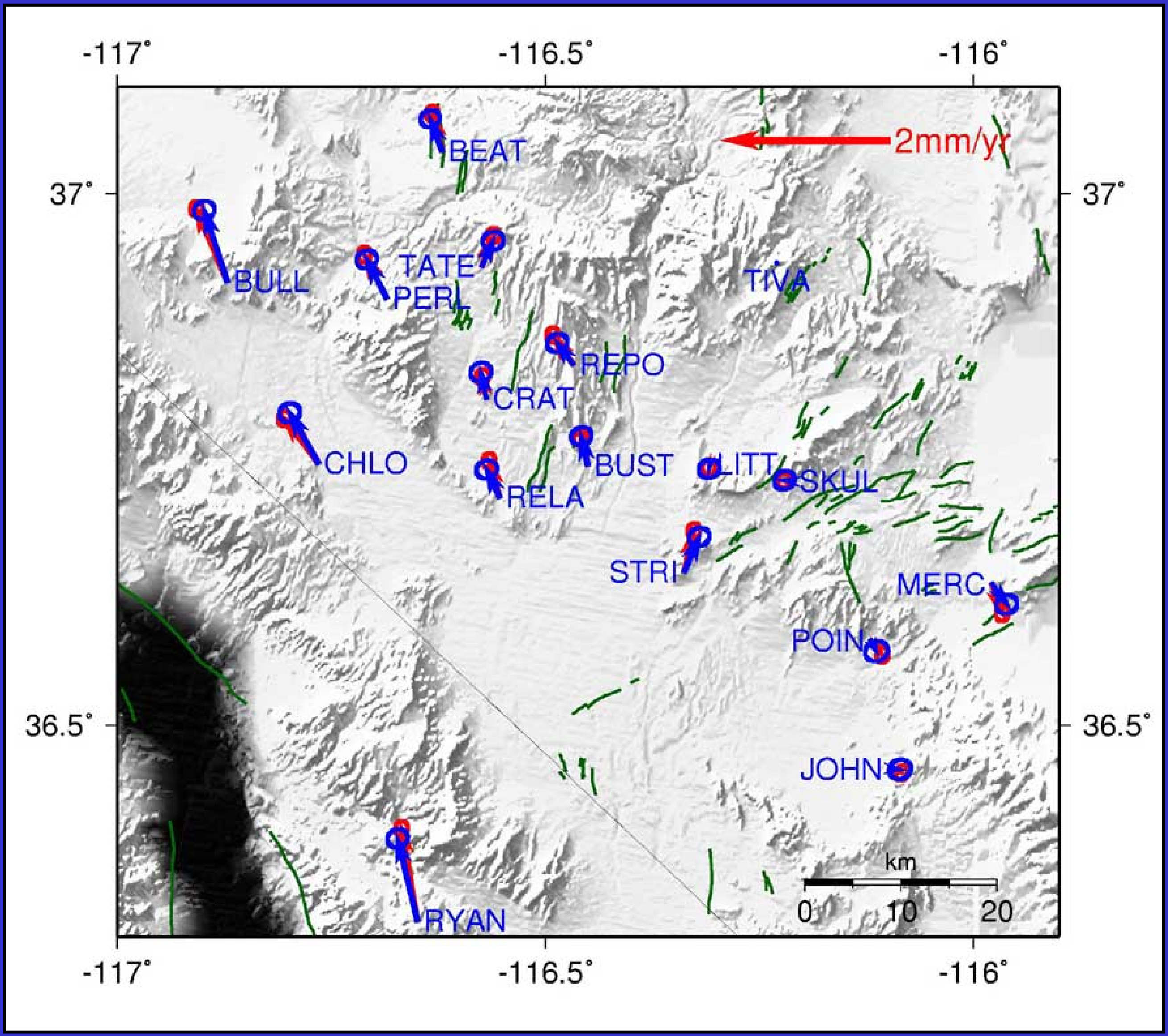


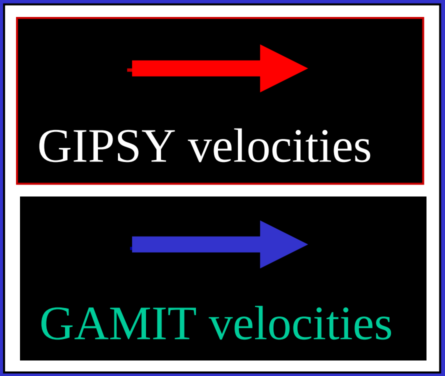


- Error ellipses are 95% confidence
- Velocities plotted relative to station TIVA (blue triangle)
- North American reference frame

slide courtesy of Emma Hill

Comparison of GIPSY and GAMIT results





RMS of velocity differences:

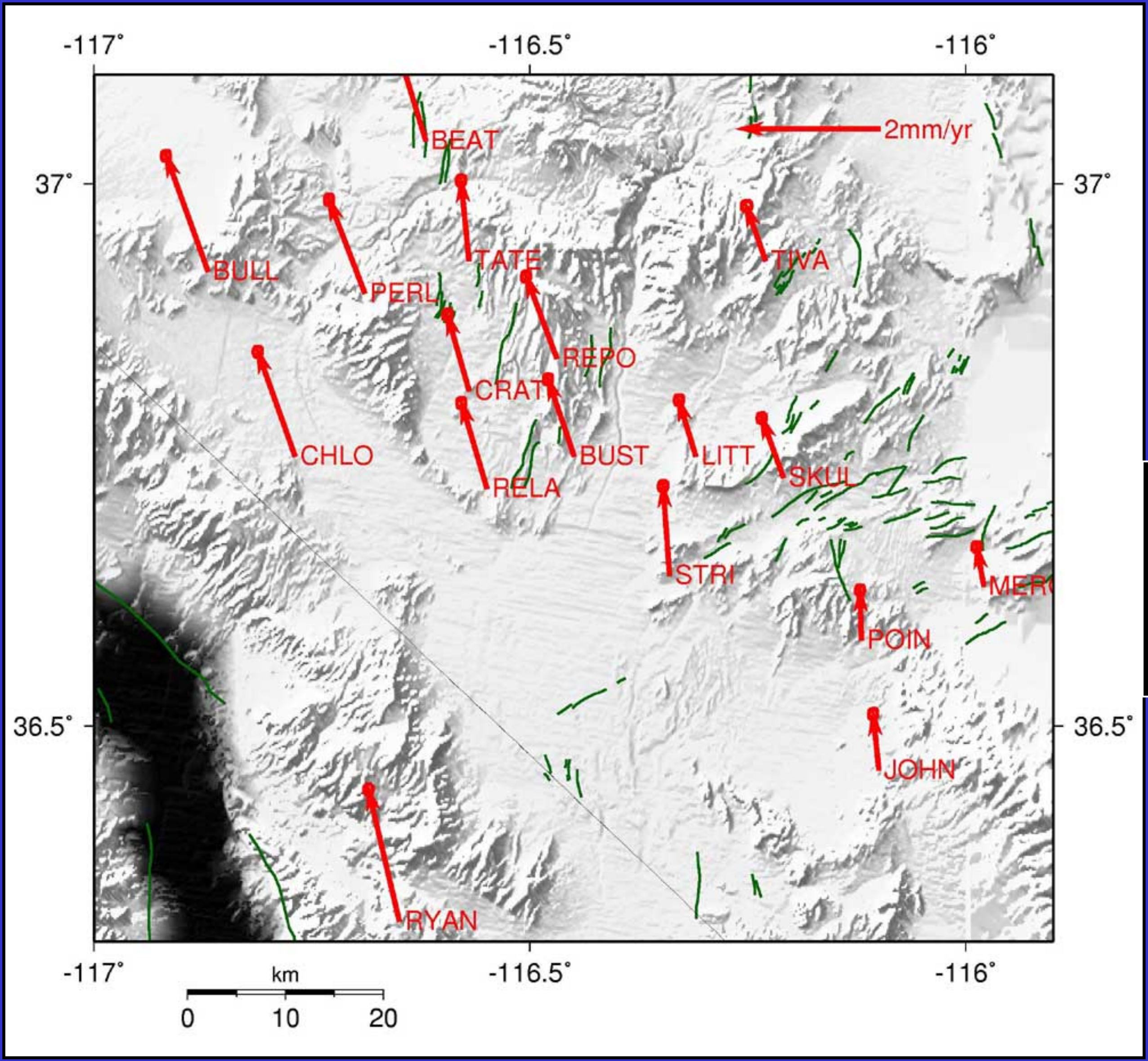
0.07 mm/yr for the east

0.11 mm/yr for the north

(Velocities plotted relative to TIVA in a NA reference frame. 95% confidence error ellipses.)

slide courtesy of Emma Hill

GIPSY results



Velocity difference for

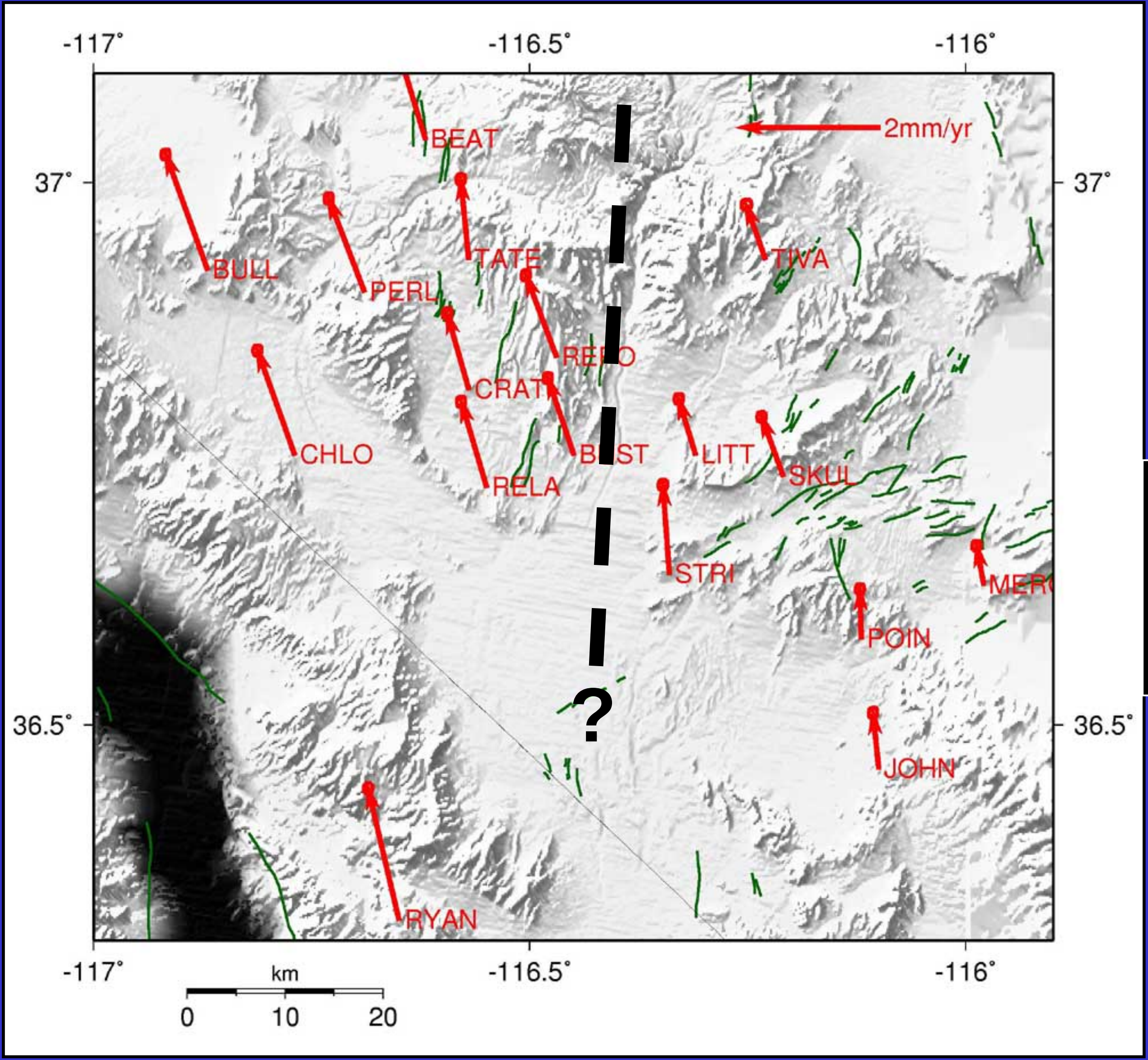
TIVA-BULL:

1.0 ± 0.1 mm/yr

(Velocities plotted relative to ECHO in a NA reference frame. 95% confidence error ellipses.)

slide courtesy of Emma Hill

GIPSY results



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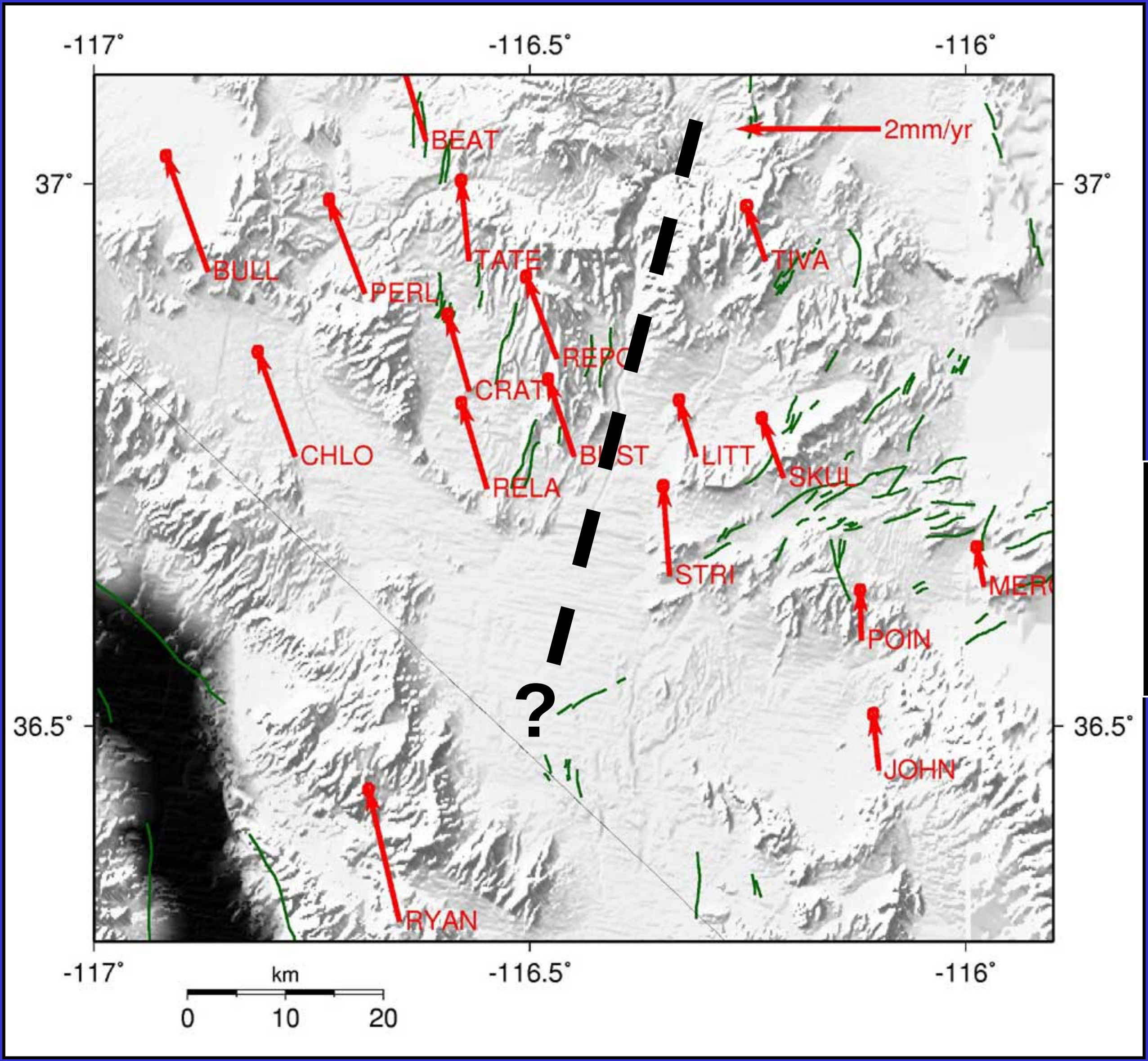

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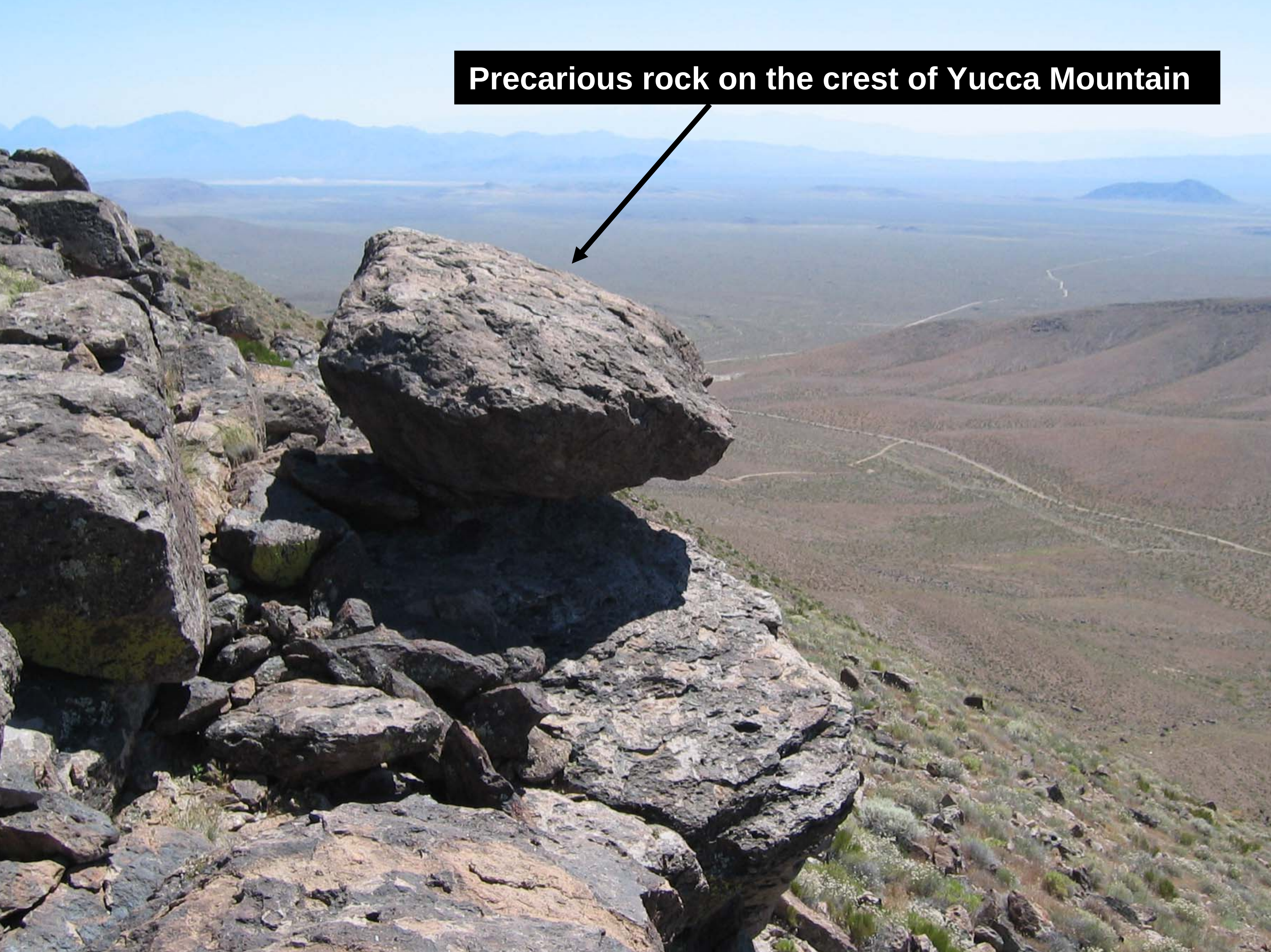
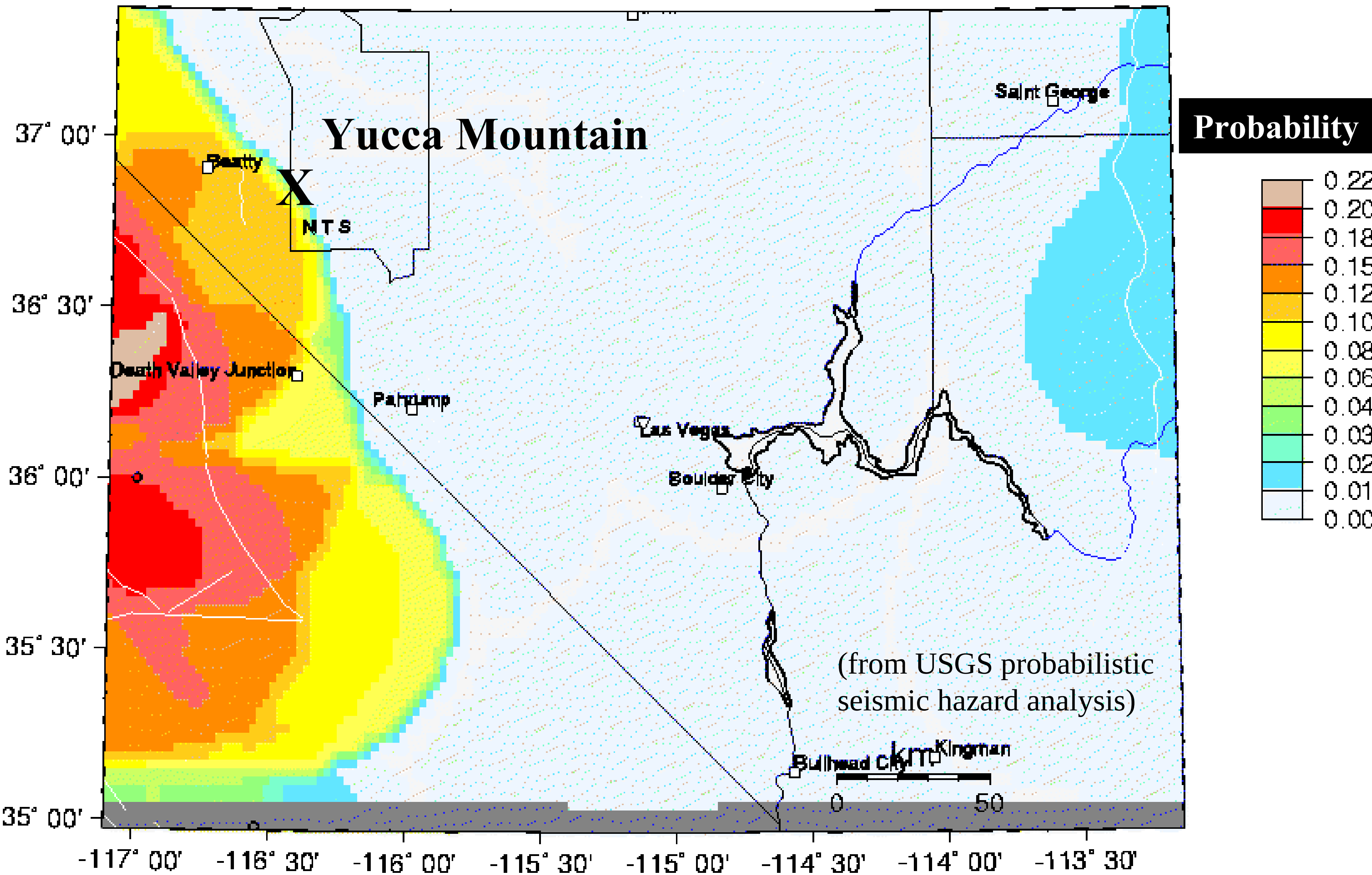
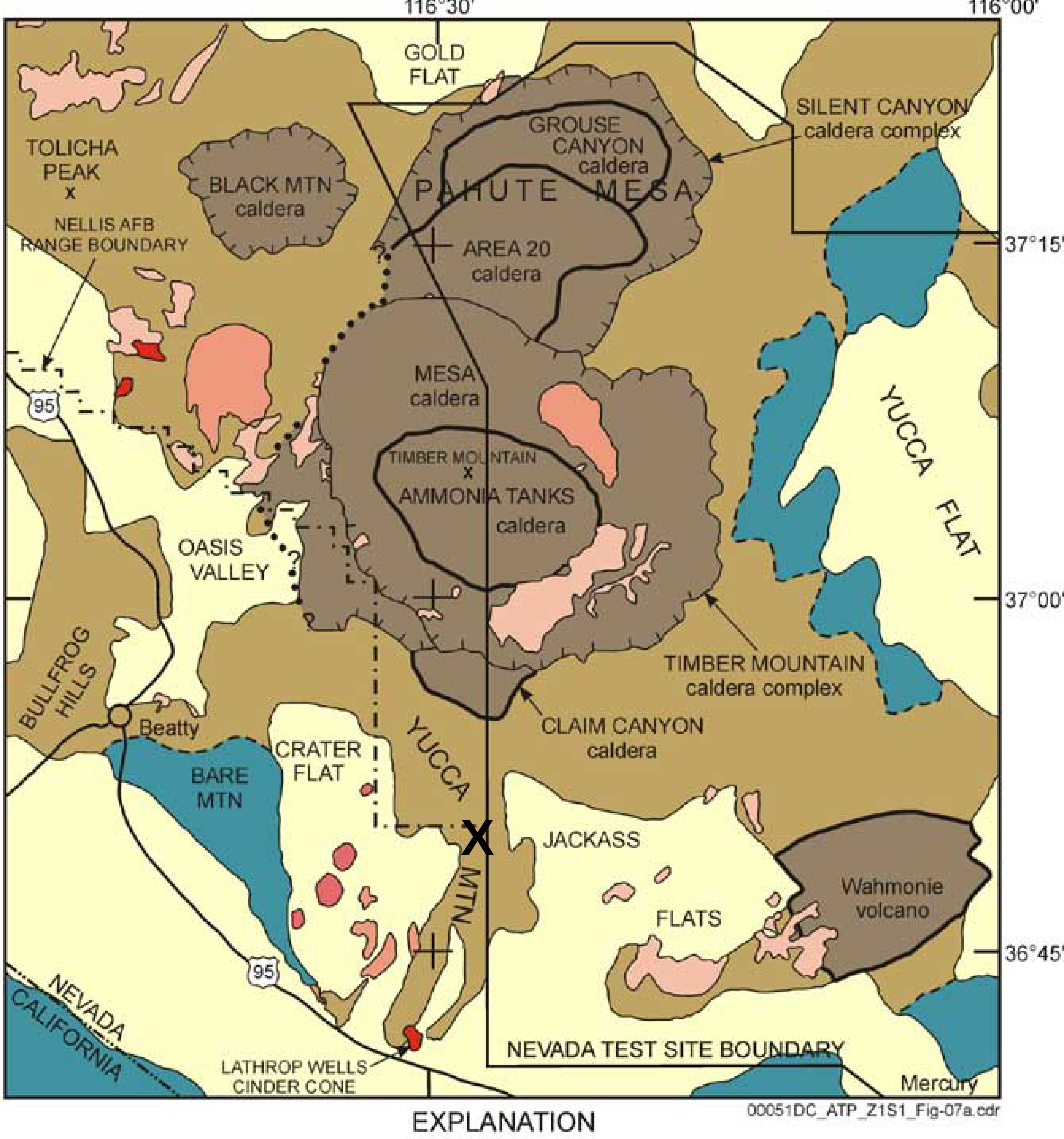

Precarious rock on the crest of Yucca Mountain

Probability of an earthquake of magnitude 7.0 or greater occurring within 50 km in 50 years: ~2 to 6% chance for Yucca Mountain site

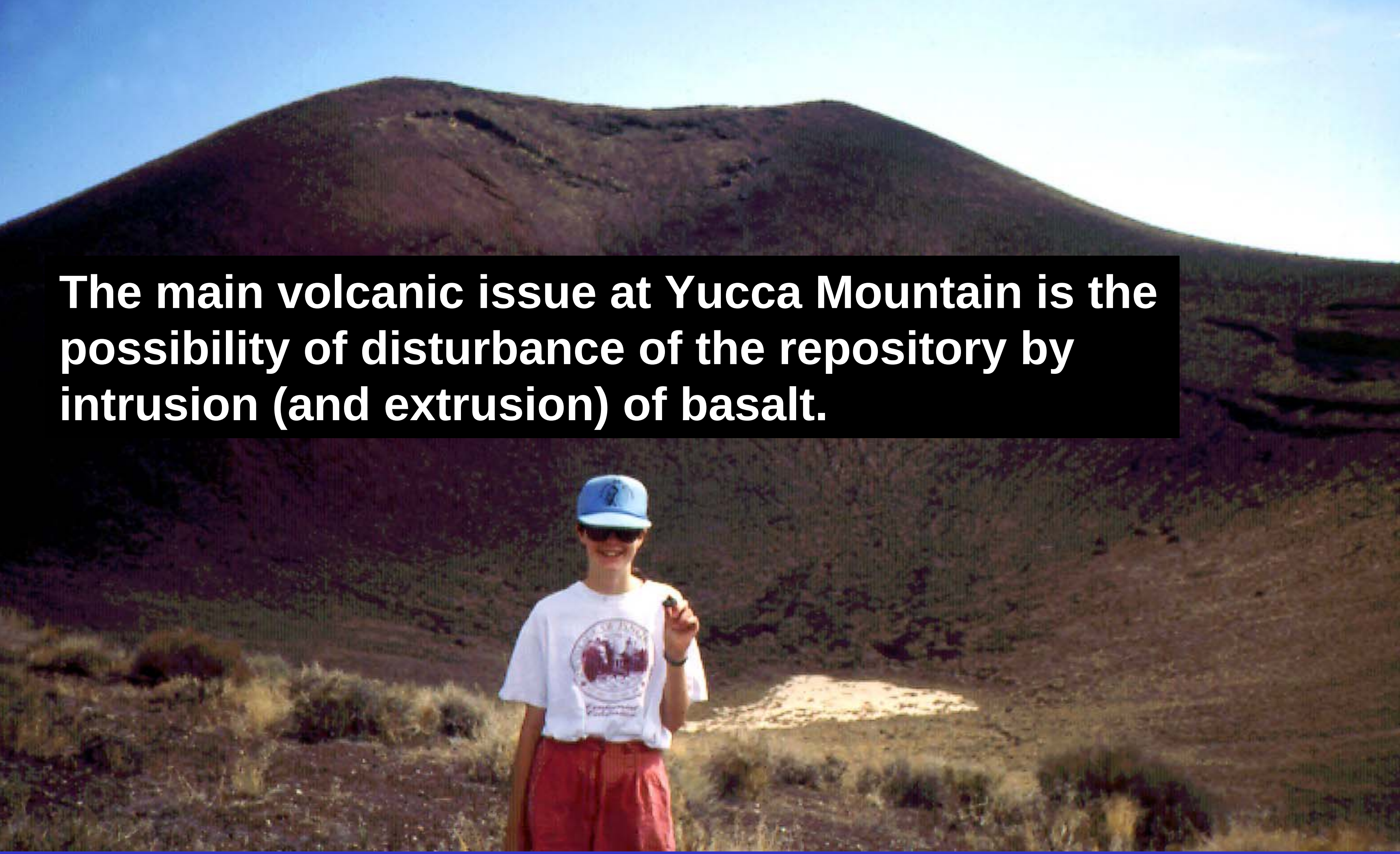


(from USGS probabilistic seismic hazard analysis)

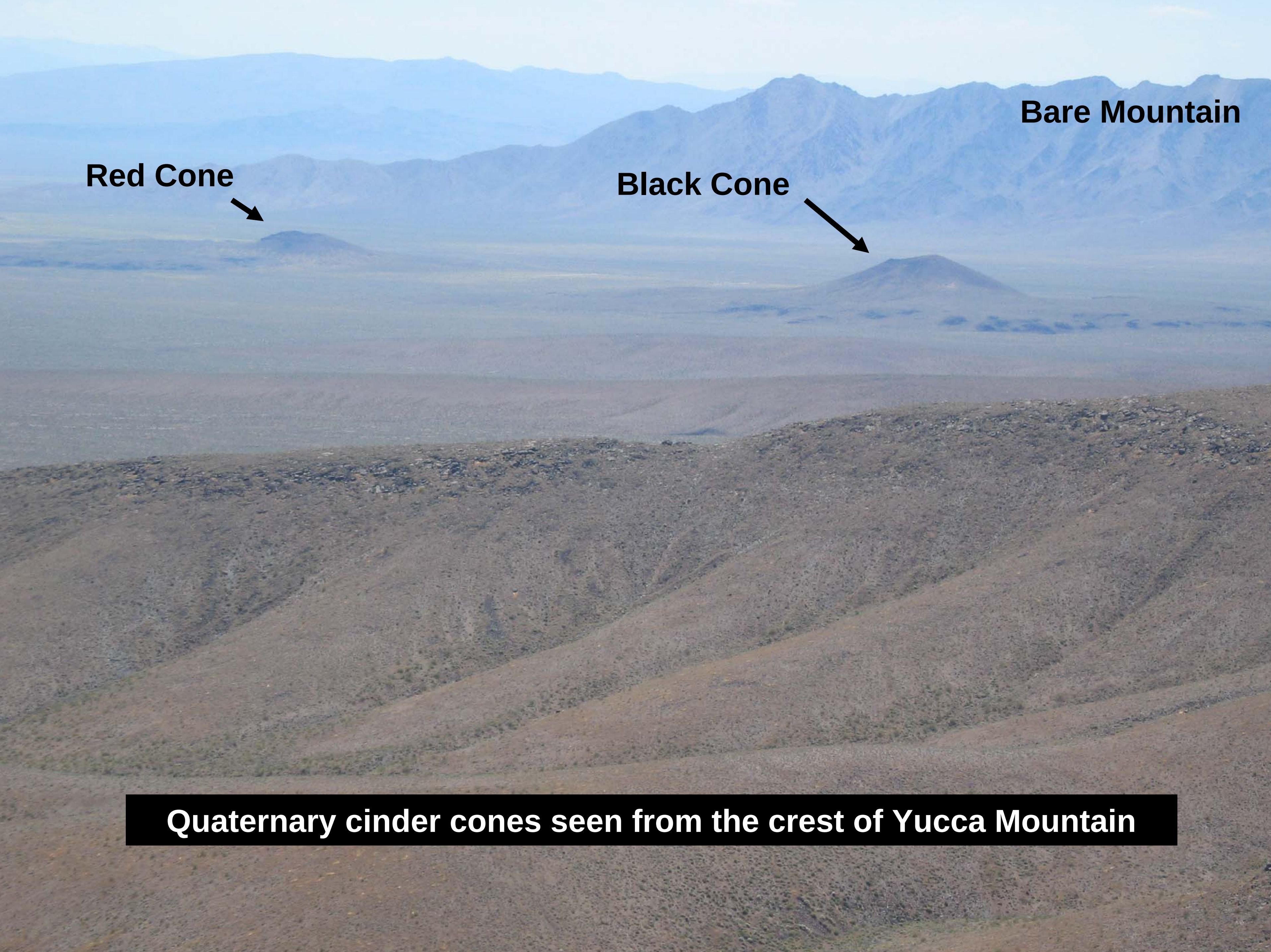


Yucca Mountain is underlain and surrounded by volcanic rocks, mostly >10 million years old.

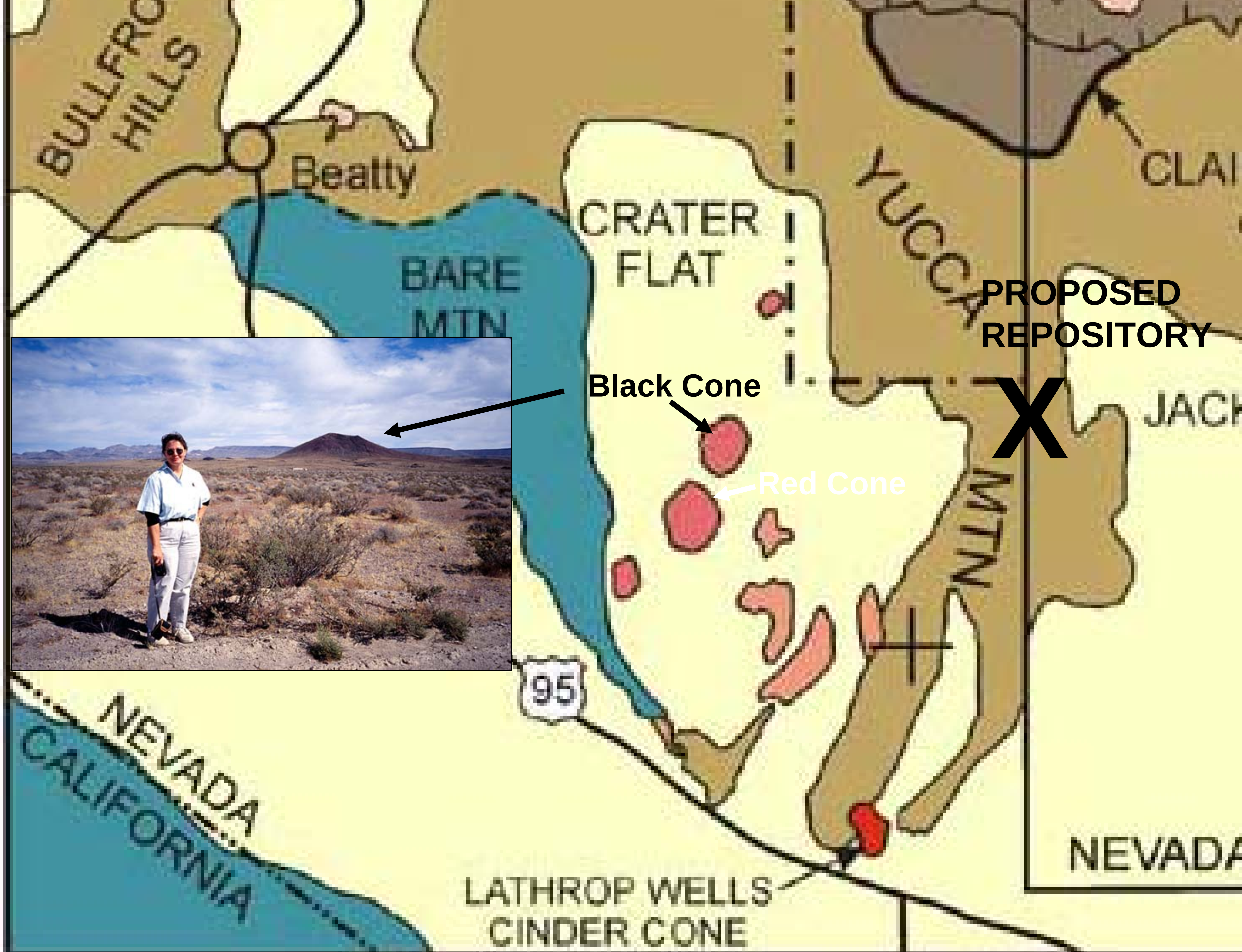
Massive eruptions, as in the Cascades, are highly unlikely at Yucca Mountain.



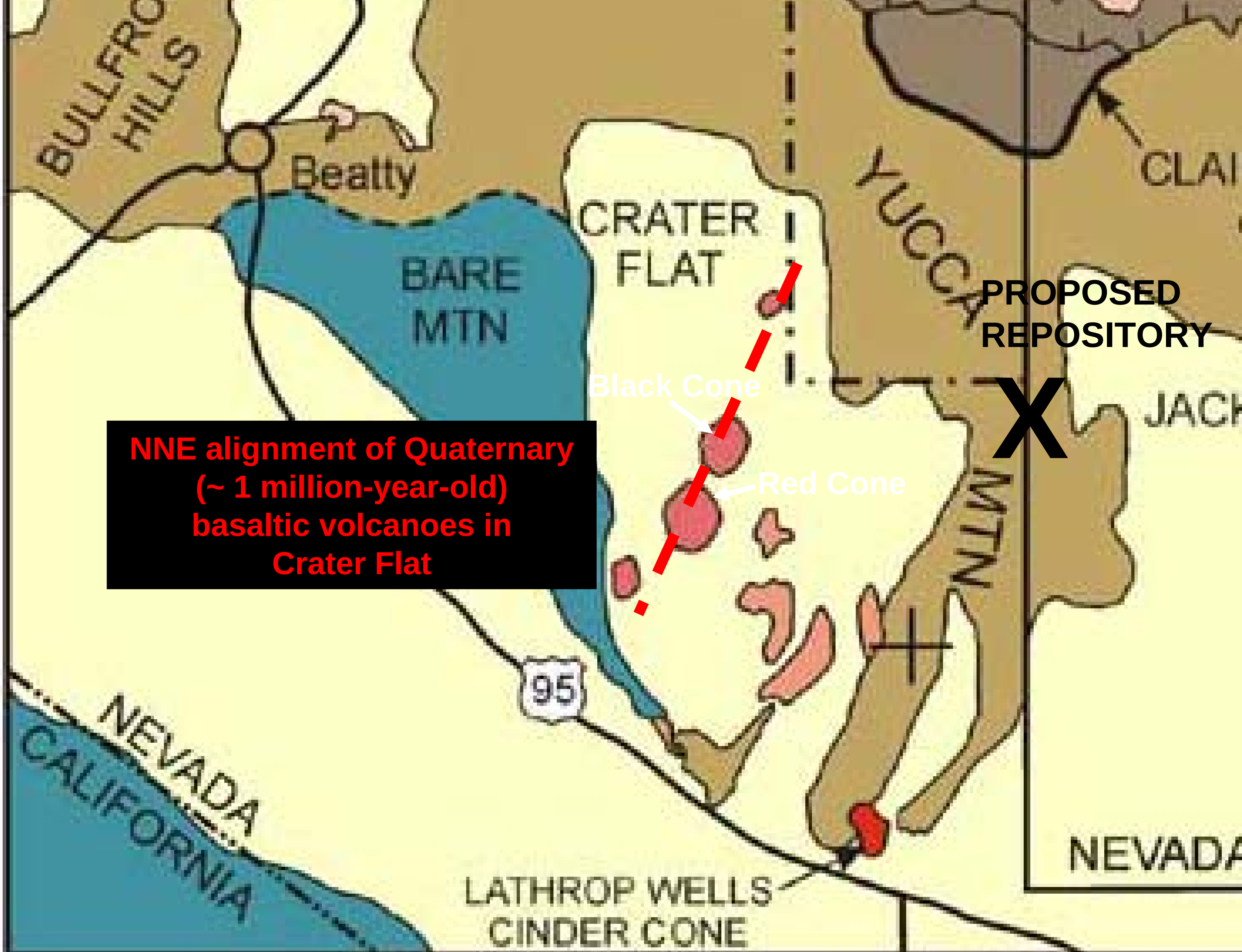
Easy Chair crater, Nye County, Nevada – one of several areas in Nevada with Quaternary basaltic cinder cones and lava flows



Quaternary cinder cones seen from the crest of Yucca Mountain



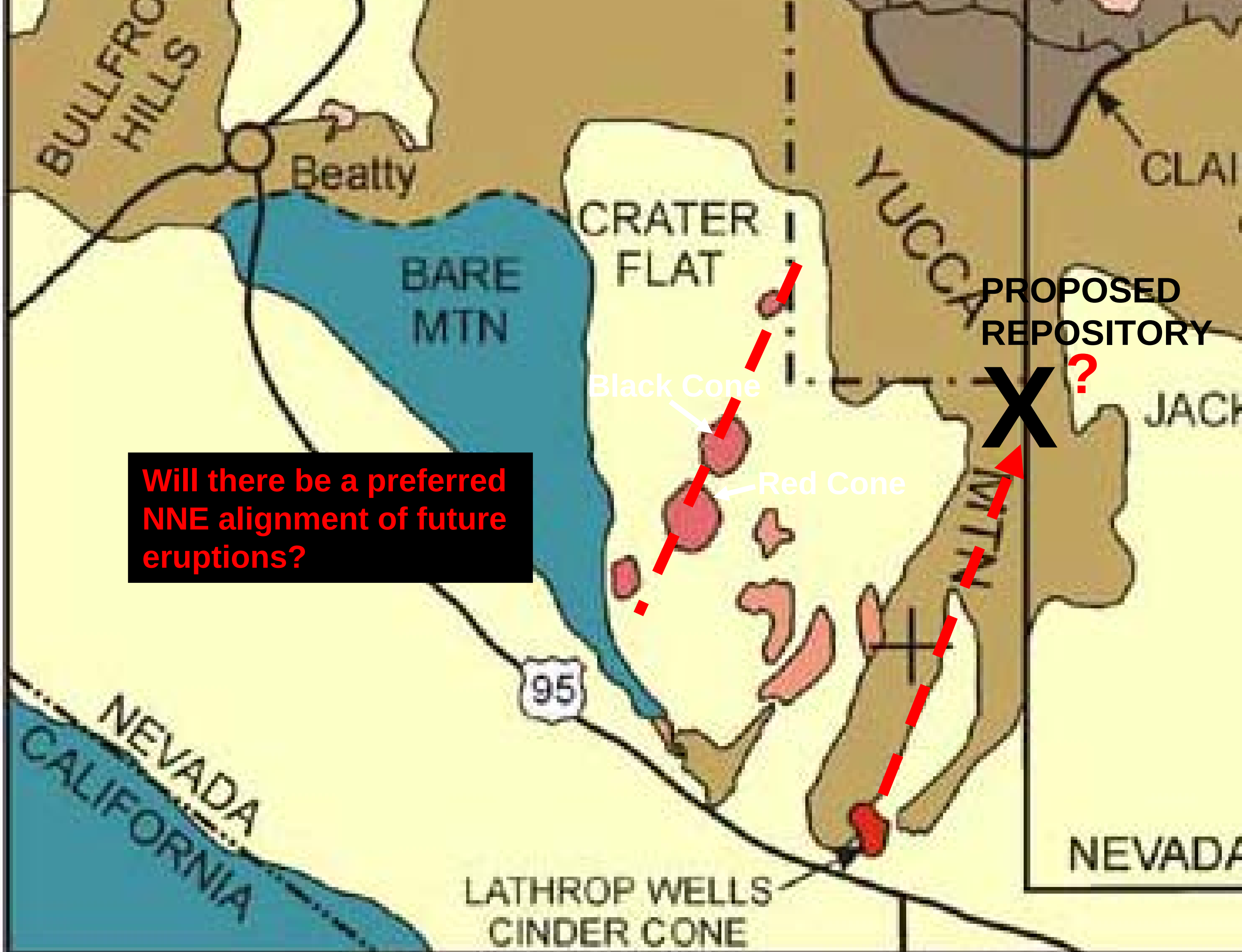
BULLFRO
HILLS
Beatty
CRATER FLAT
BARE MTN
YUCCA MTN
CLAI
PROPOSED REPOSITORY
X
Black Cone
Red Cone
JACK
95
NEVADA
CALIFORNIA
LATHROP WELLS CINDER CONE
NEVADA



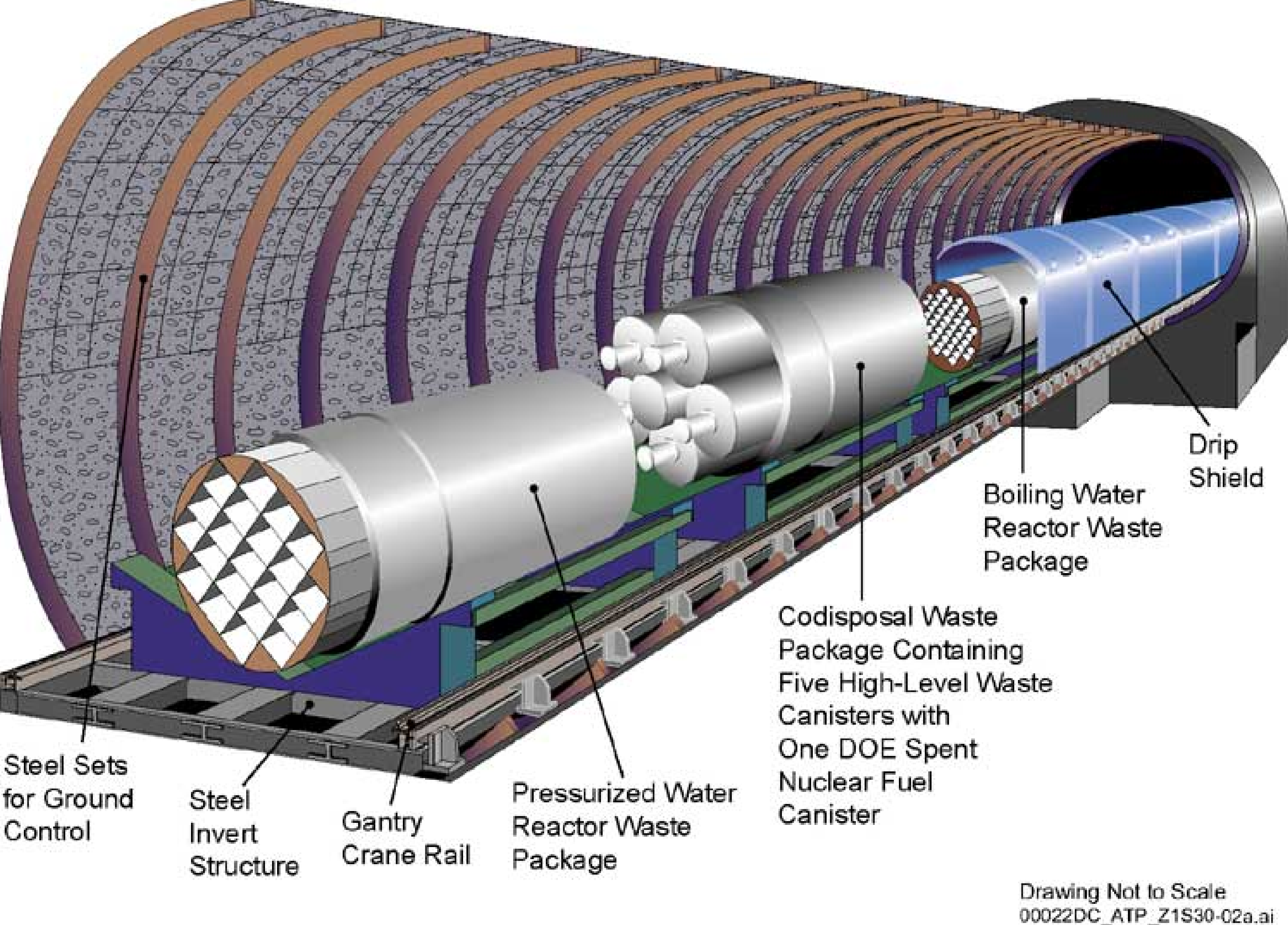
HILLS
Beatty
BARE MTN
CRATER FLAT
YUCCA MTN
PROPOSED REPOSITORY
X
Black Cone
Red Cone
NNE alignment of Quaternary (~ 1 million-year-old) basaltic volcanoes in Crater Flat
95
NEVADA
CALIFORNIA
LATHROP WELLS CINDER CONE
NEVADA


looking south at the Lathrop Wells cinder cone from the crest of Yucca Mountain

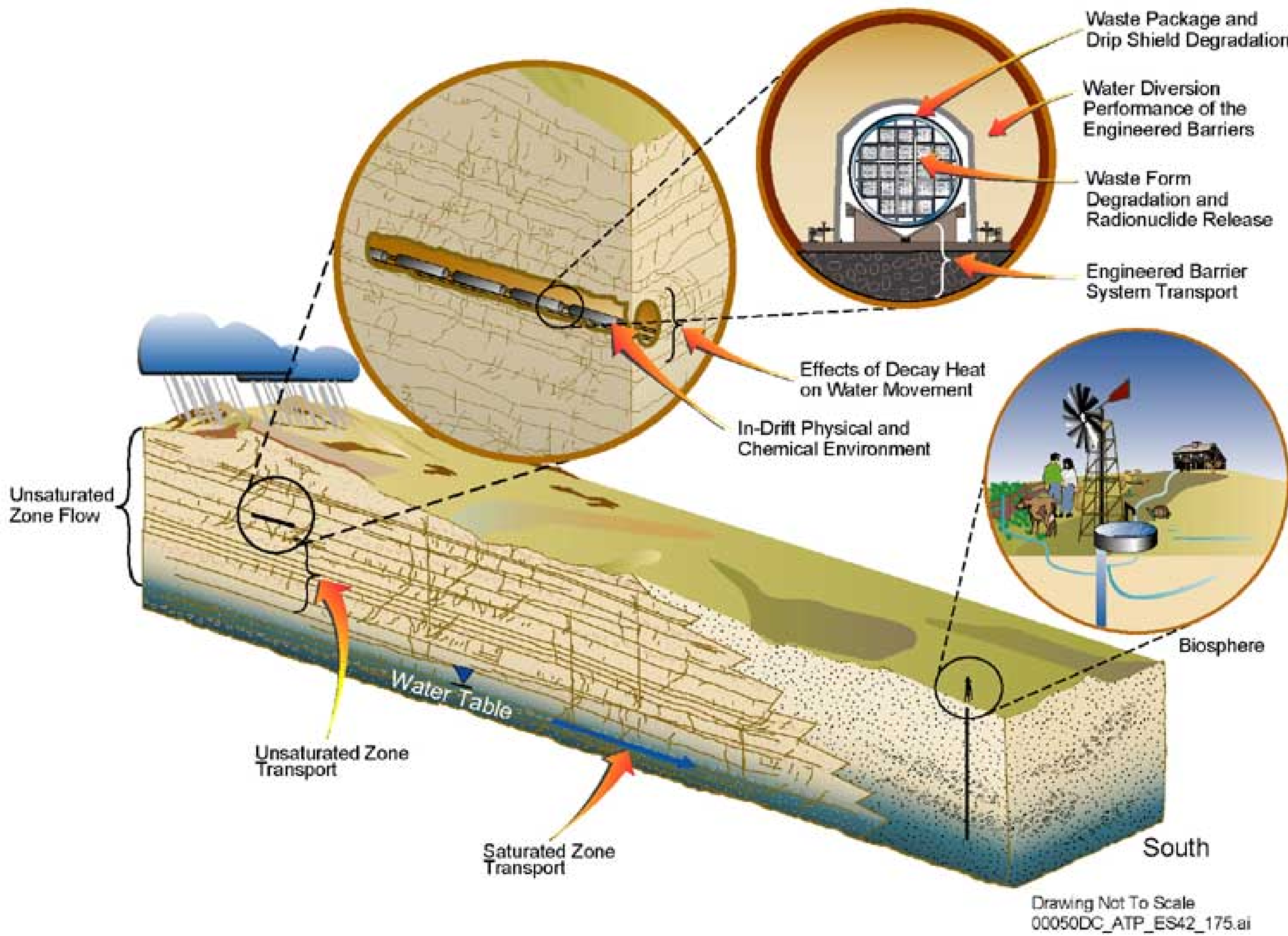
looking north at Lathrop Wells cinder cone, ~80,000 years old

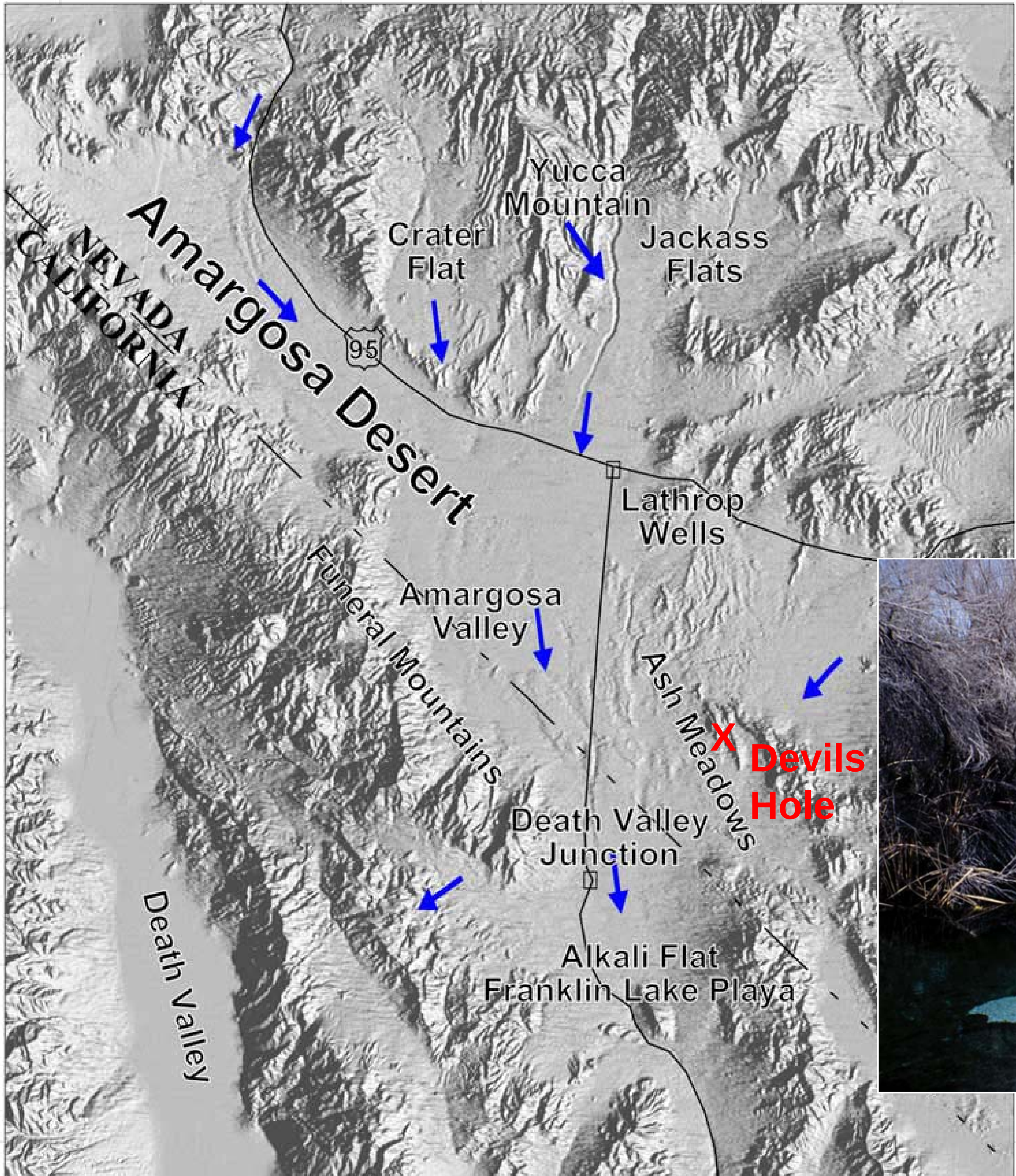

BULLFRO
HILLS
Beatty
BARE MTN
CRATER FLAT
YUCCA
MTN
PROPOSED REPOSITORY
X
?
CLAI
JACK
Black Cone
Red Cone
Will there be a preferred NNE alignment of future eruptions?
95
NEVADA
CALIFORNIA
LATHROP WELLS CINDER CONE
NEVADA

Trench 14 – evidence of meteoric water having moved downward along fractures.



Steel Sets for Ground Control
Steel Invert Structure
Gantry Crane Rail
Pressurized Water Reactor Waste Package
Codisposal Waste Package Containing Five High-Level Waste Canisters with One DOE Spent Nuclear Fuel Canister
Boiling Water Reactor Waste Package
Drip Shield
Drawing Not to Scale
00022DC_ATP_Z1S30-02a.ai

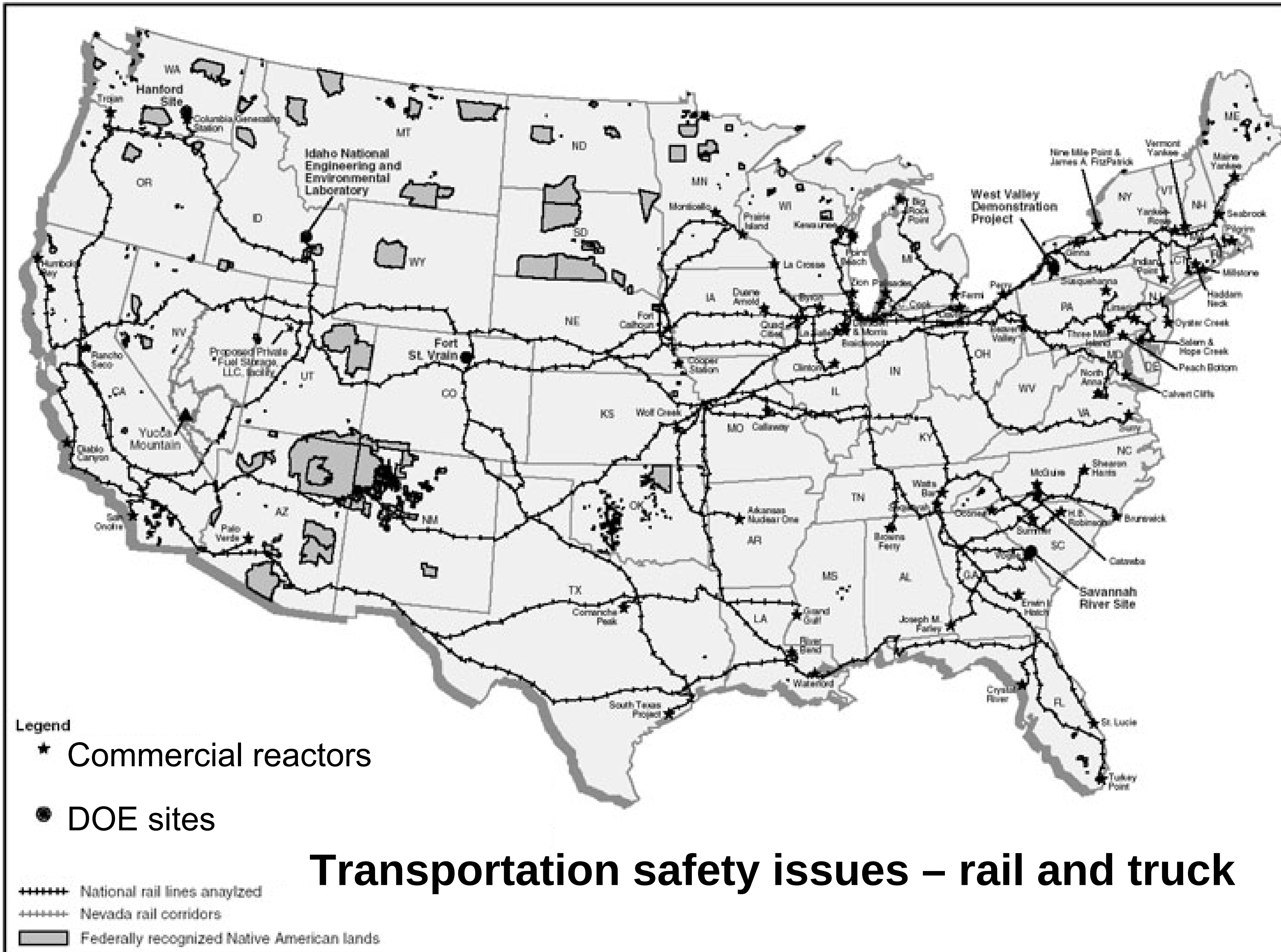

Waste Package and
Drip Shield Degradation
Water Diversion
Performance of the
Engineered Barriers
Waste Form
Degradation and
Radionuclide Release
Engineered Barrier
System Transport
Effects of Decay Heat
on Water Movement
In-Drift Physical and
Chemical Environment
Unsaturated
Zone Flow
Biosphere
Water Table
Unsaturated Zone
Transport
Saturated Zone
Transport
South
Drawing Not To Scale
00050DC_ATP_ES42_175.ai



Directions of regional ground-water flow

Spring in Amargosa Valley

Transportation safety issues – rail and truck



On 9 August 2005, EPA released draft standards for radiation release at Yucca Mountain: 15 millirems per year in Amargosa Valley for the first 10,000 years and 350 millirems per year for the next 990,000 years.

On 9 August 2005, EPA released draft standards for radiation release at Yucca Mountain: 15 millirems per year in Amargosa Valley for the first 10,000 years and 350 millirems per year for the next 990,000 years.

For comparison,

chest x-ray = 10 millirem;

CT head scan = 4,000 to 6,000 millirem;

average background radiation = 300 millirem per year in the USA, 350 millirem per year in Amargosa Valley (near Yucca Mountain); and 700 millrem per year in Colorado;

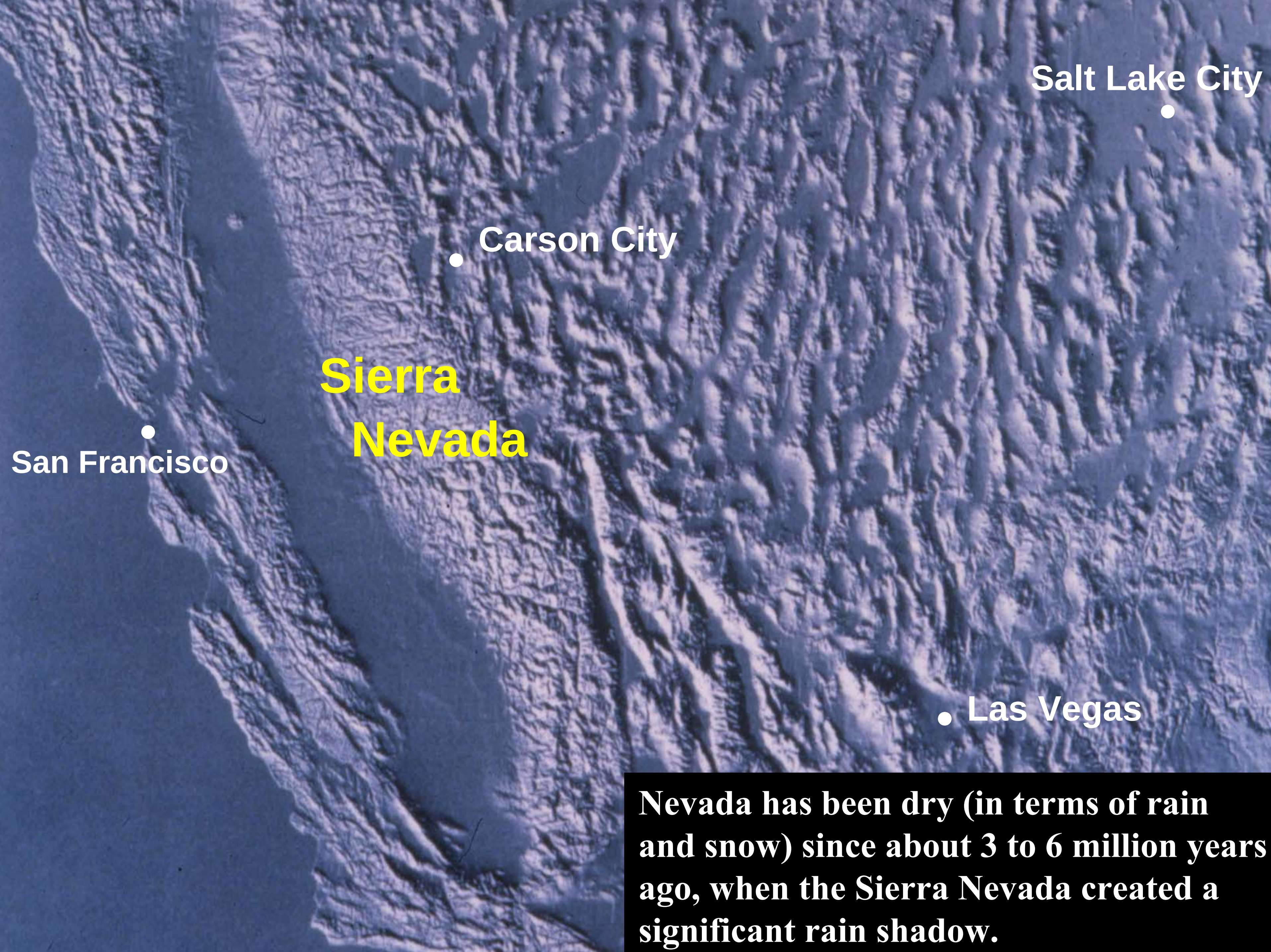
On 9 August 2005, EPA released draft standards for radiation release at Yucca Mountain: 15 millirems per year in Amargosa Valley for the first 10,000 years and 350 millirems per year for the next 990,000 years.

underground uranium mining = 61 millirem/yr;

nuclear reactor = 0.1 to 0.6 millirem/yr (average annual dose to maximally exposed member of the public);

<25, 100, or 500 millirem/yr for decommissioned nuclear facilities.


Climate changes through geologic time.
Hazen pit, Lyon County
(during Earth Science Week field trip –
second full week of October)
Miocene (~ 15
million year old)
fish in diatomite –
evidence of wetter
times in the past



Nevada has been dry (in terms of rain and snow) since about 3 to 6 million years ago, when the Sierra Nevada created a significant rain shadow.


Lake Las Vegas


BELLAGIO

Subsidence and fissuring in Las Vegas Valley

Lake Mead at Hoover Dam, 24 May 2004

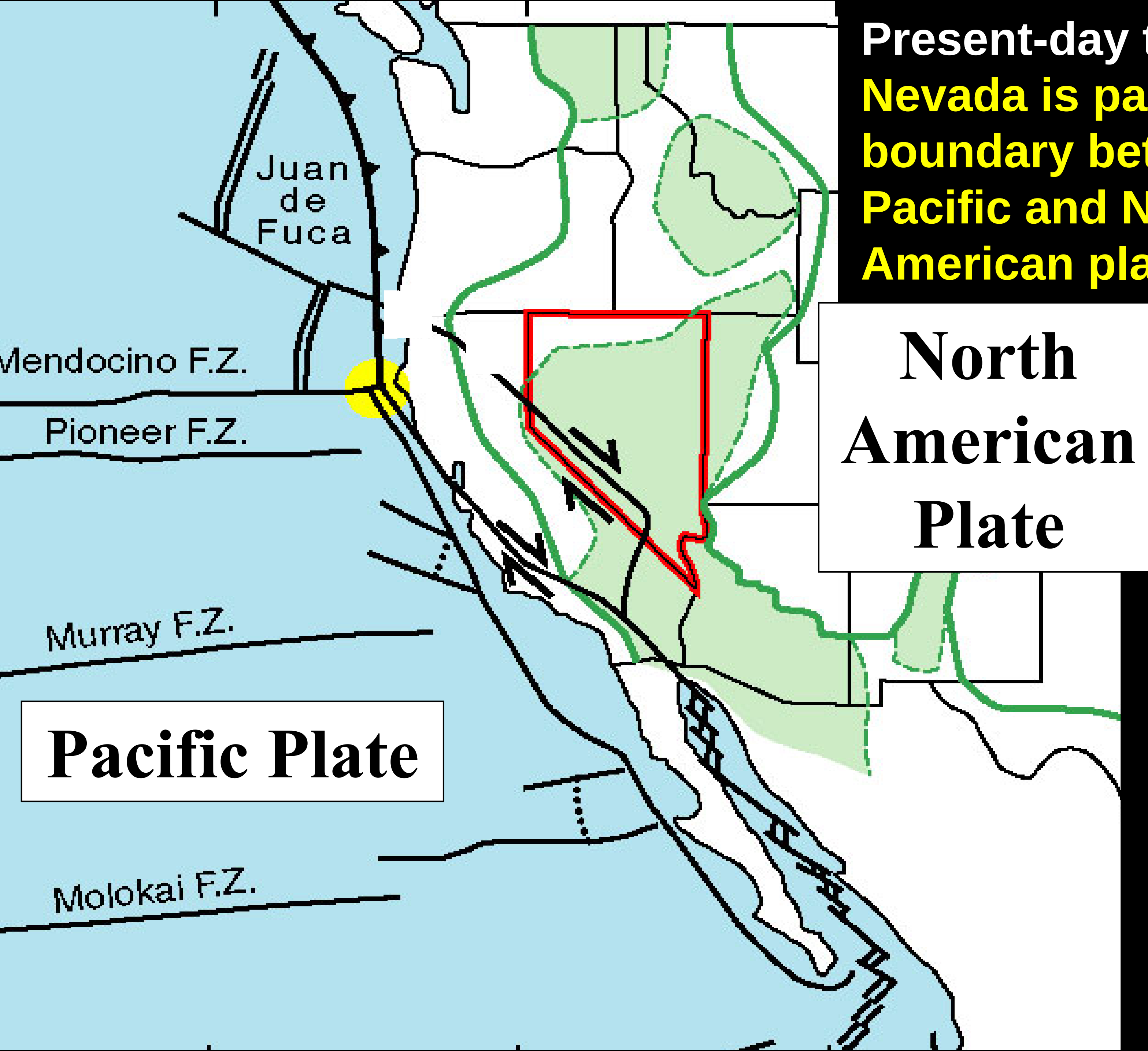
Meadow Valley Wash, January 2005
(photo courtesy of Gale Fraser, Clark County Regional Flood Control District)

Virgin River at Mesquite, January 2005

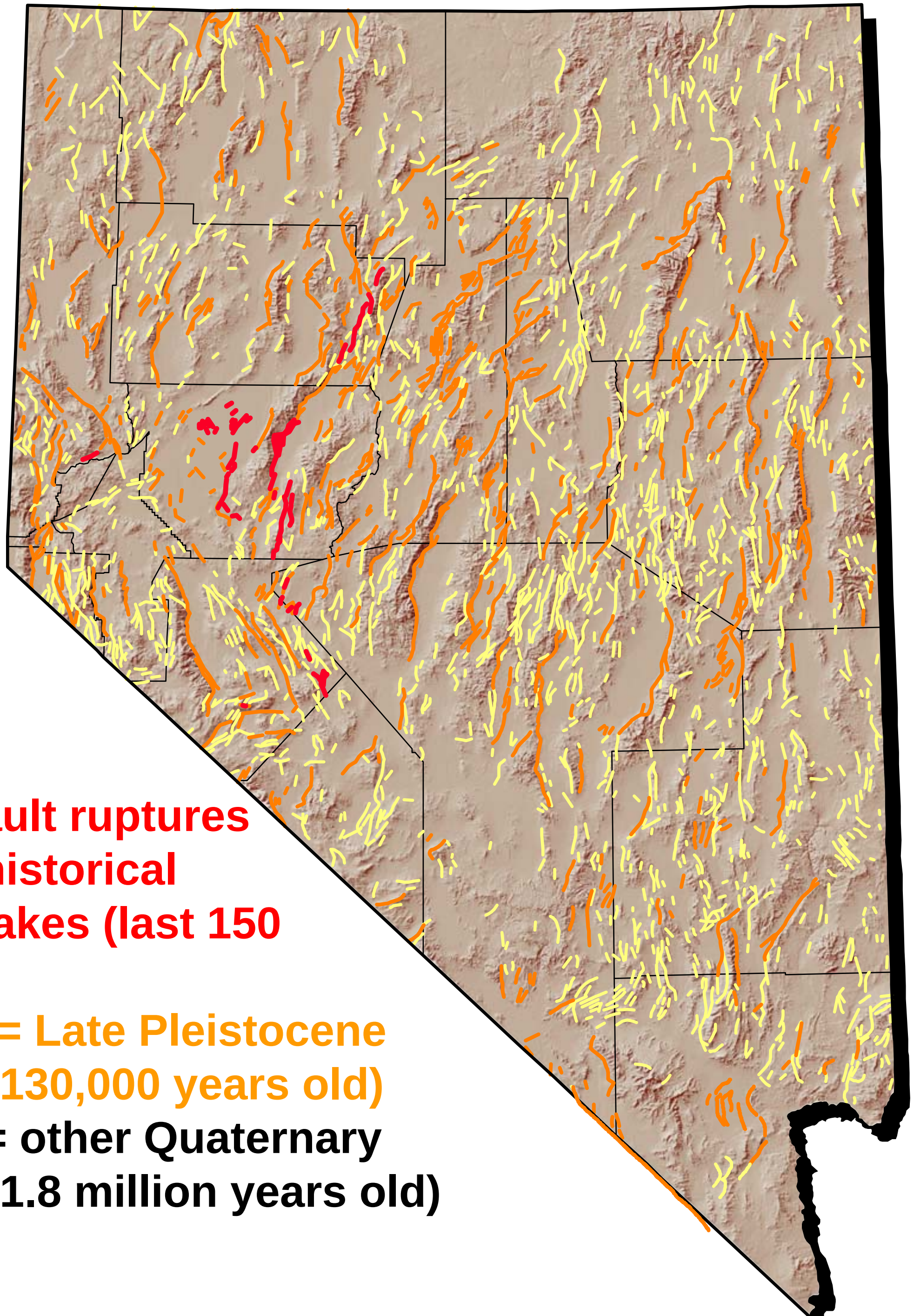
Photo courtesy of Gale Fraser, Clark County Regional Flood Control District

Present-day tectonics:

Nevada is part of the boundary between the Pacific and North American plates



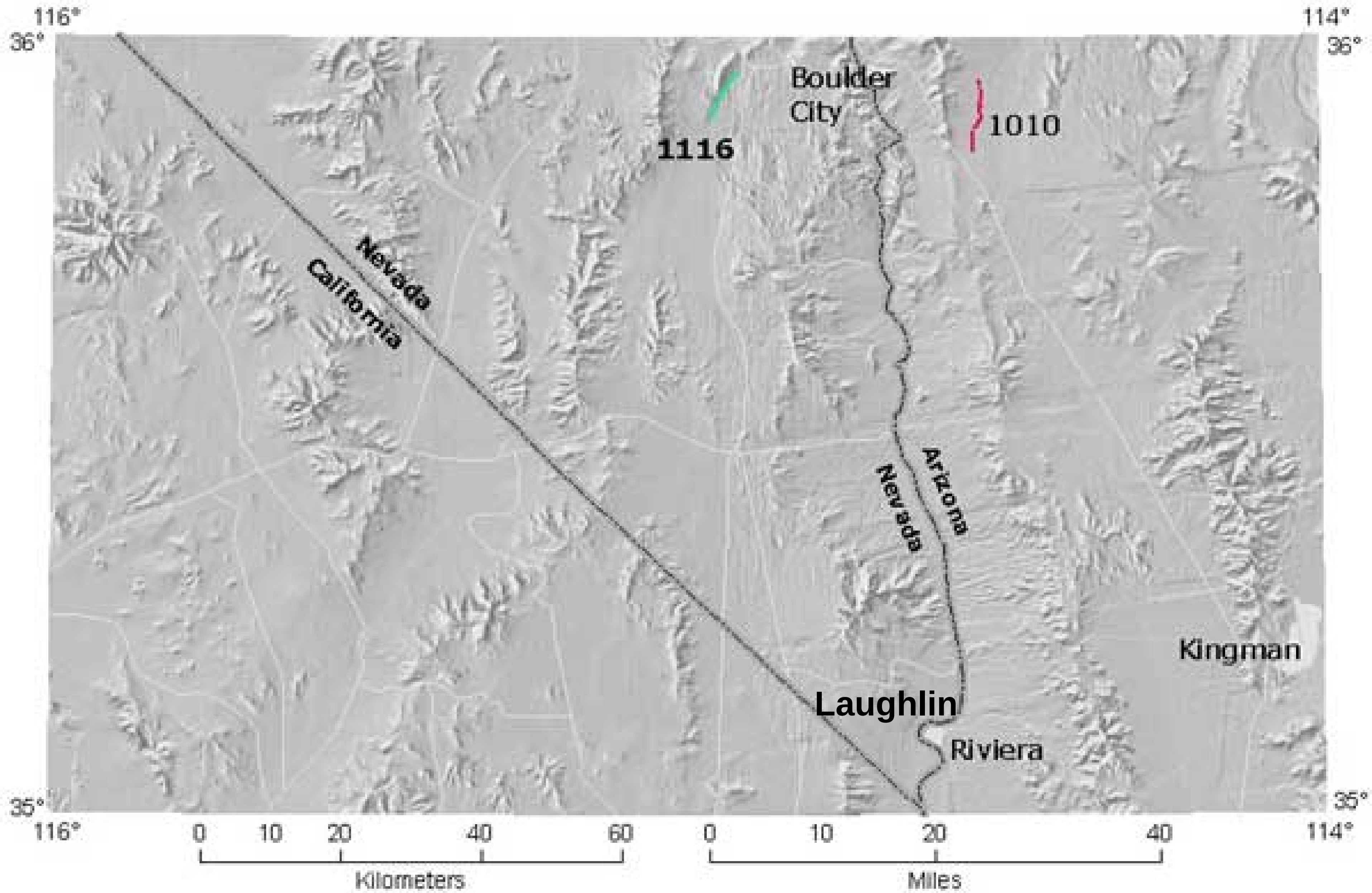
Slide courtesy of Jim Faulds



Red = fault ruptures during historical earthquakes (last 150 years)
Orange = Late Pleistocene faults (<130,000 years old)
Yellow = other Quaternary faults (<1.8 million years old)

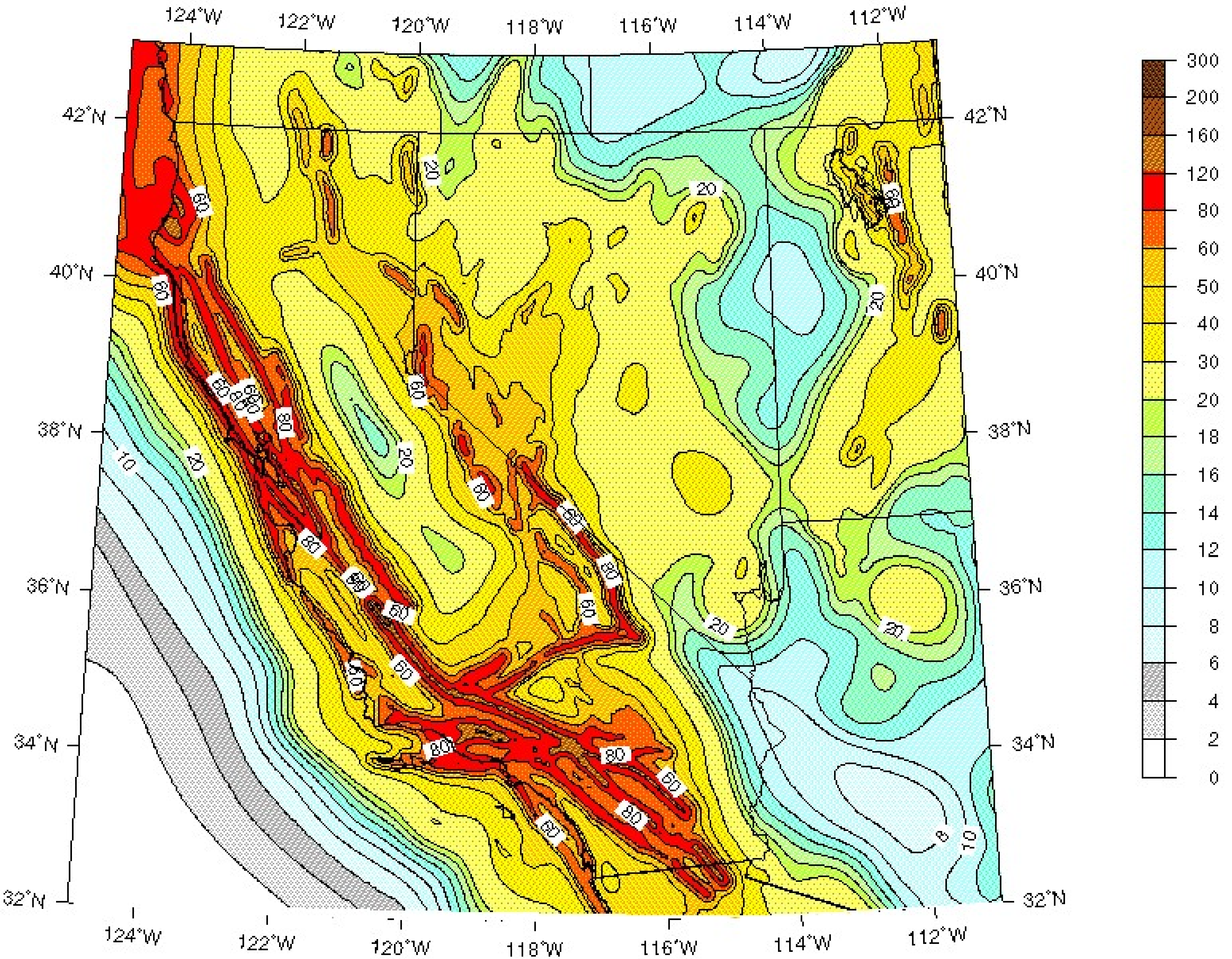
There are active faults nearly everywhere in Nevada,

but not everywhere.

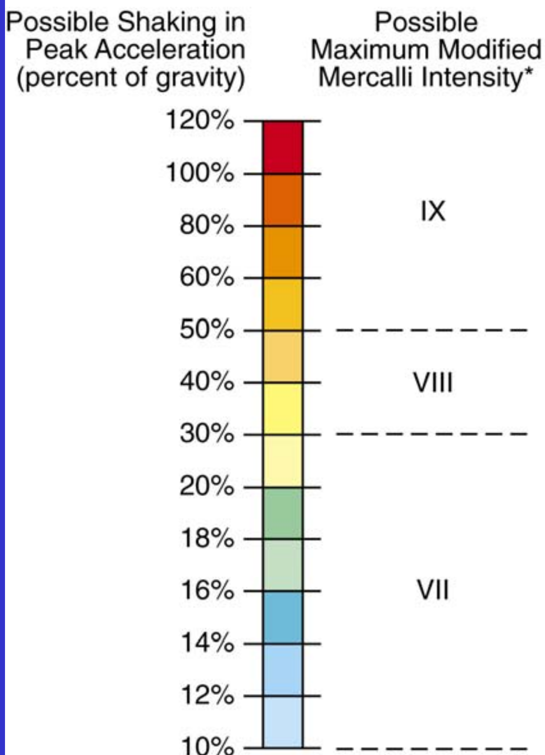


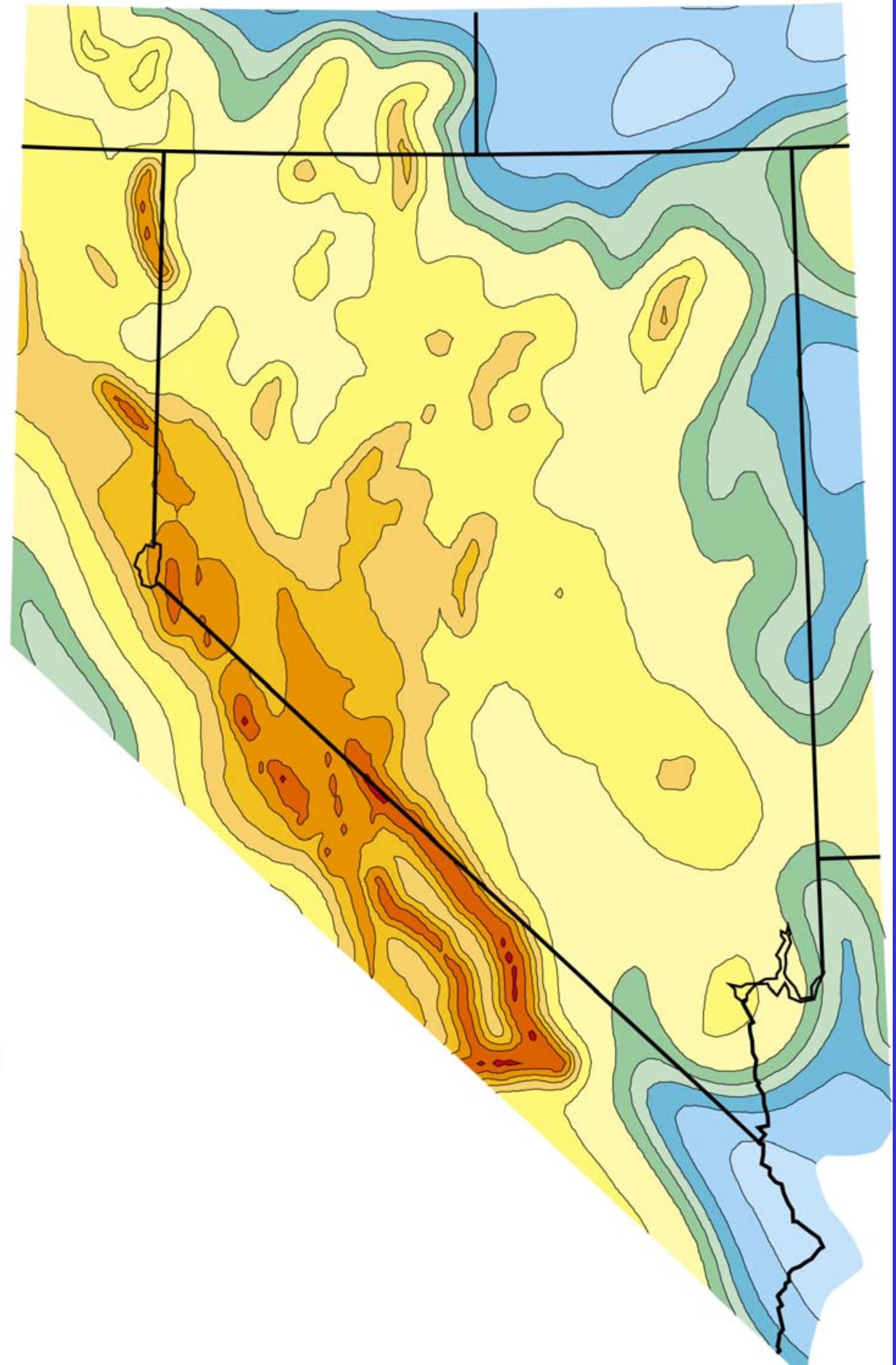
Faults on the Kingman 1 x 2-degree sheet

Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years
USGS Map, Oct. 2002rev

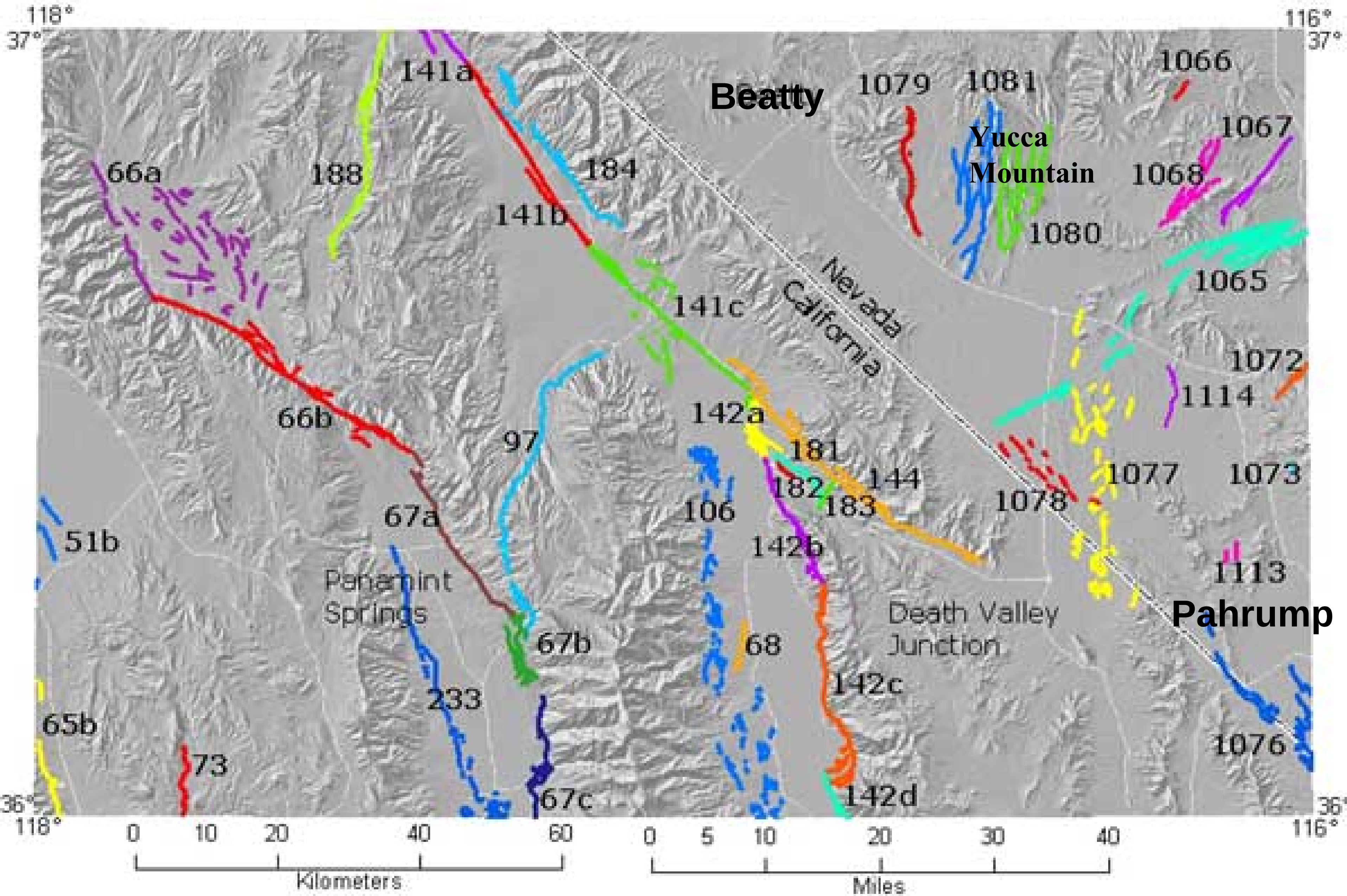


Shaking Potential Map for Nevada

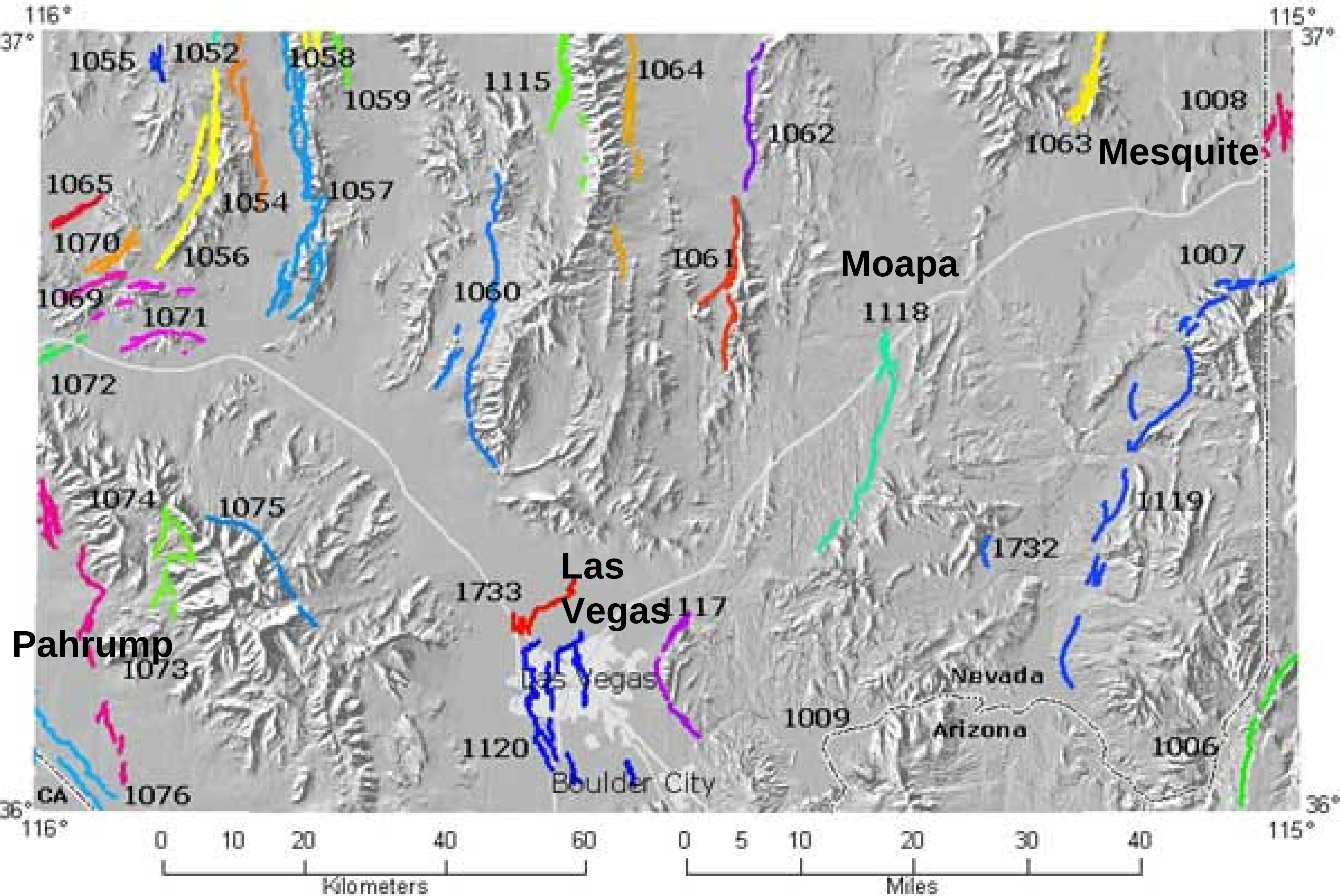




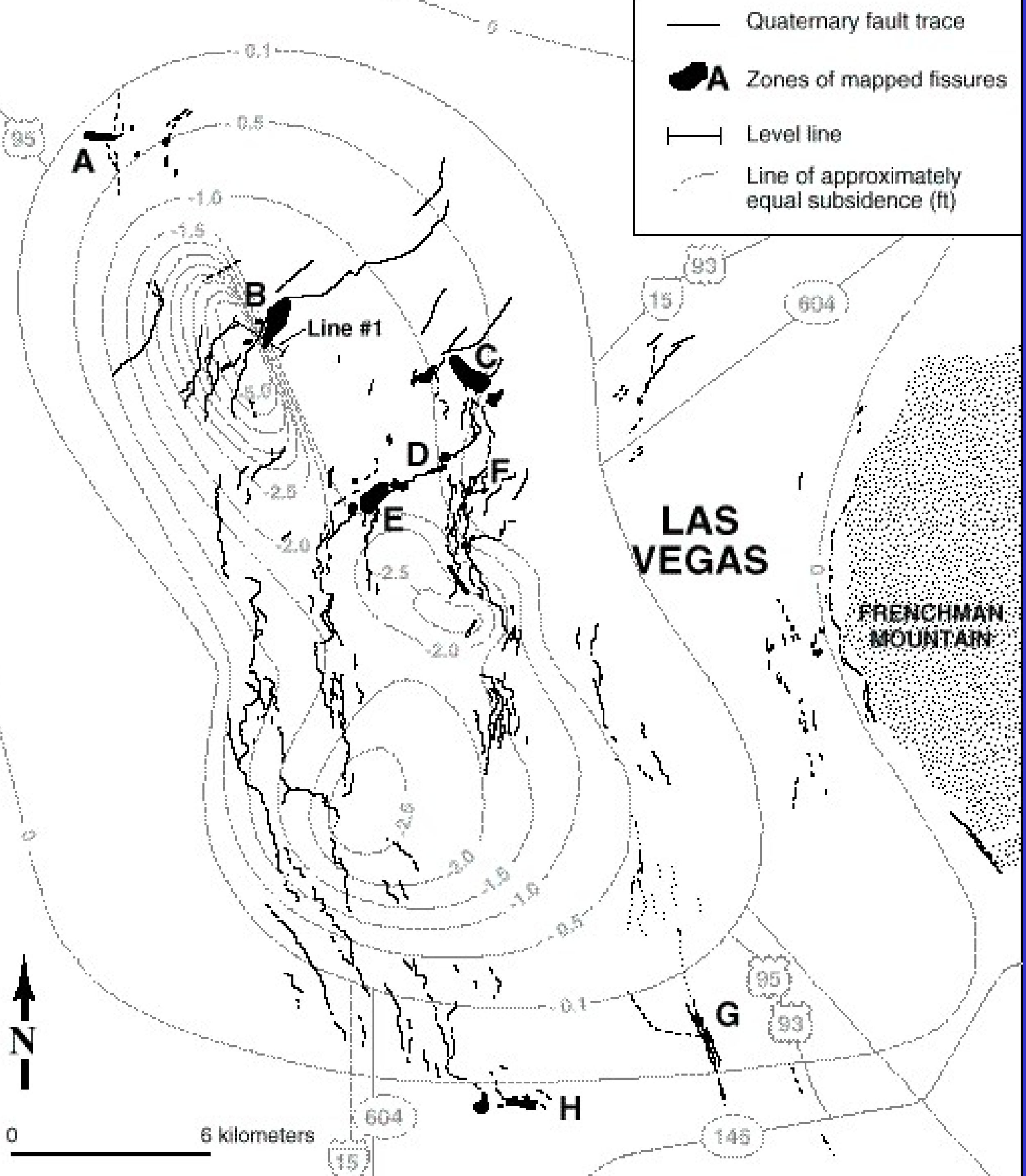
* See page 4 for descriptions of Intensity VII and VIII. In Intensity IX, general panic occurs and there may be damage to some well-built structures.



Faults on the Death Valley 1 x 2-degree sheet

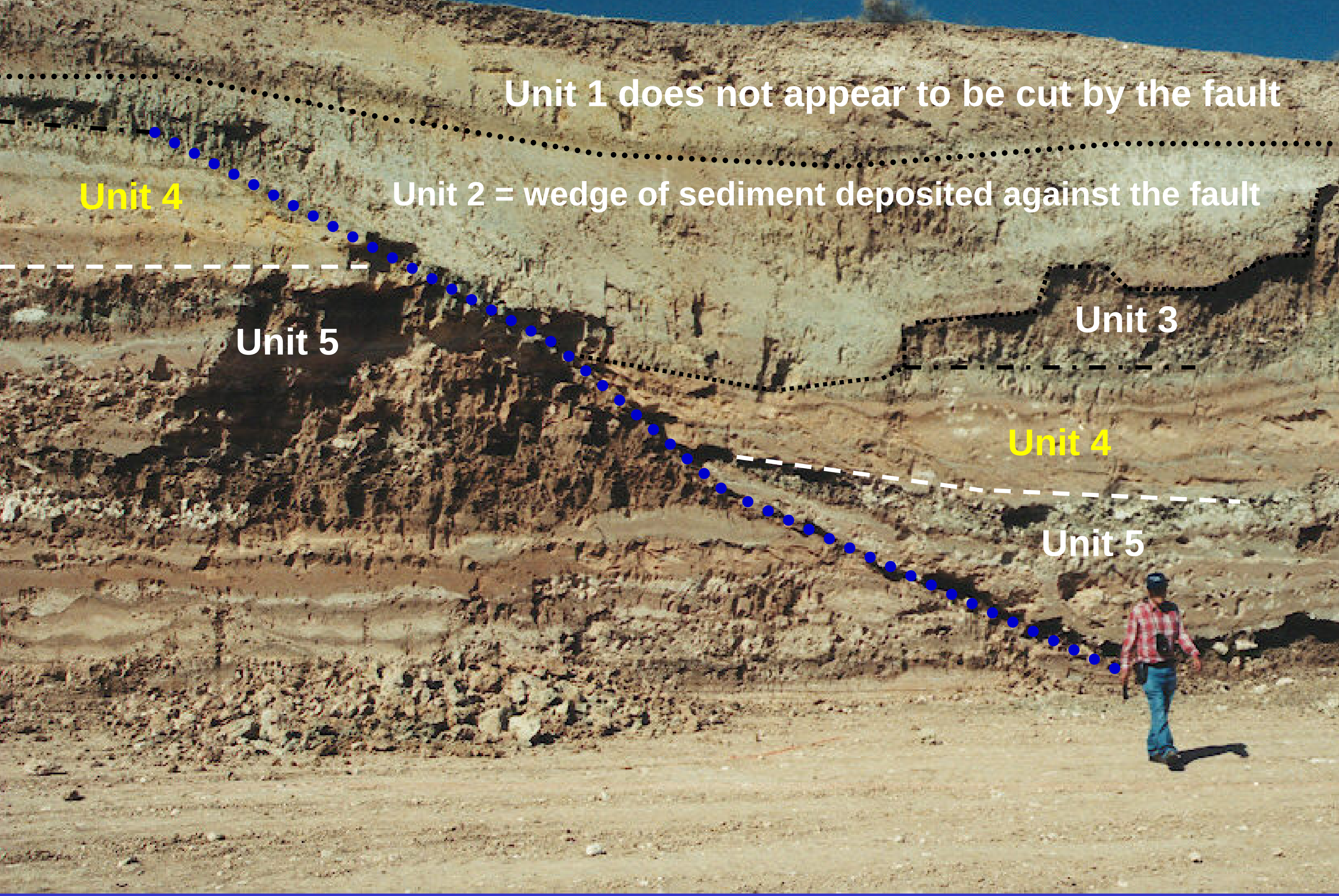


Faults on the Las Vegas 1 x 2-degree sheet

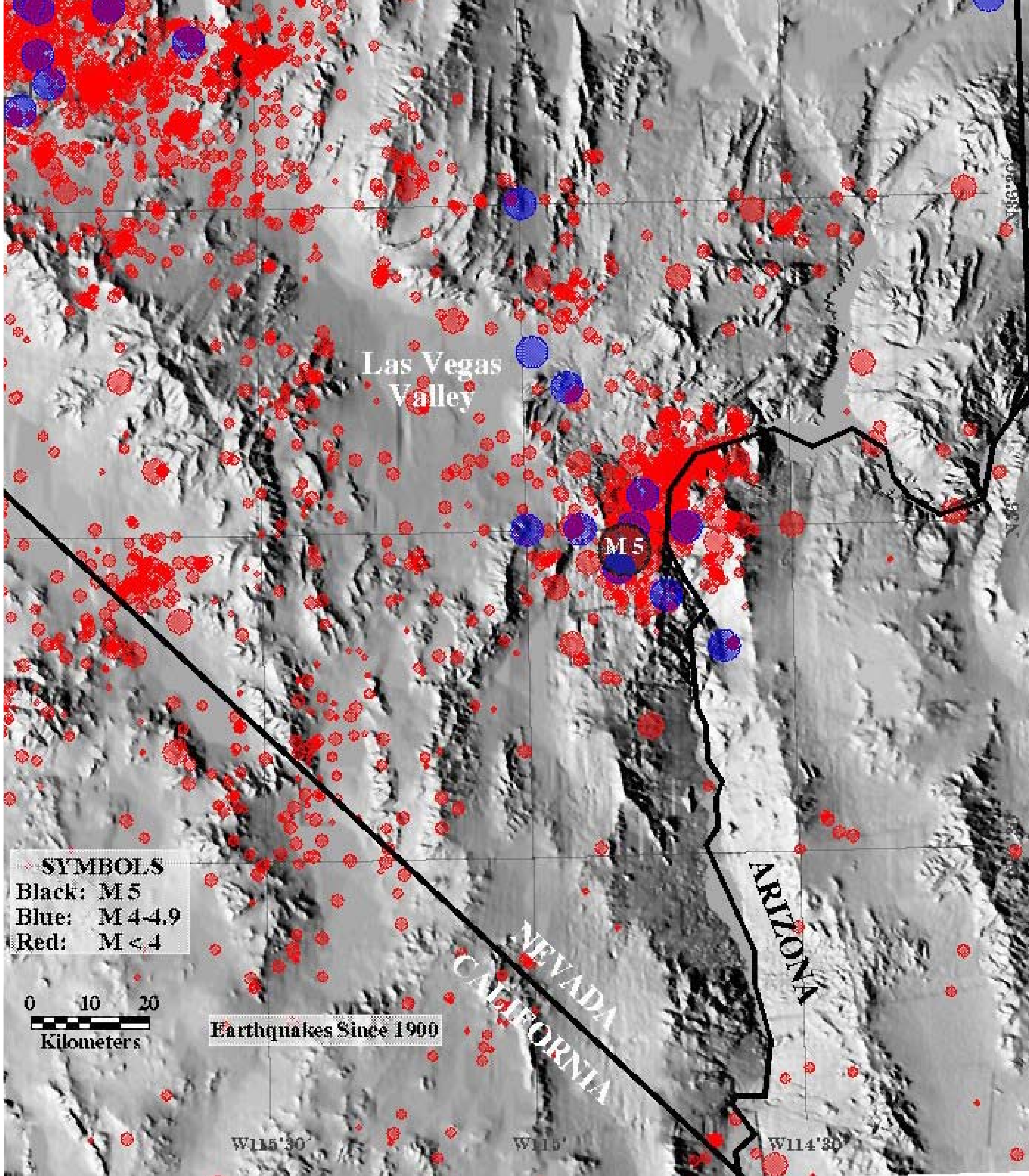


Quaternary faults in Las Vegas Valley

Quaternary fault exposed at construction site in Las Vegas Valley



Quaternary fault exposed at construction site in Las Vegas Valley



Measured earthquakes in the Las Vegas area

The risks are huge.

For a magnitude 6.6 earthquake on the Frenchman Mountain fault, HAZUS estimated:

$4.4 to 17.7 billion in economic loss

major damage to approximately 30,000 buildings

3,000 to 11,000 people needing public shelter

200 to 800 fatalities.

For a magnitude 5.9 daytime earthquake on the Frenchman Mountain fault, HAZUS estimated, for all of Clark County:

$2.2 to 8.9 billion in economic loss,

of which $1.2 to 4.7 billion would be in building damage,
$0.3 to 1.3 billion would be in damage to building contents, and
$0.7 to 2.9 billion in business interruption losses related to the building stock;

major damage to 4,000 to 17,000 buildings

(655 completely destroyed),

3,000 to 12,000 people needing public shelter,

300 to 1,200 people needing hospital care (*but only 768 of 2,341 beds would be available in the county during the first day, up to 910 at Day 3 and 1,730 at Day 30*)**; and**

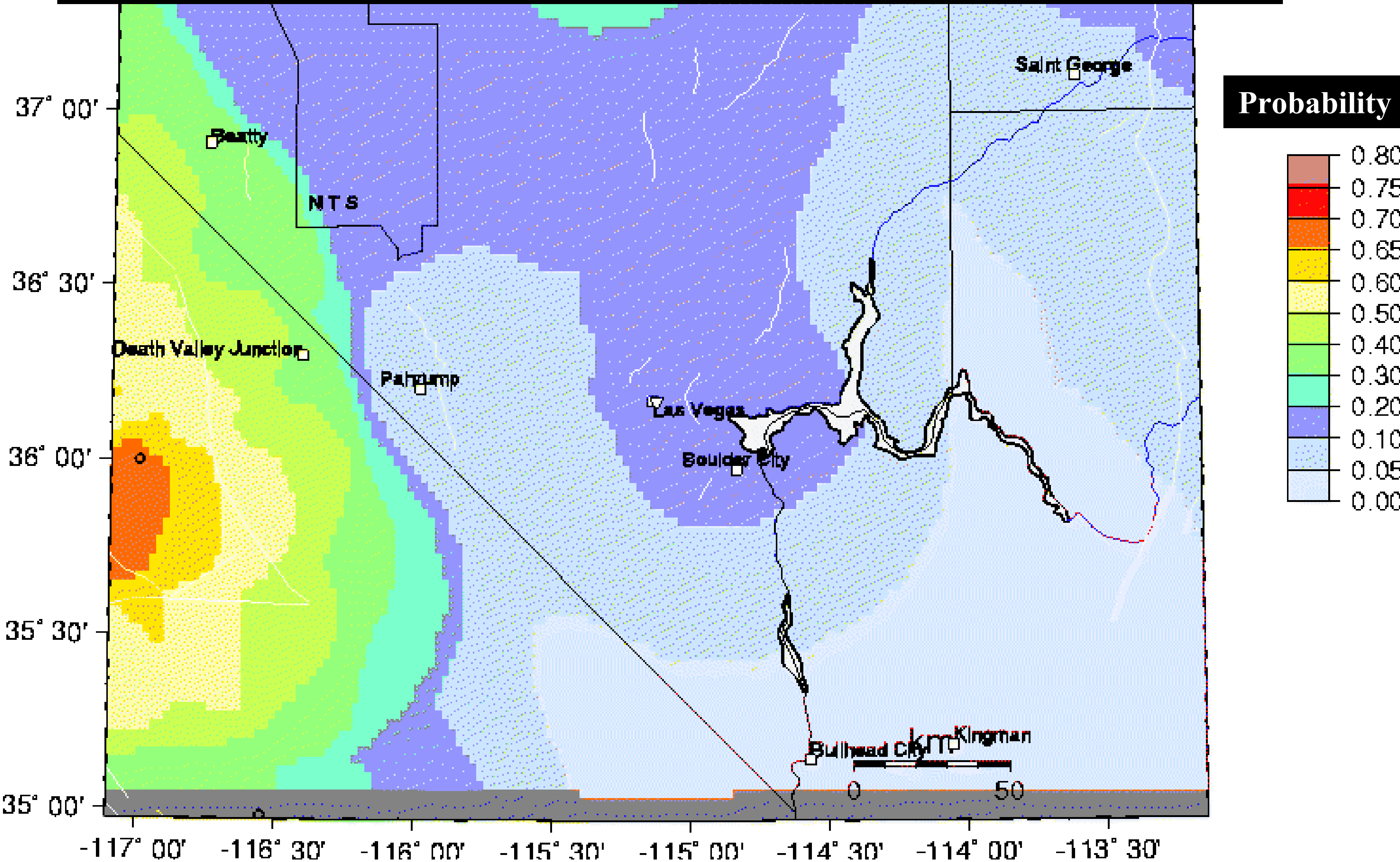
80 to 300 fatalities.

(Casualty numbers are expected to be less for either a night-time or commute-time earthquake.)

(from NBMG-NDEM-FEMA-sponsored earthquake exercise for the City of Las Vegas, 2003)

Probability of an earthquake of magnitude 6.0 or greater occurring within 50 km in 50 years (from USGS probabilistic seismic hazard analysis)

10-20% chance for Las Vegas area, magnitude 6



1. The earthquake risks are huge in Nevada.

2. We can do something about it.

   a. Be prepared to respond.

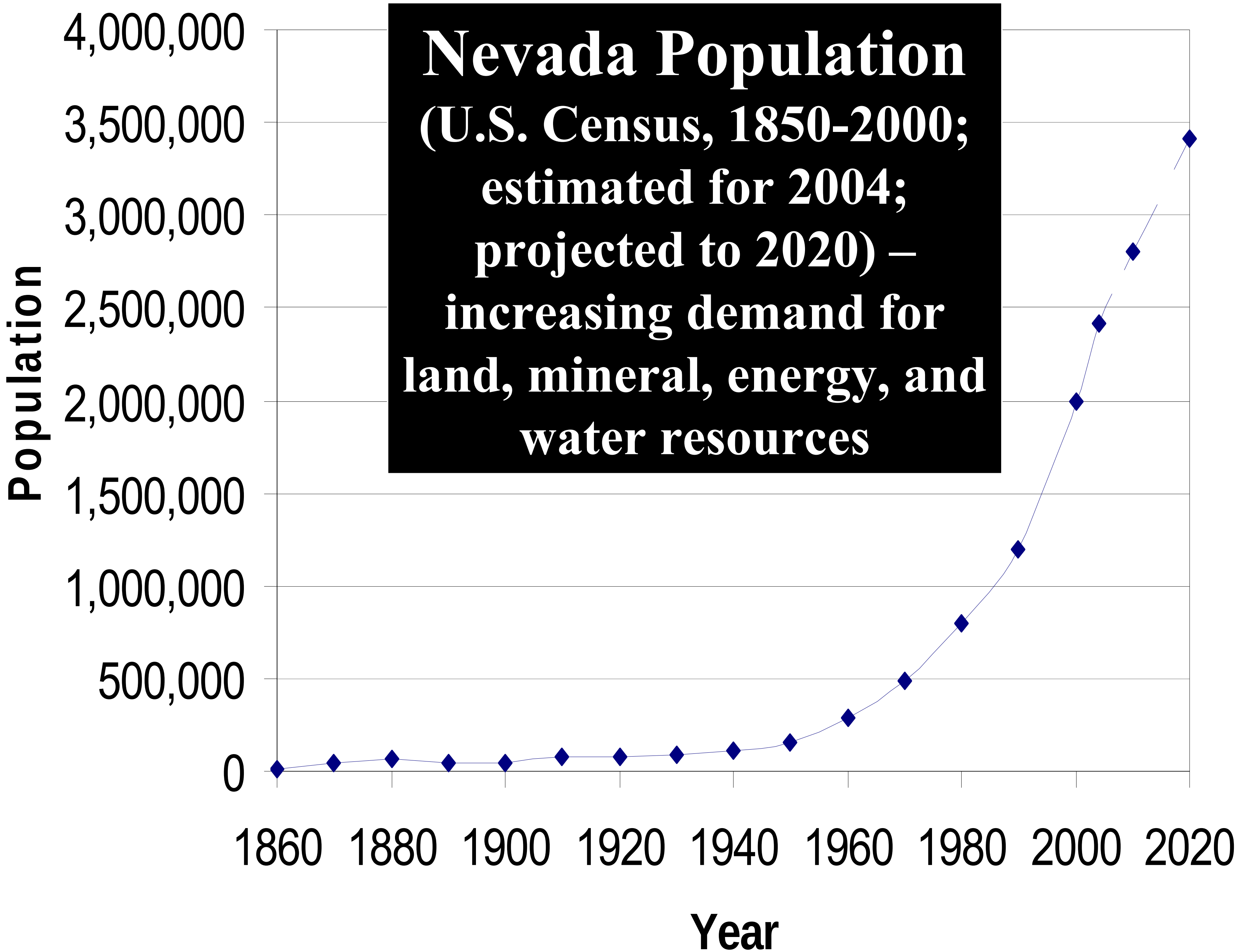
   b. Mitigate structural risks, largely through building codes and avoiding faults and areas of liquefaction.

   c. Mitigate nonstructural risks.

Nonstructural damage often can be easily prevented.

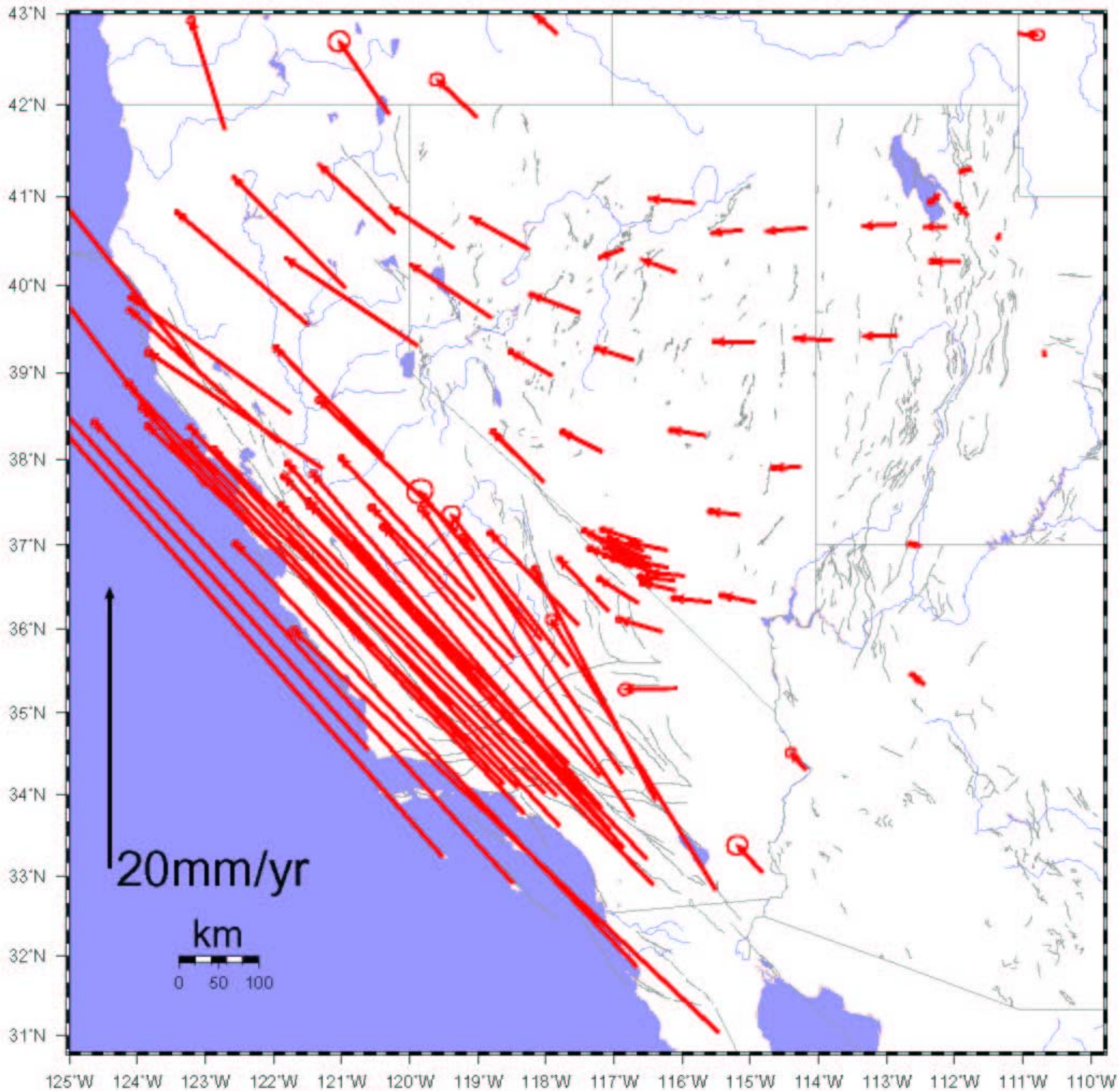
Earthquake-secure bookshelves in the office of the State Geologist

Secured computers at the Clark County Building Department

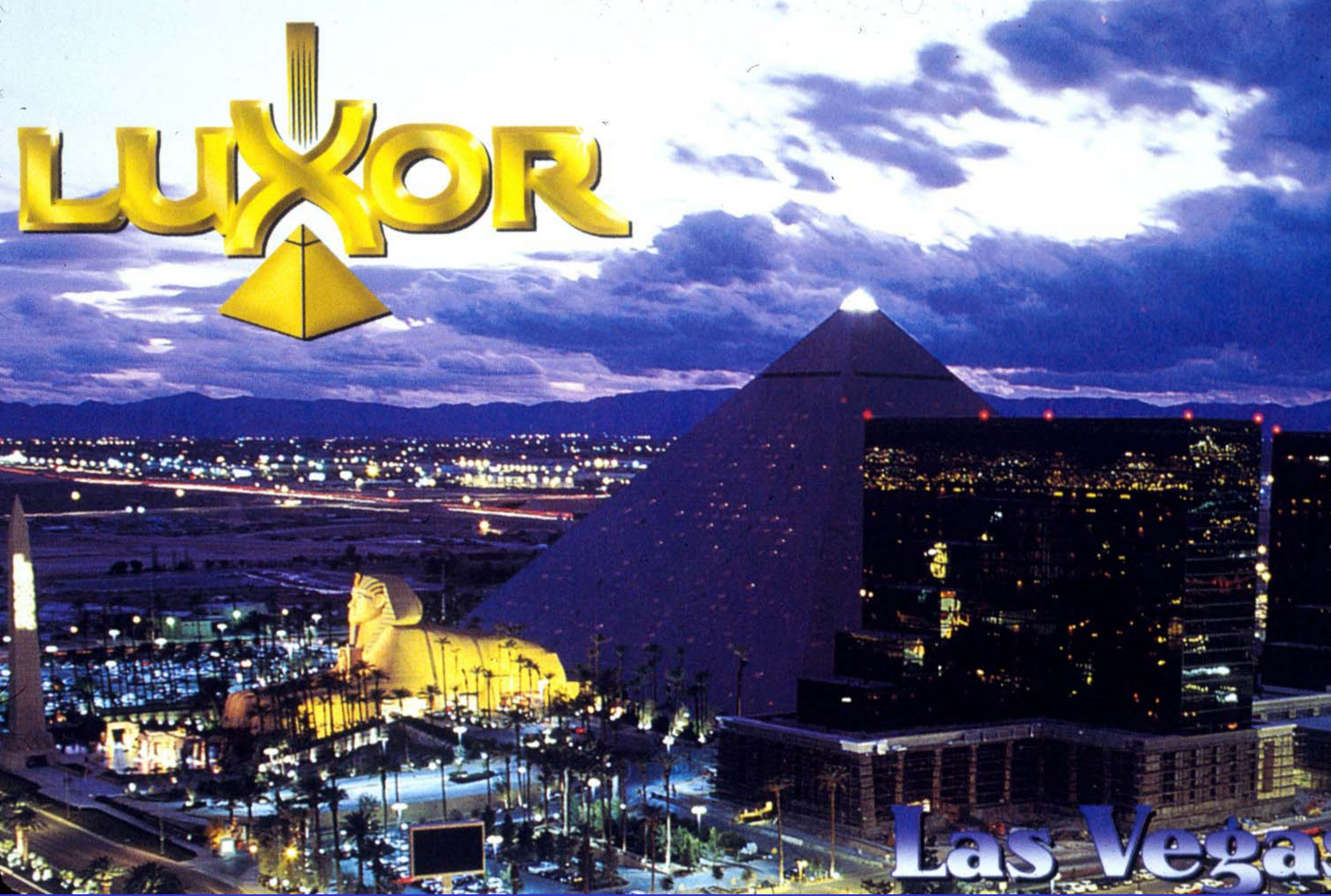


Nevada Population
(U.S. Census, 1850-2000;
estimated for 2004;
projected to 2020) –
increasing demand for
land, mineral, energy, and
water resources
Population
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year

The Las Vegas urban area is growing in population at a rate of 9 to 10 people per hour and in area of developed land at a rate of 2 acres per hour.



Geodetic data indicate that we are only gaining about 1.5 acres of area per year through crustal extension.



Where are those 1.5 acres on the Strip?

Main Point:

Geology (including rocks types and how the rocks formed) is the key to understanding our mineral, energy, and water resources; our history; and our future as we face the challenges of natural hazards and growth.

Nevada Bureau of Mines and Geology
(www.nbmg.unr.edu)