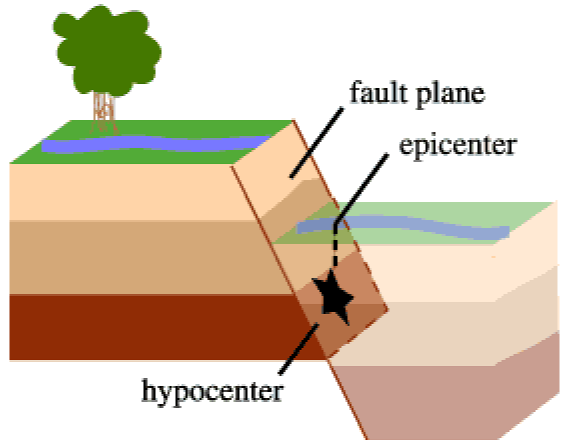
All About Earthquakes: The Science Behind Earthquakes

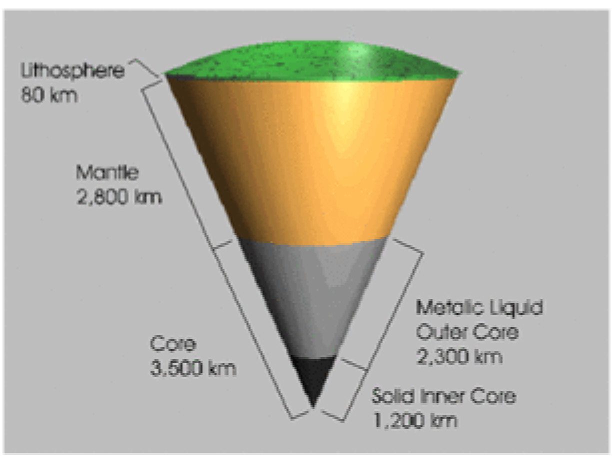
What is an earthquake?

An earthquake is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter.



Sometimes an earthquake has foreshocks. These are smaller earthquakes that happen in the same place as the larger earthquake that follows. Scientists can't tell that an earthquake is a foreshock until the larger earthquake happens. The largest, main earthquake is called the mainshock. Mainshocks always have aftershocks that follow. These are smaller earthquakes that occur afterwards in the same place as the mainshock. Depending on the size of the mainshock, aftershocks can continue for weeks, months, and even years after the mainshock!

What causes earthquakes and where do they happen?

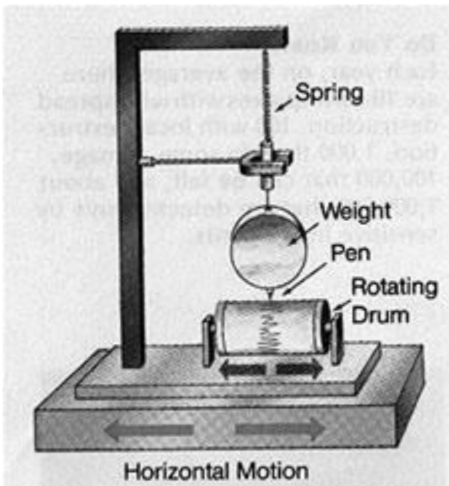


The earth has four major layers: the inner core, outer core, mantle and crust. (figure 2) The crust and the top of the mantle make up a thin skin on the surface of our planet. But this skin is not all in one piece – it is made up of many pieces like a puzzle covering the surface of the earth. (figure 3) Not only that, but these puzzle pieces keep slowly moving around, sliding past one another and bumping into each other. We call these puzzle pieces tectonic plates, and the edges of the plates are called the plate boundaries. The plate boundaries are made up of many faults, and most of the earthquakes around the world occur on these faults. Since the edges of the plates are rough, they get stuck while the rest of the plate keeps moving. Finally, when the plate has moved far enough, the edges unstick on one of the faults and there is an earthquake.

Why does the earth shake when there is an earthquake?

While the edges of faults are stuck together, and the rest of the block is moving, the energy that would normally cause the blocks to slide past one another is being stored up. When the force of the moving blocks finally overcomes the friction of the jagged edges of the fault and it unsticks, all that

stored up energy is released. The energy radiates outward from the fault in all directions in the form of seismic waves like ripples on a pond. The seismic waves shake the earth as they move through it, and when the waves reach the earth's surface, they shake the ground and anything on it, like our houses and us!

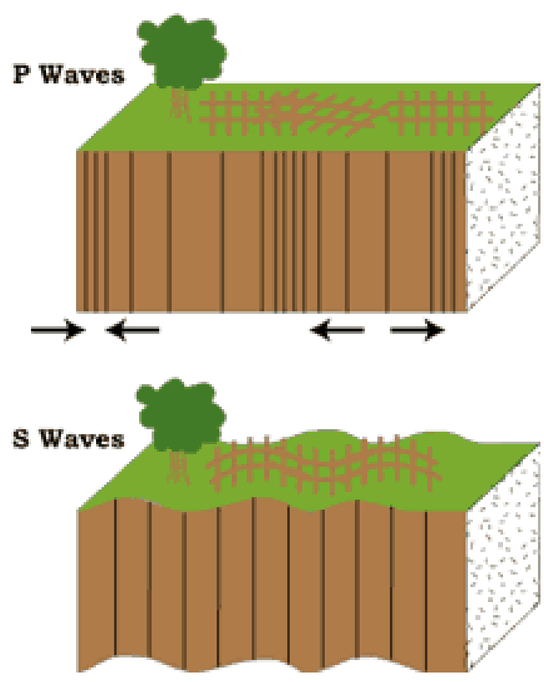


How are earthquakes recorded?
Earthquakes are recorded by instruments called seismographs. The recording they make is called a seismogram. The seismograph has a base that sets firmly in the ground, and a heavy weight that hangs free. When an earthquake causes the ground to shake, the base of the seismograph shakes too, but the hanging weight does not. Instead the spring or string that it is hanging from absorbs all the movement. The difference in position between the shaking part of the seismograph and the motionless part is what is recorded.

How do scientists measure the size of earthquakes?
The size of an earthquake depends on the size of the fault and the amount of slip on the fault, but that's not something scientists can simply measure with a measuring tape since faults are many kilometers deep beneath the earth's surface. So how do they measure an earthquake? They use the seismogram recordings made on the seismographs at the surface of the earth to determine how large the earthquake was (figure 5). A short wiggly line that doesn't wiggle very much means a small earthquake, and a long wiggly line that wiggles a lot means a large earthquake. The length of the wiggle depends on the size of the fault, and the size of the wiggle depends on the amount of slip.

The size of the earthquake is called its magnitude. There is one magnitude for each earthquake. Scientists also talk about the intensity of shaking from an earthquake, and this varies depending on where you are during the earthquake.

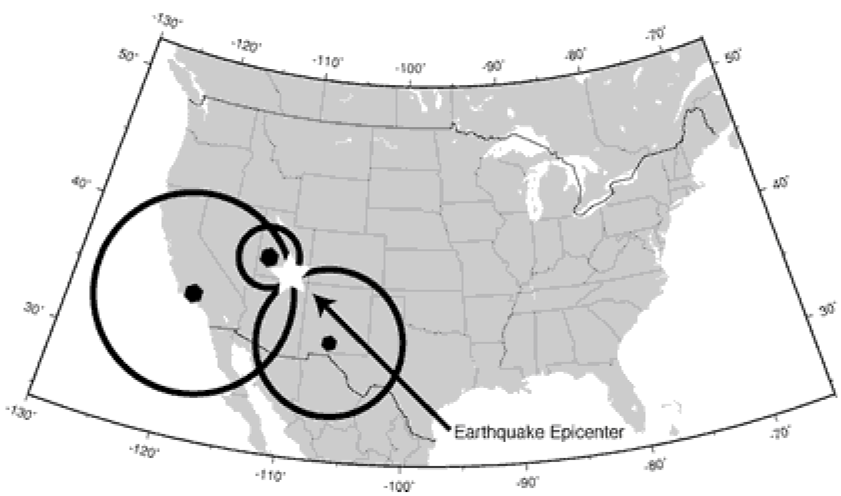
How can scientists tell where the earthquake happened?
Seismograms come in handy for locating earthquakes too, and being able to see the P wave and the S wave is important. You learned how P & S waves each shake the ground in different ways as they travel through it. P waves are also faster than S waves, and this fact is what allows us to tell where an earthquake was. To understand how this works, let's compare P and S waves to lightning and thunder. Light travels faster than sound, so during a thunderstorm you will first see the lightning and then you will hear the thunder. If you are close to the lightning, the thunder will boom right



after the lightning, but if you are far away from the lightning, you can count several seconds before you hear the thunder. The further you are from the storm, the longer it will take between the lightning and the thunder.

P waves are like the lightning, and S waves are like the thunder. The P waves travel faster and shake the ground where you are first. Then the S waves follow and shake the ground also. If you are close to the earthquake, the P and S wave will come one right after the other, but if you are far away, there will be more time between the two. By looking at the amount of time between the P and S wave on a seismogram recorded on a seismograph, scientists can tell how far away the earthquake was from that location. However, they can't tell in what direction from the seismograph the earthquake was, only how far away it was. If they draw a circle on a map around the station where the radius of the circle is the determined distance to the earthquake, they know the earthquake lies somewhere on the circle. But where?

Scientists then use a method called triangulation to determine exactly where the earthquake was (figure 6). It is called triangulation because a triangle has three sides, and it takes three seismographs to locate an earthquake. If you draw a circle on a map around three different seismographs where the radius of each is the distance from that station to the earthquake, the intersection of those three circles is the epicenter!



Can scientists predict earthquakes?
No, and it is unlikely they will ever be able to predict them. Scientists have tried many different ways of predicting earthquakes, but none have been successful. On any particular fault, scientists know there will be another earthquake sometime in the future, but they have no way of telling when it will happen.

Is there such a thing as earthquake weather? Can some animals or people tell when an earthquake is about to hit?
These are two questions that do not yet have definite answers. If weather does affect earthquake occurrence, or if some animals or people can tell when an earthquake is coming, we do not yet understand how it works.

Liquefaction

What is liquefaction?

Liquefaction may occur when water-saturated sandy soils are subjected to earthquake ground shaking. When soil liquefies, it loses strength and behaves as a viscous liquid (like quicksand) rather than as a solid. This can cause buildings to sink into the ground or tilt, empty buried tanks to rise to the ground surface, slope failures, nearly level ground to shift laterally tens of feet (lateral spreading), surface subsidence, ground cracking, and sand blows.

Why is liquefaction a concern?

Liquefaction has caused significant property damage in many earthquakes around the world, and is a major hazard associated with earthquakes in Utah. The 1934 Hansel Valley and 1962 Cache Valley earthquakes caused liquefaction, and large prehistoric lateral spreads exist at many locations along the Wasatch Front. The valleys of the Wasatch Front are especially vulnerable to liquefaction because of susceptible soils, shallow ground water, and relatively high probability of moderate to large earthquakes.

Where is liquefaction likely to occur?

Two conditions must exist for liquefaction to occur: (1) the soil must be susceptible to liquefaction (loose, water-saturated, sandy soil, typically between 0 and 30 feet below the ground surface) and (2) ground shaking must be strong enough to cause susceptible soils to liquefy. Northern, central, and southwestern Utah are the state's most seismically active areas. Identifying soils susceptible to liquefaction in these areas involves knowledge of the local geology and subsurface soil and water conditions. The most susceptible soils are generally along rivers, streams, and lake shorelines, as well as in some ancient river and lake deposits.

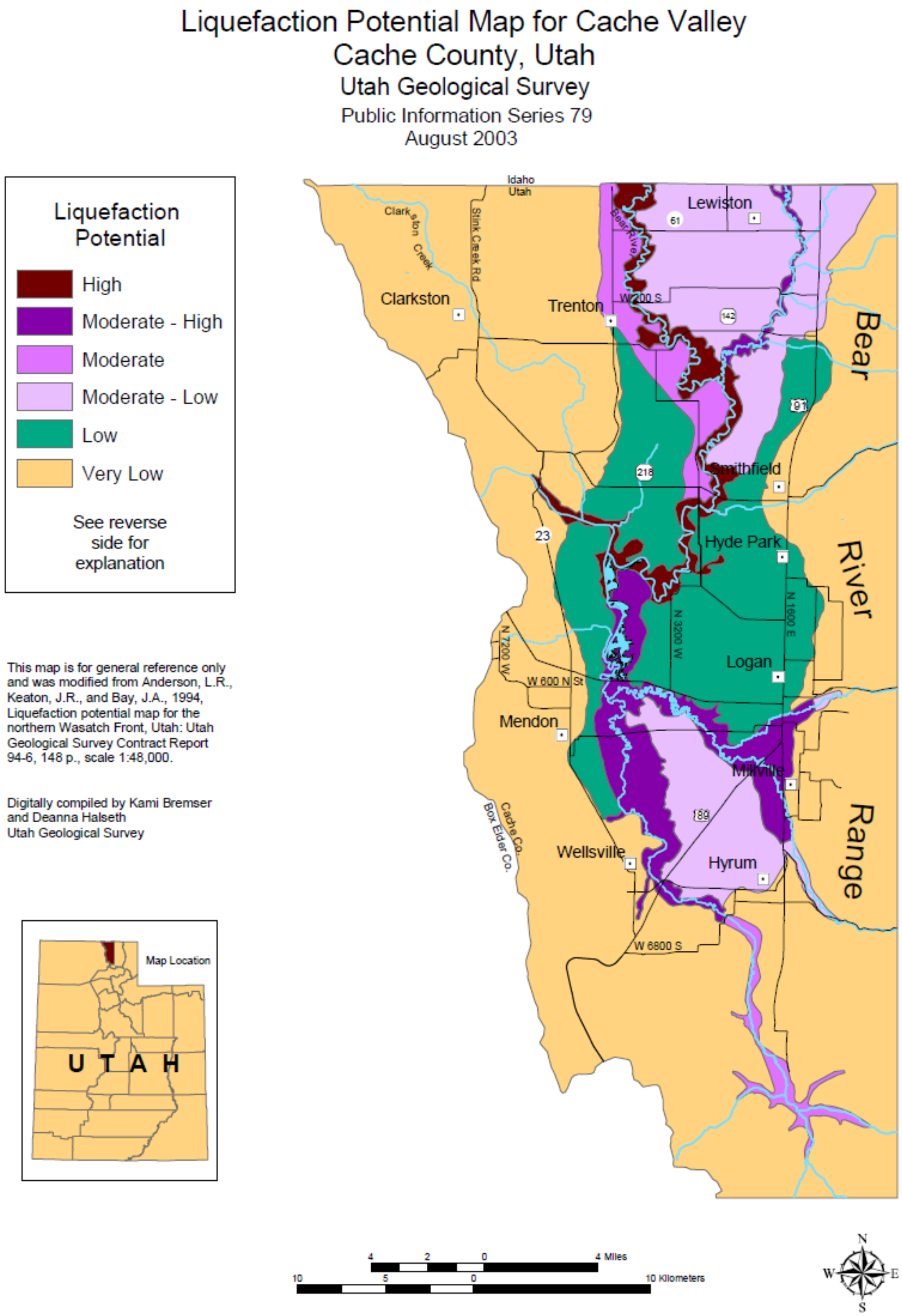
How is liquefaction potential determined?

The liquefaction potential categories shown on this map depend on the probability of having an earthquake within a 100-year period that will be strong enough to cause liquefaction in those zones. **High** liquefaction potential means that there is a 50% probability of having an earthquake within a 100-year period that will be strong enough to cause liquefaction. **Moderate** means that the probability is between 10% and 50%, **low** between 5 and 10%, and **very low** less than 5%.

What can be done?

To determine the liquefaction potential and likelihood of property damage at a site, a site-specific geotechnical investigation by a qualified professional is needed. If a hazard exists, various hazard-reduction techniques are available, such as soil improvement or special foundation design. The cost of site investigations and/or mitigation measures should be balanced with an acceptable risk.

Liquefaction Maps



LIQUEFACTION-POTENTIAL MAP FOR A PART OF DAVIS COUNTY, UTAH

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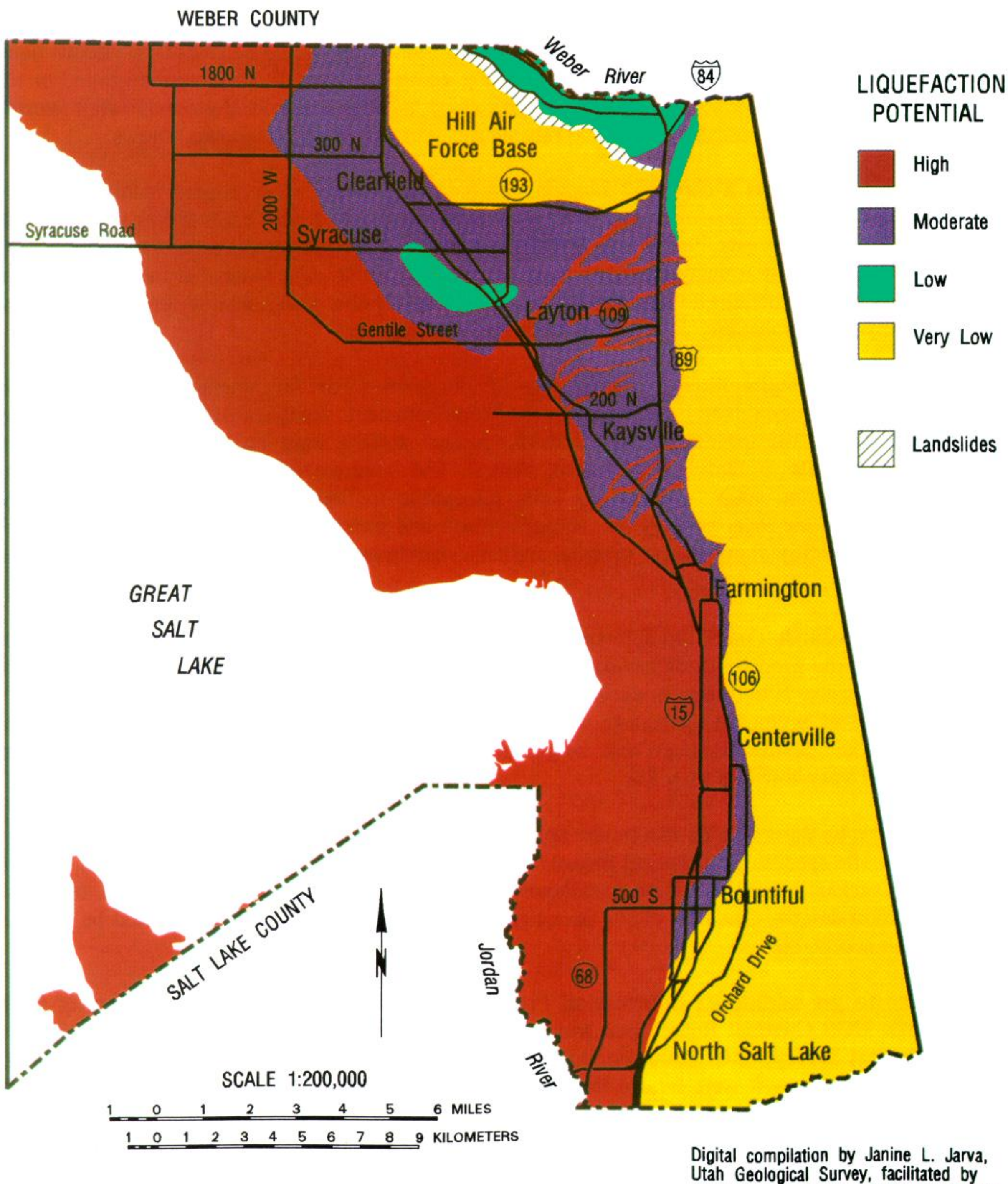

Digital compilation by Janine L. Jarva, Utah Geological Survey, facilitated by Automated Geographic Reference Center

This map is for general reference only and was modified from Anderson, L.R., Keaton, J.R., Aubry, Kevin, and Ellis, S.J., 1994, Liquefaction potential map for Davis County, Utah: Utah Geological Survey Contract Report 94-2, 50 p., scale 1:48,000.

LIQUEFACTION-POTENTIAL MAP FOR A PART OF SALT LAKE COUNTY, UTAH

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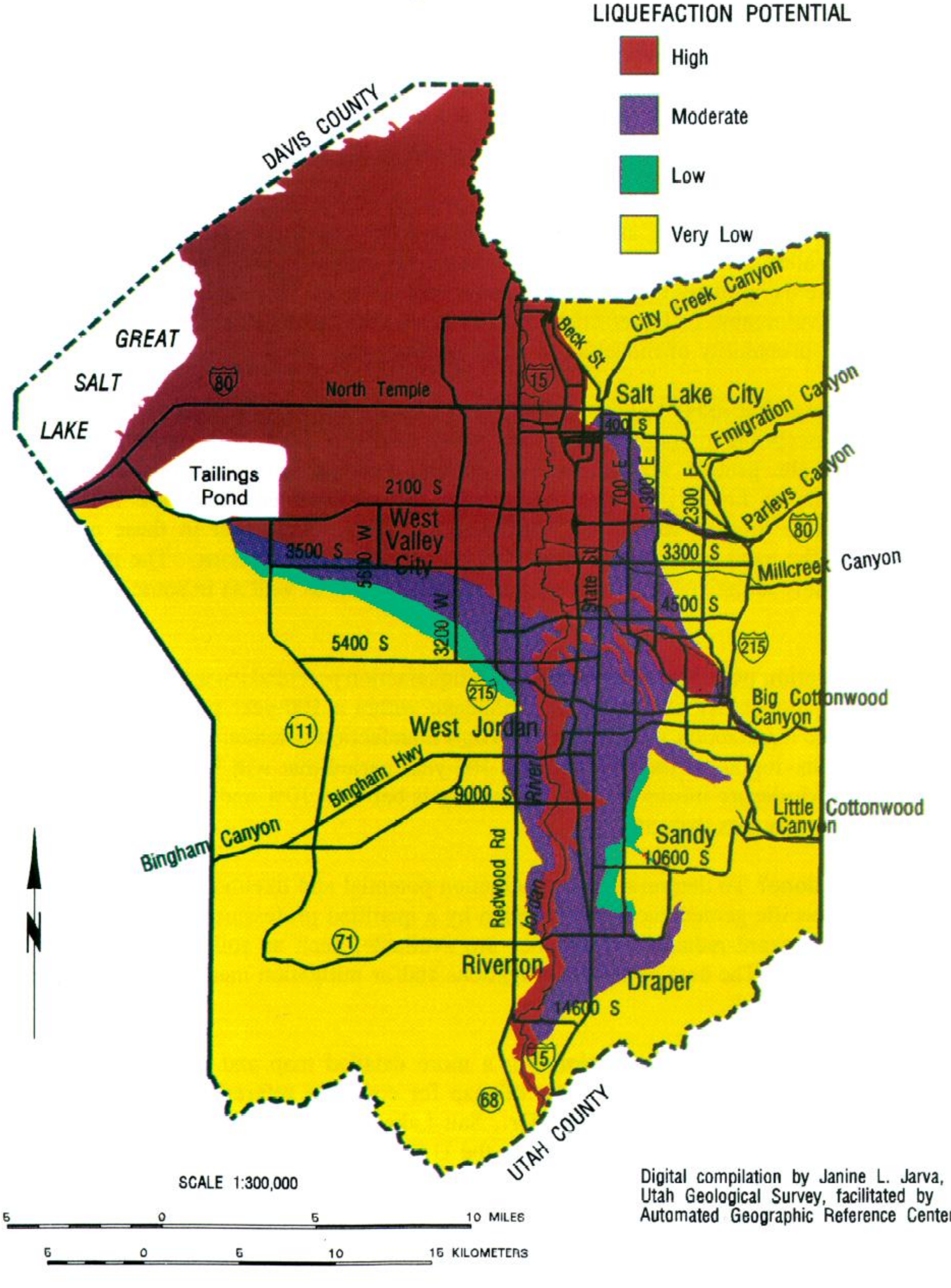
August 1994



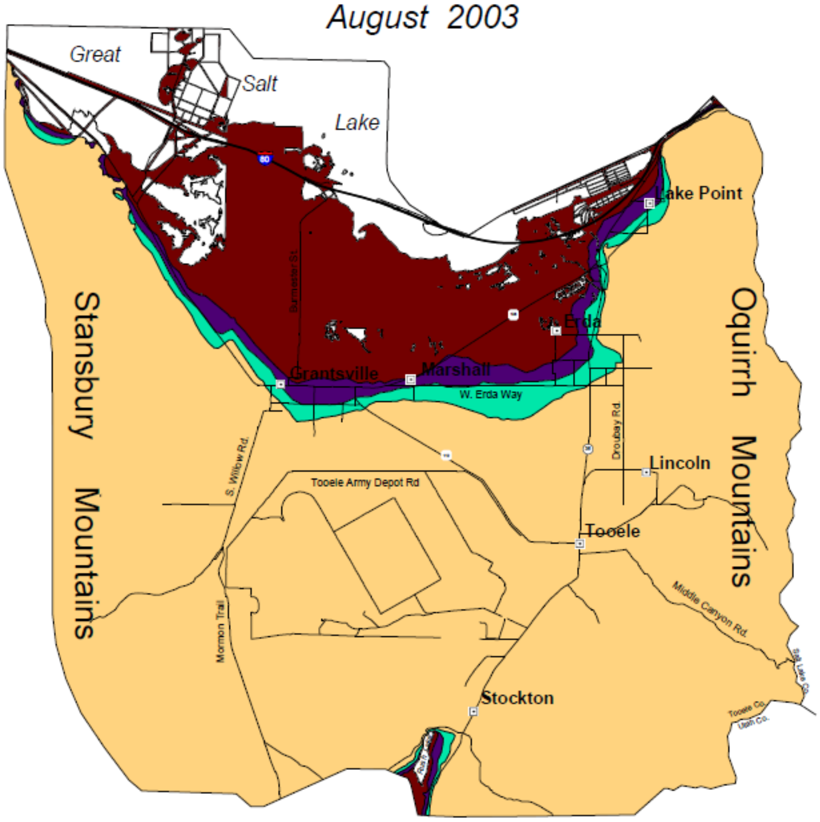
Digital compilation by Janine L. Jarva, Utah Geological Survey, facilitated by Automated Geographic Reference Center

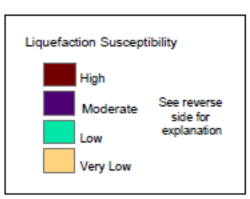
Liquefaction Susceptibility Map for Tooele Valley
Tooele County, Utah

Utah Geological Survey

Public Information Series 80

August 2003





This map is for general reference only.

Base map from U.S. Geological Survey 30x60-minute topographic quadrangles of Tooele, Rush Valley, and Bonneville Salt Flats. Liquefaction susceptibility map from Black, B.D, Solomon, B.J. and Harty, K.M., 1999, Geology and geologic hazards of Tooele Valley and the West Desert Hazardous Industry area,Tooele County, Utah: Utah Geological Survey Special Survey Study 96, 65 p., scale 1:100,000

Digitally compiled by Kami Bremser and Deanna Halseth
Utah Geological Survey

LIQUEFACTION-POTENTIAL MAP FOR A PART OF UTAH COUNTY, UTAH

UTAH GEOLOGICAL SURVEY

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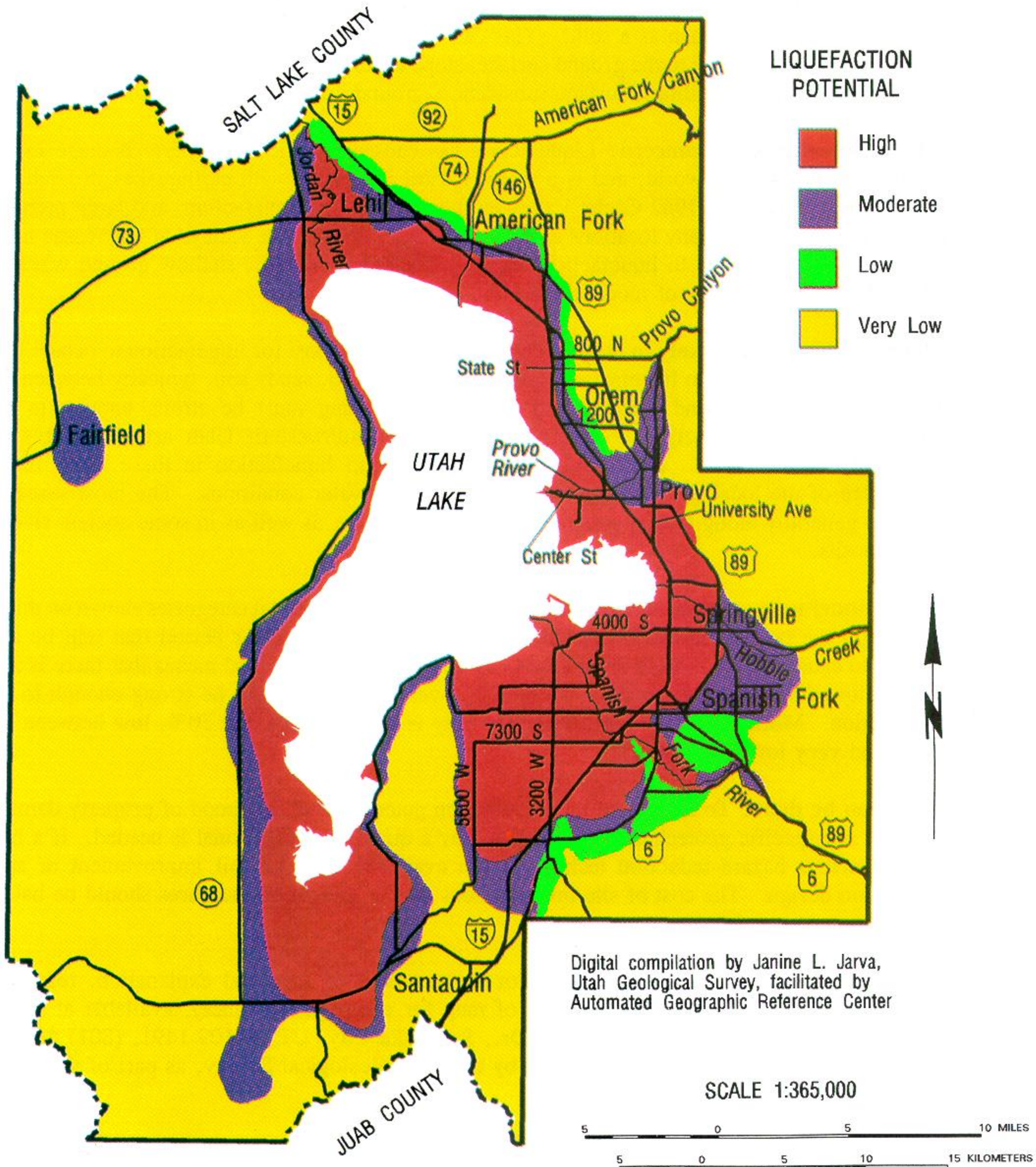
August 1994



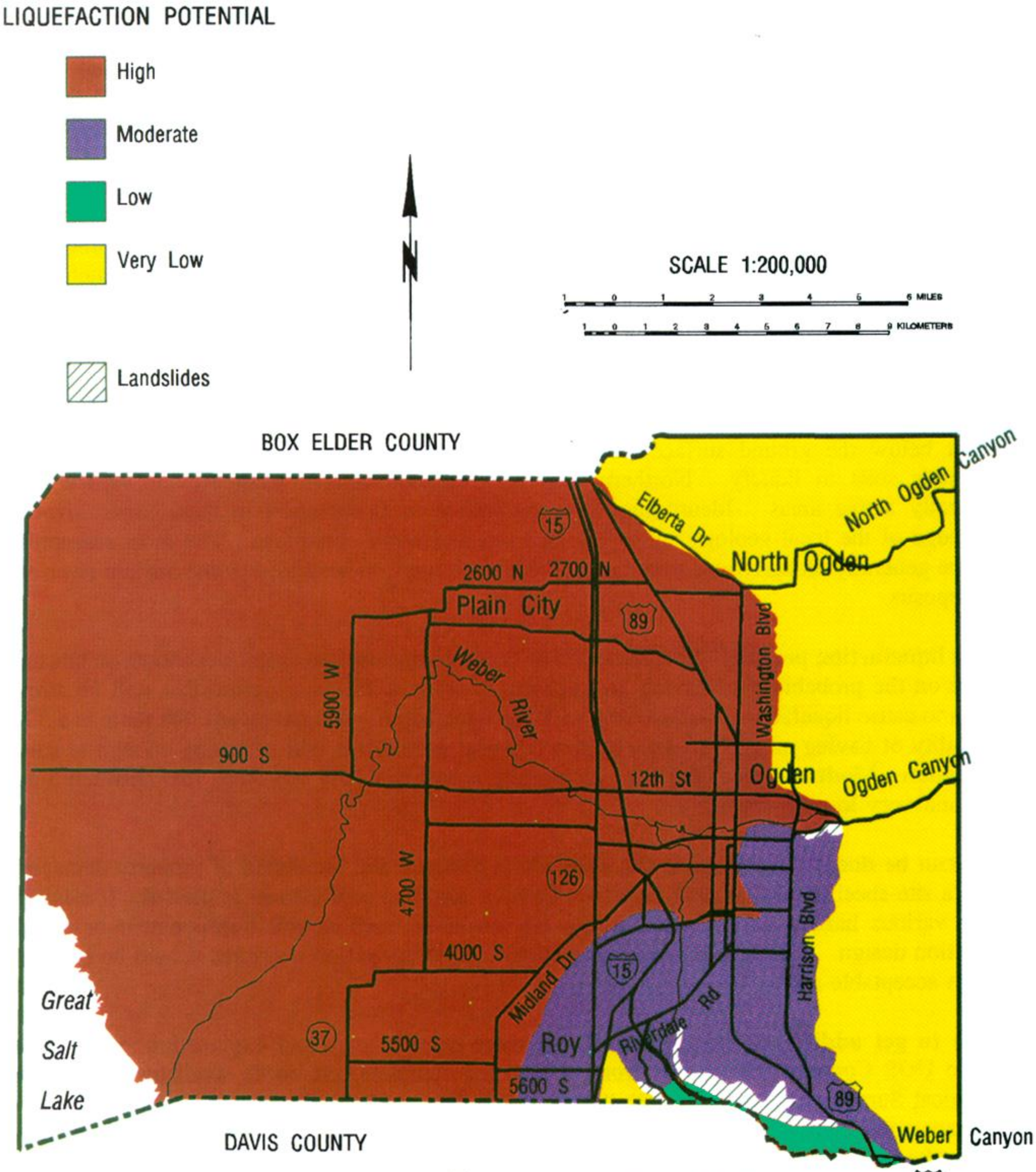
This map is for general reference only and was modified from Anderson, L.R., Keaton, J.R., and Bischoff, J.E., 1994, Liquefaction potential map for Utah County, Utah: Utah Geological Survey Contract Report 94-3, 46 p., scale 1:48,000. Copies of this report are available at the Utah Geological Survey.

LIQUEFACTION-POTENTIAL MAP FOR A PART OF WEBER COUNTY, UTAH

UTAH GEOLOGICAL SURVEY

Public Information Series 27

August 1994



Digital compilation by Janine L. Jarva,
Utah Geological Survey, facilitated by
Automated Geographic Reference Center

This map is for general reference only and was modified from Anderson, L.R., Keaton, J.R., and Bay, J.A., 1994, Liquefaction potential map for the northern Wasatch Front, Utah: Utah Geological Survey Contract Report 94-5, 150 p., scale 1:48,000. Copies of this report are available at the Utah Geological Survey.

All About Earthquakes: Utah Earthquakes

1.) Utah Earthquake History

-July 18, 1894: Ogden, VI-VII (Mag 5.0)

-August 1, 1900: Santaquin, VI-VII

-November 13, 1901: Parowan-Richfield, VIII

-November 14, 1901: Parowan-Richfield Aftershocks, VII

-November 17, 1902: Pine Valley, St. George, Santa Clara, VII

-October-December 1909: Series of 30-60 quakes within Garland and Tremonton, VII

-May 22, 1910: Salt Lake City, VII (Mag 5.0)

-May 13, 1914: Ogden, VII (Mag 5.5)

-September 29, 1921: Elsinore, Monroe, Richfield, 2 strong earthquakes 12 hours apart, VIII

-March 12, 1934: Kosmo, shore of Great Salt Lake, VIII (Mag 6.6)

-August 30, 1962: Franklin, Logan, Preston, Richmond (Cache County) Mag 5.7

-October 4, 1967: Marysvale, Mag 5.2

-March 28, 1975: Idaho-Utah border, Mag 6.1

**See more info at: http://earthquake.usgs.gov/earthquakes/states/utah/history.php

2.) Largest Earthquake in Utah

-March 12, 1934: Hansel Valley, near Kosmo (30 miles north of Great Salt Lake) Mag 6.6

Photo from Phillip Shenon report
Courtesy of Robert B. Smith

Photo from Wilbur Smith collection
Courtesy of Robert B. Smith

Photo courtesy of
The Salt Lake Tribune newspaper

Photo from Special Collections
Department
University of Utah Libraries

Photo from Wilbur Smith collection
Courtesy of Robert B. Smith

Newspaper Articles:

http://www.seis.utah.edu/lqthreat/nehrp_htm/1934hans/n1934ha1.shtml#efhy

3.) Salt Lake City Earthquake

-May 22, 1910: Salt Lake City, Mag 5.5

Newspaper Articles**:**
http://www.seis.utah.edu/lqthreat/nehrp_htm/1910salt/n1910sl1.shtml#tessbsl

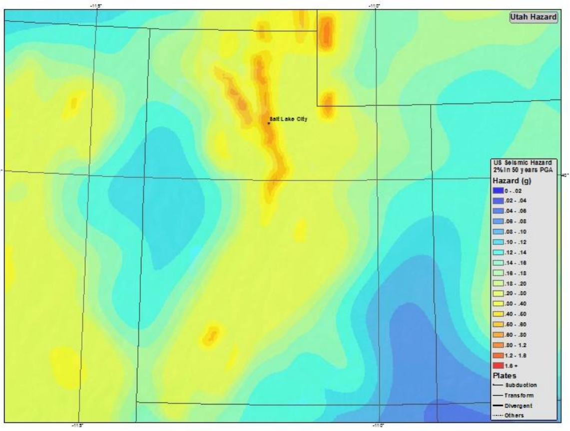
4.) Wasatch Fault Zone, Salt Lake City

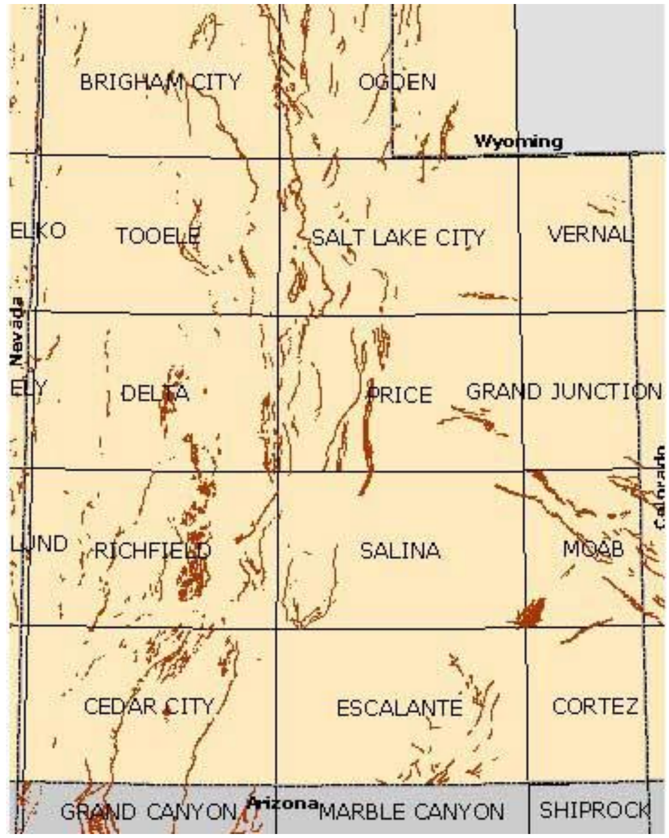
The Wasatch fault zone is one of the longest and most tectonically active normal faults in North America. The fault zone shows abundant evidence of recurrent Holocene surface faulting and has been the subject of detailed studies for over three decades. Half of the estimated 50 to 120 post-Bonneville surface-faulting earthquakes in the Wasatch Front region have been on the Wasatch fault zone.

This fault has 10 sections. The nearly 350-km-long Wasatch fault zone has traditionally been divided into seismogenic segments that are thought to rupture at least somewhat independently. The southern eight sections are entirely in Utah. To the north, the Clarkston Mountain section straddles the state line between Idaho and Utah and the northernmost (Malad City) section is entirely in Idaho. The chronology of surface-faulting earthquakes on the Wasatch fault is one of the best dated chronologies in the world and includes 16 earthquakes since 5.6 ka, with an average repeat time of 350 yr. Four of the central five sections [2351e-h] ruptured in the last hundreds to about a thousand years ago, whereas the next section to the north, Brigham City [2351d], has not ruptured in the past 2,125 yr. Slip rates of 1-2 mm/yr are typical for the central sections during Holocene time. In contrast, middle and late Quaternary (<150-250 ka) slip rates on these sections are about an order of magnitude lower. This substantial change in the slip rate may indicate a causal relation between increased Holocene slip rates and isostatic rebound/crustal relaxation following deep lake cycles such as Bonneville

Where: Davis County, Salt Lake County
Land Features: Basin and Range
Length: This section is 43 km of a total fault length of 357 km
Slip rate: Between 1.0-5.0 mm/year

http://geohazards.usgs.gov/cfusion/qfault/qf_web_disp.cfm?disp_cd=B&qfault_or=5326&ims_cf_cd=cf





0.3-s SA with 2% in 50 year PE. BC rock. 2008 USGS