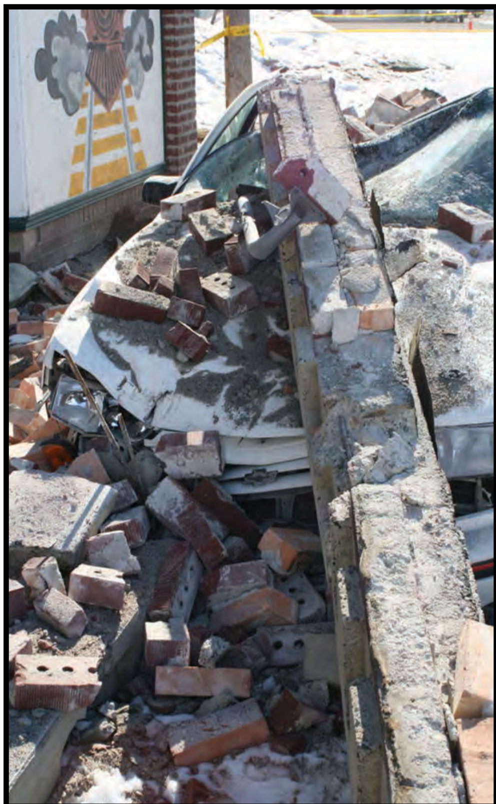
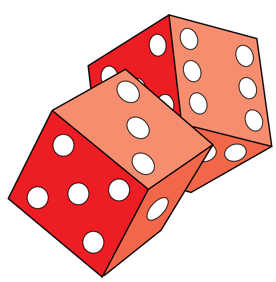


LIVING WITH EARTHQUAKES IN NEVADA

Put the odds in your favor!

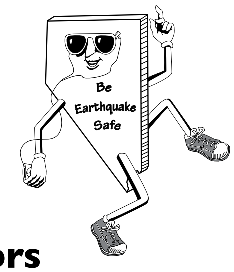


Nevada Bureau of Mines and Geology
Mackay School of Earth Sciences and Engineering
College of Science
University of Nevada, Reno

A Nevadan's guide to preparing for, surviving, and recovering from an earthquake

Your personal handbook for earthquake safety

This handbook identifies the earthquake threat to Nevada and reviews earthquake safety, how to be prepared for earthquakes, and mitigation of possible hazards from shaking and fault offset.



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Nevada Bureau of Mines and Geology
Special Publication 27
Third Edition, 2010

Cover Photographs

Upper left: Car crushed by fallen debris during the 2008 Wells, Nevada earthquake. *Photo by C. M. dePolo.* **Middle:** Major structural damage during the 2008 Wells, Nevada earthquake. *Photo by C. M. dePolo.* **Lower left:** Classroom damage from the 1983 Coalinga, California earthquake, which emphasizes the importance of school "Duck, Cover, and Hold" maneuvers and securing light fixtures. *Photo by Earthquake Engineering Research Institute.*

Photo by Karl Steinbrugge

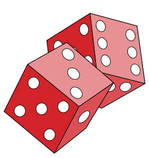
Ground offset of about eight feet from the 1954 Dixie Valley earthquake forming the small cliff to the left of the cabin.

Nevada is Earthquake Country

There have been several large earthquakes in Nevada and more will occur. In fact, over the last 150 years, Nevada has been the third most active state in the Union in the number of large earthquakes. Since the 1850s, 63 earthquakes with potentially destructive magnitudes of 5.5 or greater have occurred in the state. Given the many "earthquake-generating" faults there are in Nevada, the geodetic deformation measured between the mountains, and the many historical earthquakes, it is clear that earthquakes will continue to occur in the state. Some of these events will be very large, and some will be near our communities.

For those who experience the next major earthquake that affects Nevada, whether in a rural or urban setting, the financial and psychological impacts can be life changing. If earthquake preparedness is neglected, the shaking from earthquakes can even be life threatening. Recent earthquakes in Nevada, California, Haiti, Italy, and Japan remind us that awareness of the earthquake threat is not enough.

Awareness must lead to action—YOUR action



Earthquakes will continue to occur, but much of the damage from earthquakes can be avoided. We can construct buildings that will not fall down from shaking, and bridges that will sway but not break. On a personal level, we can secure water heaters and computers to keep them from falling, install cabinet latches to keep glassware and china contained, and keep heavy objects away from our beds. We can store water and practice family safety plans to overcome fear and better cope with the aftermath of earthquakes. A big lesson of the last decade of earthquakes is that you can make your home, your workplace, and your family safer.

Confronting the Inevitable

Earthquakes are a part of Nevada's natural history. The Earth's crust is being pulled apart and wrenched sideways in Nevada, and much of this deformation is accompanied by earthquakes. In western Nevada, where the hazard is the highest in the state, most citizens have experienced small events every couple of years. Earthquakes have occurred less frequently in other parts of the state, and some people may not be aware of the earthquake threat. In 1954, east of Fallon, five earthquakes of magnitude 6 or greater (two of magnitude 7) occurred over a period of six months and strongly shook central Nevada. The most recent major earthquake occurred in 2008, near Wells, leaving 19 million dollars in damage.

We know earthquakes will occur in the future in Nevada because

- small earthquakes indicating seismic activity occur every day in the state,
- active faults, the sources of most earthquakes, are found throughout the state, and
- precise measurements indicate that Nevada's crust is deforming and storing up stress for future earthquakes.

How does this affect our daily lives? Do we only have to worry if we live near an earthquake fault or where a large earthquake has occurred in the past? Is every place just as dangerous? What can we do about it anyway? Is it worth the effort, or should we just take our chances and deal with an earthquake after it occurs?

This guide includes the most recent information on the earthquake hazards in Nevada. It shows ways to be prepared for earthquakes and to survive them when they occur, minimizing their impact on your life.

Natural Hazards are Inevitable

Loss of Life and Property Due to Earthquakes is Not!

Further Reading:

dePolo and dePolo (1999) Earthquakes in Nevada
Wallace (1984) 1915 Pleasant Valley Earthquake
Nevada Seismological Lab website: www.seismo.unr.edu

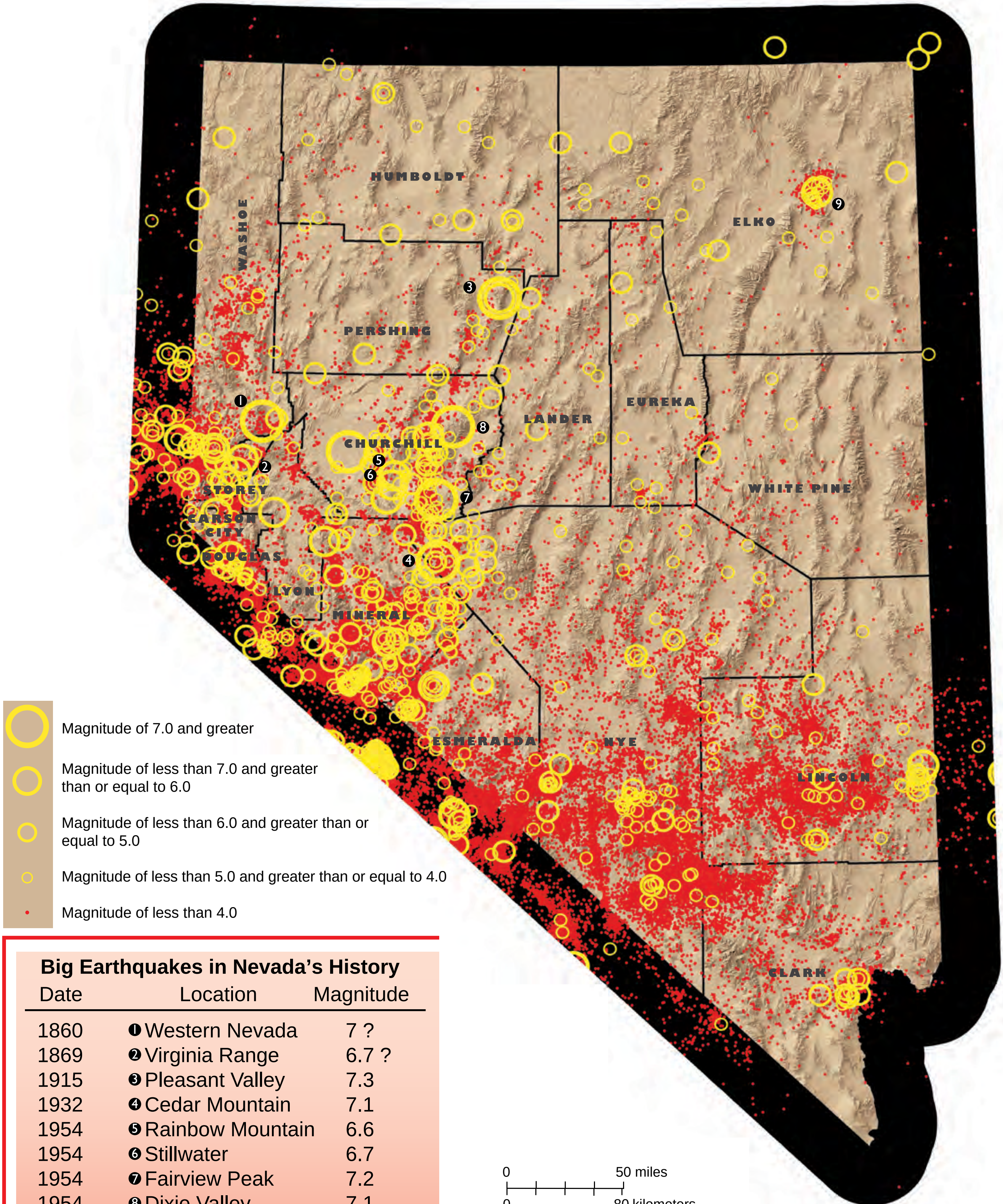
An Account of Nevada's Largest Earthquake, The 1915 Pleasant Valley Earthquake[1]

The first indication of disturbance was felt at exactly 3:40 p.m. Saturday, 2nd inst., when with a terrific report, similar to a large dynamite blast, the mountain side of Kennedy gave a lurch due north and then vibrated for about five seconds in a manner which I would say was rather violent, considering California disturbances. This shock had hardly subsided when another deep rumble was heard, followed by swaying motion, which appeared to be in a northerly direction. From this time on it was one continuous disturbance; one quake hardly died before a rumble announced another. This state of affairs occurred continuously until 5:45 p.m. when the only indication that conditions were not right was a sort of subdued rumble, such as might be experienced were there a great cauldron boiling and bubbling under foot, just beneath the earth's surface. About this time the inhabitants at Kennedy apparently became accustomed to this condition and settled down satisfied that the disturbance had spent itself and was a thing of the past, when all of a sudden without the slightest warning a great roar was heard and the earth's surface began to roll and sway up and down, evidently in all directions. This convulsion continued without stop for fully one and a half minutes. This disturbance was in my estimation about twice as violent as that experienced in San Francisco in 1906.

During this performance of the earth it was next to impossible for a person to stand erect. From this disturbance on, it was incessant continued disturbance, the earth never appeared quiet. About 9 p.m. we retired for the night and as near as I can imagine the situation, one could shut his eyes and imagine he was occupying a berth in a moving Pullman car, accompanied with creakings and rattling of windows, to be abruptly awakened by outbreaks at intervals of twenty to thirty minutes, lasting from five to ten seconds. At 10:55 things had quieted, or perhaps we were unconscious in sleep, when without the slightest warning a great roar and rumbling was heard and we were thrown violently out of bed and buffeted in all directions continuously for not less than fifteen minutes. During this disturbance it would appear to tire itself and would hesitate for an instant as if it were changing hands and fumbling in trying to get a good grip and would then shake violently with the other hand; then it would change hands and repeat the operation. This shake started at 10:55 p.m. Western Union time, as recorded[2]. I did not note the time of starting, but when the disturbance subsided sufficiently to allow one to enter the house in quest of sufficient apparel, as it was next to freezing outside, I noted the time was 11:10 p.m.

[1]Account from Letter to the Editor of the Silver State, October 5, 1915 edition, by L.D. Roylance.
[2]The Pleasant Valley earthquake mainshock was recorded at 10:53 pm PST on October 2, 1915.

Earthquakes in Nevada
1840s to 2009



Big Earthquakes in Nevada's History

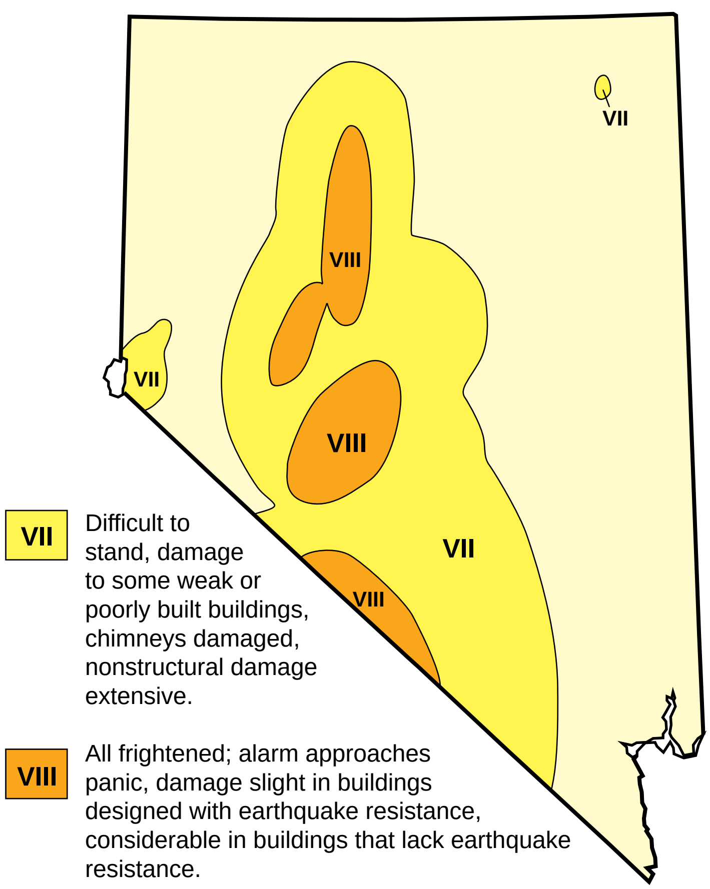
Date	Location	Magnitude
1860	❶ Western Nevada	7 ?
1869	❷ Virginia Range	6.7 ?
1915	❸ Pleasant Valley	7.3
1932	❹ Cedar Mountain	7.1
1954	❺ Rainbow Mountain	6.6
1954	❻ Stillwater	6.7
1954	❼ Fairview Peak	7.2
1954	❽ Dixie Valley	7.1
2008	❾ Wells	6.0

What are the Chances of Experiencing Strong SHAKING?

The Chance of Having an Earthquake in Nevada

Over the last 150 years, 25 earthquakes of magnitude 6 and larger and about 5 earthquakes of magnitude 7 and larger have occurred in Nevada. This leads to an average time of 6 years between earthquakes with magnitudes equal to or larger than 6, but actual values have ranged from less than 5 minutes to 42 years. The largest events, those of magnitude 7 and greater, occur in Nevada on average every 30 years. These are relatively high rates of earthquake activity. The map below shows where the most intense shaking in Nevada has occurred between 1857 and 2008.

Areas of Strong Shaking Experienced in Nevada 1857–2008



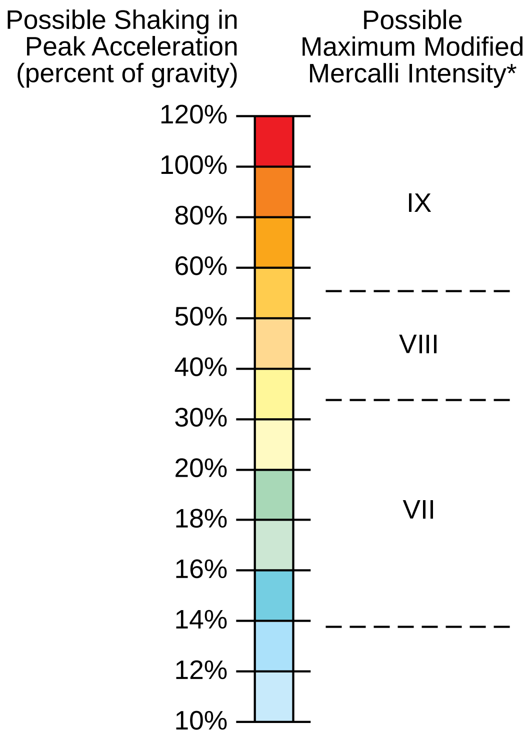
The Earthquake Hazard Perspective

We can't worry about every one of the several hundred earthquake-generating faults in Nevada every time a building is built. Nor do we need to. To prepare for earthquakes we mainly need to know the intensity of shaking we can anticipate over the expected life of the structure. Even though nobody knows for sure how long a building will last, an estimate of 50 years is commonly used. An approach is to estimate the strength of shaking that has a 1 in 50 chance of being exceeded in 50 years and design the building to be strong enough to resist damage from such a quake.

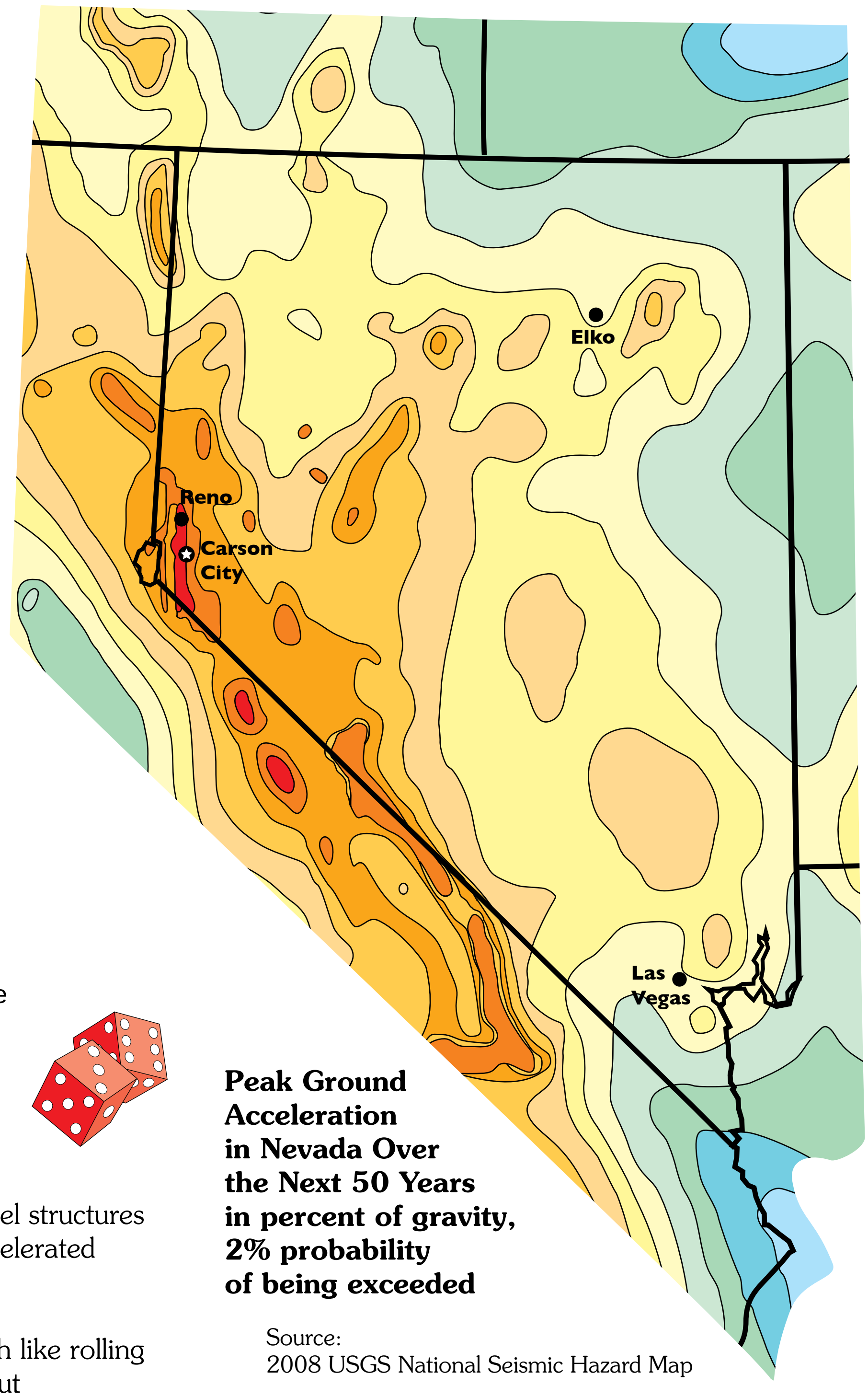
Maps like the one to the right are made by considering all the faults and the shaking that each might cause. Every fault needs to be identified and mapped. We study the characteristics needed to estimate the magnitude, primarily the fault length and maximum surface offset during a single earthquake. We also determine the average time between earthquakes or the average slip rate (see page 25). Finally we need to know how strong, on average, the shaking will be at every place when this fault has an earthquake. Shaking is more intense near the earthquake rupture and gradually decreases as you get farther away. Putting all this together, along with information from historical earthquakes, we make ground-motion maps like the one on the right. This map is similar to the maps that are used in the International Building Code (building codes give guidelines for constructing safe buildings). The map depicts peak ground shaking in percentage of the force of gravity (acceleration). The redder colors represent areas where the shaking is expected to be the strongest.

Using a measure of acceleration is common in earthquake engineering although many other measurements are needed for a complete description of ground motion; one "g" (gravity unit) is the force the Earth exerts on an object that makes it fall toward the Earth. You experience acceleration when you speed up or slow down quickly in a car. Your body is pushed back when you speed up or accelerate and is thrown forward when you slow down or decelerate.

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 damaging, earthquake occurs in a part of Nevada that has less frequent earthquakes (yellow to blue colors), the shaking will be every bit as strong as earthquakes we anticipate in western Nevada.

If we correlate this shaking potential map with possible damage, all of Nevada could experience damaging shaking. This is why Nevadans need to take messages of earthquake preparedness seriously.

When an earthquake occurs, another probability becomes important—the chance, given strong shaking, that something bad will happen to you! This is the probability you can do something about. **By securing shaking hazards around your home and workplace, you can put the odds in your favor that you, your loved ones, your customers, and your valuable and important possessions will be safe from earthquakes.**

What Will Happen if a Disastrous Earthquake Strikes?

Unfortunately, at some point in the future, earthquakes will occur close to Nevada communities and, depending on how well constructed the buildings are and how well prepared people are, a disaster may happen. This disaster could have many injuries, possible deaths, large property losses, and major disruption of services. Disruption of services really means disruption of everything. For example, in past earthquake disasters, the electricity goes out, which means gas pumps, computers, cash registers, ATMs, as well as any of your electric appliances will not work unless you have a backup generator that is functional. Natural gas may be out. Water may be out or unsafe for use. Telephone lines will be overwhelmed. Stores and businesses will not be able to be open immediately following an event. For the first few days you are largely on your own. Shelters may be set up within 24 hours, but keep in mind that shelters, a school for example, need to be inspected first to assure public safety from aftershocks, and there may be a delay in opening. It is also likely that in the disaster setting, you or those around you will have to administer any initial first aid, if needed, and in many cases, will have to transport the injured to the nearest hospital. Your battery-powered radio will be your source of information about shelters and open hospitals. Following a disaster, the many agencies, companies, and emergency workers involved in getting aid to people and restoring services will be working as fast as they can, but it takes time. Each situation is different, often with many surprises. You may be on your own for 5 days or more. For the first few days to possibly months, many businesses and schools will be closed.


Photo by Earthquake Eng. Res. Inst.

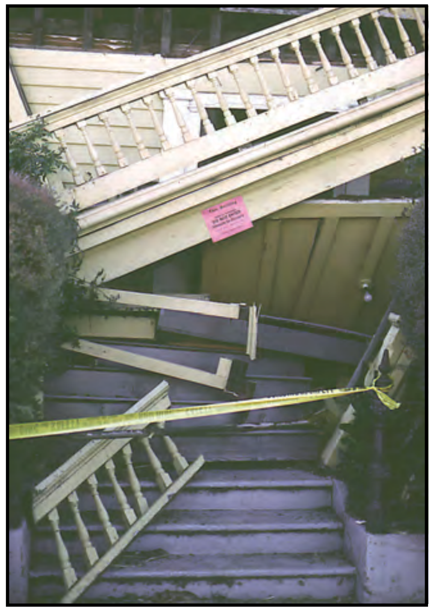


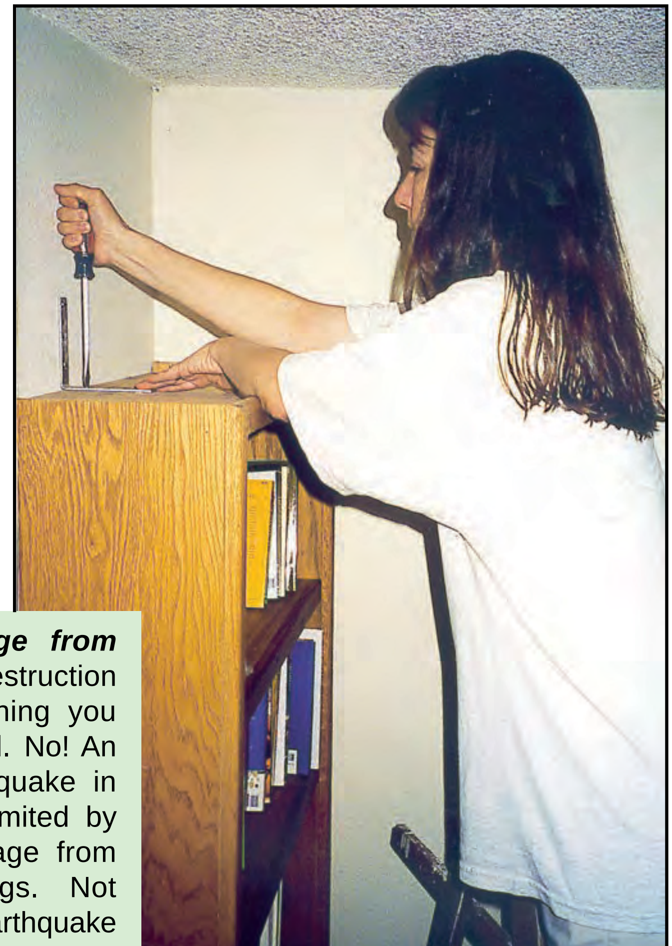
Photo by Craig dePolo


Photo by U.S.Army Corps of Engineers


Photo by Earthquake Engineering Research Institute

During a disaster your first priorities and attention should be given to your family and immediate neighbors or community. This includes first aid, comforting and reassuring, understanding problems that require immediate attention, and taking the action to solve them. At all times we need to proceed cautiously being mindful of possible aftershocks and hazardous situations, such as a broken natural gas line. People working together to deal with the earthquake effects and begin the road to recovery will gain a certain empowerment over the situation, and will minimize the overall impact on their lives.

Ideally, disasters do not have to happen, even though earthquakes will continue to occur. Many Nevadans, state and local governments, and businesses have taken steps to help prevent dangerous situations from earthquakes in Nevada. But it takes a much larger and deeper commitment to make Nevada truly earthquake resistant. What is clear from recent earthquakes in California, where a lot of preparedness has occurred, is that lives can be saved and property damage minimized with preparedness and mitigation efforts.

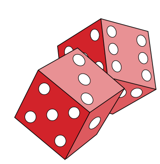


Taking *Control!*

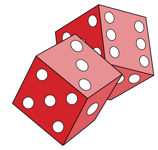
Earthquakes are inevitable, but the damage from earthquakes is not. Many people think the destruction caused by earthquakes is unavoidable, something you suffer through, then pick up the pieces afterward. No! An important lesson of the 1994 Northridge earthquake in California is that earthquake damage can be limited by preparation. Many also think that all the damage from earthquakes comes from collapsing buildings. Not necessarily! The dollars lost in the Northridge earthquake from nonstructural damage (damage to furniture, appliances, water heaters, stairs, etc.) was comparable to that lost in structural damage.

You, as an individual, can make your home, school, or workplace safer in the next earthquake by securing your building and its contents. Securing contents can prevent injuries and save lives. These precautions can also save you a lot of money when your chimneys and foundations, TVs and stereos, china and artwork come through an earthquake unbroken. If we all take these precautions, we will save ourselves billions of dollars in the next large earthquake.

Much of the fear of earthquakes comes from the lack of control we all feel when the Earth shakes our foundations. ***By learning more about earthquakes now and taking steps to reduce the damage from them, we can make earthquakes less frightening, increase our safety, and reduce our losses.*** In the next few pages we will show you how you can help save your property and your loved ones in the next earthquake.



Your Personal Safety



The following pages concentrate on making your environment safer before the next earthquake. What should you do during an earthquake? The next big earthquake will be less traumatic if you

1) prepare an earthquake plan and practice it,

2) know what to do during a big earthquake, and

3) store supplies to make life more comfortable after the earthquake (see what you will need in the "Life with Aftershocks" section, page 10).

Prepare a Plan

How rational do you think you will be during the violent shaking of a major earthquake? Before the next earthquake, get together with your family or housemates to plan now what you will do during and after that event. See page 37 for a useful plan.

- Teach everyone to "duck, cover, and hold."
- Identify safe spots in every room, such as sturdy desks and tables, and interior walls.
- Teach everyone who could be home alone how to turn off the gas—but only if they smell, hear, or see a leak.
- Establish an out-of-area contact person who can be called by all family members to relay information. In an emergency, out-of-area calls are often easier to place than local calls.
- Store supplies and prepare a personal earthquake bag.

Practice your plan often before the next earthquake, so habit can overcome fear.

Also work with your neighbors to prepare a neighborhood plan. You may have elderly or disabled neighbors who could need your help. The support of friends and neighbors could reduce the stress for everyone.

DUCK, COVER, and HOLD

During an earthquake, ***duck*** under a sturdy desk or table if possible, or crouch near an inside wall; ***cover*** your head and eyes with your hands and arms, and turn away from possible breaking glass or falling objects; and ***hold*** onto the desk or table so that it doesn't move away from you; move with it—it is your protection. Stay there until the shaking stops.

The area near the exterior walls of buildings is the most dangerous place to be. Windows, facades, and architectural details are the first parts of the building to collapse. To stay away from this danger zone, **stay inside if you are inside a building and outside if you are outside during the earthquake.**

Do not try to run outside or to another room—severe shaking will make it difficult to move. Duck, cover, and hold—wherever you are. Doorways are no safer than elsewhere in the home. If your building begins to collapse, you are safest under a sturdy piece of furniture that can shield you from falling debris.

Focus on personal safety when covering yourself. If the chair or table you are under moves, move with it. Turn away from potential flying hazards, such as breaking glass from a window or mirror. Expect many noises. The house or building will creak from moving, items will fall and make crashing noises, and some glassware may break. Animals will "shout" in alarm (barking, squawking, etc.).

Head for the doorway?—It is better to get under a table!

An enduring earthquake image is a collapsed adobe house with the doorway as the only standing part. From this came the belief that a doorway is the safest place to be during an earthquake. True—if you live in an old, unreinforced adobe house. In modern houses, doorways are no stronger than any other part of the house and usually have doors that will swing and can injure you. You are safer under a table.

WHAT TO DO DURING AN EARTHQUAKE

Indoors: Duck, cover, and hold. If you are not near a desk or table, drop to the floor against an interior wall and protect your head and neck with your arms. Avoid exterior walls, windows, hanging objects, mirrors, and tall furniture.

In a kitchen: Get away from the stove, refrigerator, and cabinets with heavy objects. Leave the kitchen if necessary. Get under a table. Duck, cover, and hold.

In a high-rise: Duck, cover, and hold. Avoid windows and other hazards. Do not use elevators. Do not be surprised if sprinkler systems or fire alarms activate.

Outdoors: Move to a clear area if you can safely do so; avoid power lines, trees, signs, buildings, vehicles, and other hazards.

Driving: Pull over to the side of the road, if safe to do so, stop, and set the parking brake. Avoid overpasses, bridges, power lines, signs, and other hazards. Stay inside the vehicle until the shaking is over. If a power line falls on the car, stay inside until a trained person removes the wire.

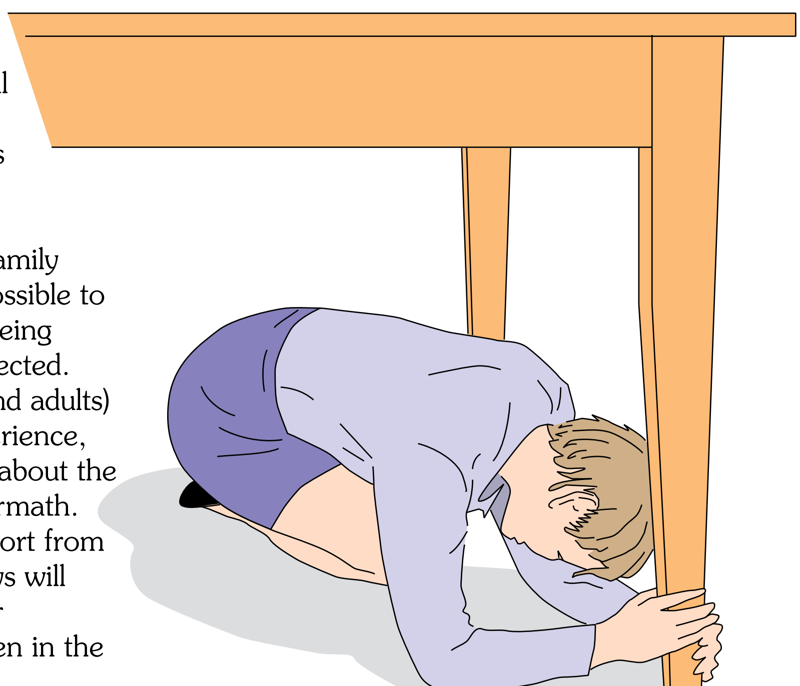
In a mall: Move away from display shelves. Look for sturdy furniture or an interior wall. Duck, cover, and hold.

In a theater or stadium: Stay at your seat and crouch on the floor. Protect your head and neck with your arms. Don't try to leave until the shaking is over. Then walk out slowly watching for anything that could fall from aftershocks.

A Special Note about Children

If earthquakes scare us because we feel out of control, think how much more true this must be for children, who already must depend on adults for so much in their lives. It is important to spend time with children in your care before the next earthquake to explain why earthquakes occur, involve them in hazard hunts, prepare earthquake kits, and practice "duck, cover, and hold." Play the Earthquake Game. Consider simulating post-earthquake conditions by going without electricity or tap water.

After an earthquake, remember that children will be under great stress. They may be frightened, their routine will be disrupted, and the aftershocks won't let them forget. Expect their behavior to regress. Adults tend to leave children to deal with many demands of the emergency, but this can be devastating to children. After a strong earthquake, keep the family together as much as possible to help alleviate fears of being abandoned and unprotected. Encourage children (and adults) to talk about their experience, reactions, and feelings about the earthquake and its aftermath. Extra contact and support from parents in the early days will pay off later. Whenever possible, include children in the recovery process.



Artwork by Min Jae Hong

The Earthquake Game

When someone calls "earthquake" everyone must pretend that an earthquake is happening and "duck, cover, and hold." After 15 seconds, you come out and take five slow breaths to practice calming down. Look around in the room you are in and briefly describe to each other what might have happened during an earthquake, such as cupboard doors opening and dishes and glassware falling out in the kitchen. Then discuss how everyone responded and what could be done better. While it is fresh in your mind, if you can quickly secure or move an identified hazard in a room, do so.

You win!

Life with Aftershocks

Once the earthquake is over, then we will have to live with its aftermath—the risk of fire, the potential lack of utilities and basic services, and the certainty of aftershocks.

Electrical, water, transportation, and other vital systems can be disrupted for several days after a large earthquake. Emergency response agencies and hospitals could be overwhelmed and may be unable to provide you with immediate assistance.

Be prepared to be on your own for 5 days or more. Knowing first aid and having supplies will make life more comfortable and help you keep your sanity after the next earthquake.

What You Will Need (disaster kit)

Maintain earthquake disaster kits. Keep them where they can be reached even if your building is badly damaged. Take them with you if you evacuate. **The kit should include these items:**

- Medications and medical consent forms for dependents
- First aid kit and book
- Emergency cash
- Copies of vital documents such as insurance policies
- Spare eyeglasses and shoes
- Snack foods, high in water and sugar
- Working flashlights, radio, and extra batteries
- Lightsticks
- Personal hygiene supplies (including toilet paper)
- Plastic bags for tarps, waste, rain ponchos, and other uses
- Comfort items such as games, crayons, writing materials, outgrown teddy bears (children regress under stress)
- Tools (a crescent wrench for example)

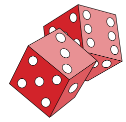
Maintain a pantry with a 5-day provisions supply including the following:

- Drinking water (minimum one gallon per person, per day) (water heaters can have 30 to 50 gallons)
- Food that is nutritious, liked by family members, and requires no refrigeration

Keep the following items readily available **in the garage or closet:**

- Charcoal or gas grill for outdoor cooking
- Cooking utensils, including a manual can opener
- Extra food for pets, pet restraints (in case the fence is down)
- Sturdy shoes, work gloves, and comfortable clothing
- Blankets
- Camping equipment and sleeping bags

Store these supplies in easily accessible locations such as hallway closets. Change stored water every three months. Check and rotate food every six months. Rethink your kit once a year.



Help Out !
Following an Earthquake

- *Replace telephone receivers shaken off the hook and restrict telephone usage to emergencies.*
- *Check on your neighbors.*
- *Listen to the radio for updates and information.*
- *Do not spread rumors—this is very important during an emergency response and recovery.*
- *Volunteer to help in neighborhoods and at shelters.*

Fire Prevention

Earthquakes cause fires. They break gas mains, causing fires, and break water mains, impeding the fighting of fires. Some tips for reducing the risk:

- Brace your water heater to prevent gas leaks. Be sure your gas appliances have flexible attachments.
- Keep a wrench near the gas main and train family members who may be home alone how to use it. Shut off gas only if you smell gas, hear a leak, or see a break (gas can be turned on only by trained personnel—and there may be a delay).
- If you lose power, use flashlights instead of candles. The flame could cause an explosion if gas is leaking, or aftershocks could knock over the candle.
- If you have power and have a gas leak, do not use electrical switches.
- Keep a fire extinguisher braced securely to the wall. Know how to use it.

See additional information on pages 16 and 17.

The Hazard Hunt

We can't control earthquakes, but we can control our environment by securing belongings and fixtures in our homes, schools, and workplaces.

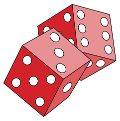
Using your common sense, walk through your house and office and look for things that could fall when shaken and think of ways to secure them. Also think about the less visible parts of your home: furnace, pipes, and water heaters. And of course, the building itself should be secured to the ground.

As you conduct your hunt, think both of the hazard to you and your family if these things were to fall and the cost to you to replace these items. Details on how to secure different items are on the following pages. Keep areas above beds and cribs clear of objects that could fall on you during the night.

If you have children, include them in the hazard hunt. Their fresh eyes can often find things you miss. Moreover, being part of the hunt will empower them. The next earthquake will be less frightening if they have taken part in making their home safe.

Further Reading:
Kimball (1988) Earthquake Ready

Hazard Hunt Checklist



Tabletop objects
- ☐ Televisions
- ☐ Stereo systems
- ☐ Art objects
- ☐ Glassware & vases
- ☐ Computers
- ☐ Monitors
- ☐ Speakers

In your kitchen
- ☐ Latched cupboards
- ☐ Microwave ovens
- ☐ Gas appliances

Objects from above
- ☐ Hanging lights
- ☐ Ceiling fans
- ☐ Picture frames
- ☐ Hanging mirrors
- ☐ Hanging plants
- ☐ On top of bookcases

Glass
- ☐ Sliding glass doors
- ☐ Windows

Tall furniture
- ☐ Tall bookcases
- ☐ File cabinets
- ☐ Armoires
- ☐ China cabinets

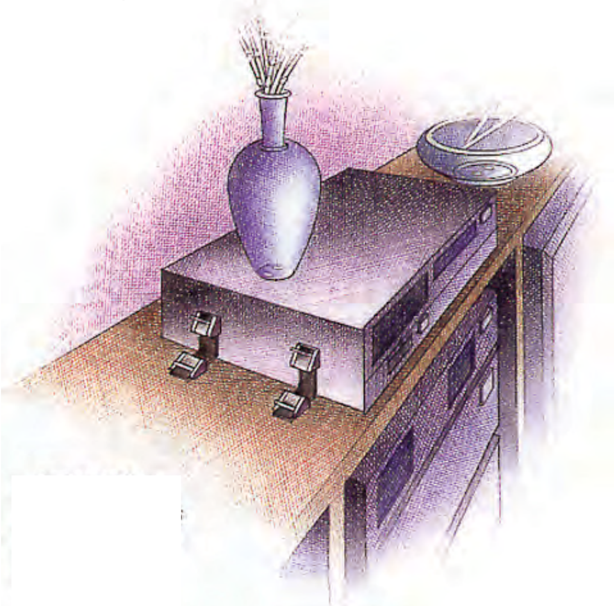
Some Important Earthquake Remedies

Earthquake safety is more than keeping our buildings from falling down. We must secure the contents of our buildings to reduce the risk to both our lives and our pocketbooks.

Four people died in the 1994 Northridge, California earthquake because of damage to building contents, such as toppling bookcases. Many billions of dollars were lost due to nonstructural damage.

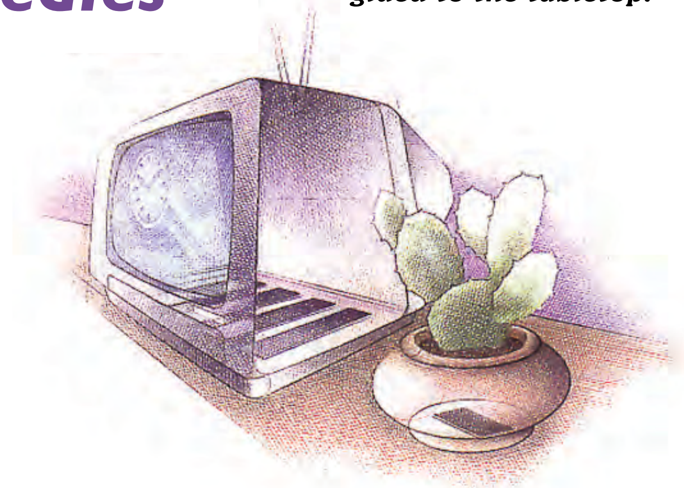
Nonstructural safety is up to you. The hazard hunt showed potential problem areas of your home. Here we show you just what you can do to secure possessions inside your home. **You should secure anything 1) heavy enough to hurt you if it falls on you, or 2) fragile and/or valuable enough to be a significant loss if it falls.**

An element of safety planning is paying attention to safely locating furniture, avoiding nonstructural hazards. For example, beds should be kept away from windows to avoid the risk of broken glass.



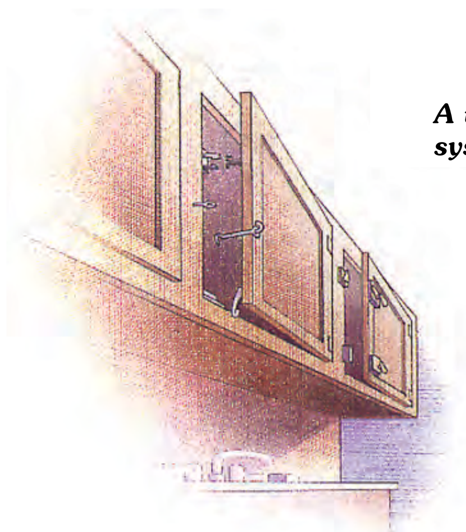
Anchor tabletop objects with straps and nondrying putty.

Velcro fasteners are glued to the tabletop.



Securing tabletop objects

Televisions, stereos, computers, lamps, and chinaware are heavy and costly to replace. They can be secured with buckles and safety straps attached to the tabletop (which allow easier movement of the unit when needed) or with Velcro fasteners glued to both table and unit. Glass and pottery objects can be secured with nondrying putty or microcrystalline wax.



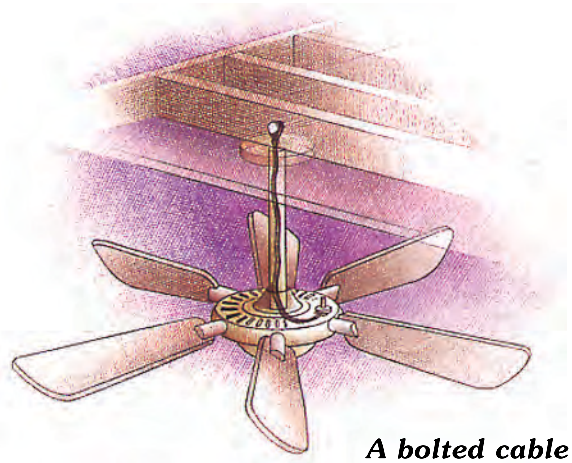
A variety of latch systems can be used.

In your kitchen

Unsecured cabinet doors fly open during earthquakes, allowing glassware and china to crash to the floor. Many types of latches are available to prevent this—child-proof latches, hook and eye latches, or positive catch latches designed for boats. Gas appliances should have flexible connectors to reduce the risk of fire.

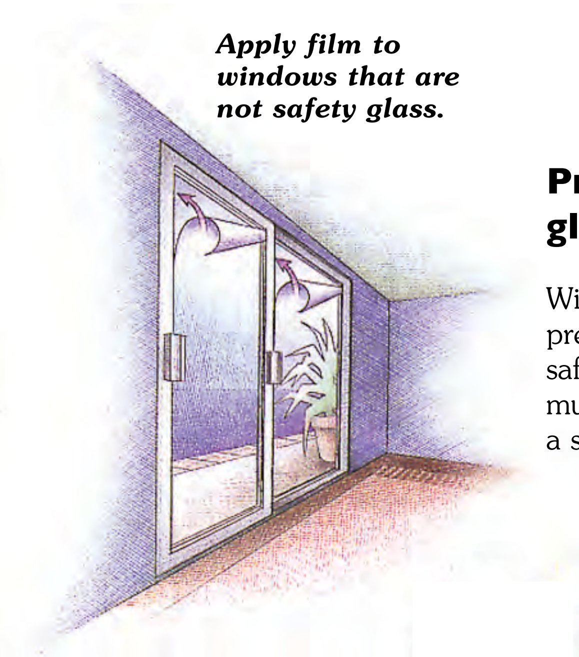
Objects from above

Ceiling lights and fans can be very heavy and present a significant safety hazard. These should be additionally supported with a cable bolted to the ceiling joist. The cable should have enough slack to allow the fixture to sway. Framed pictures, especially glass covered, should be hung from closed hooks so that they can't bounce off. Only soft art such as tapestries should be placed over beds or sofas.



A bolted cable attaches fan to ceiling joist.

Apply film to windows that are not safety glass.

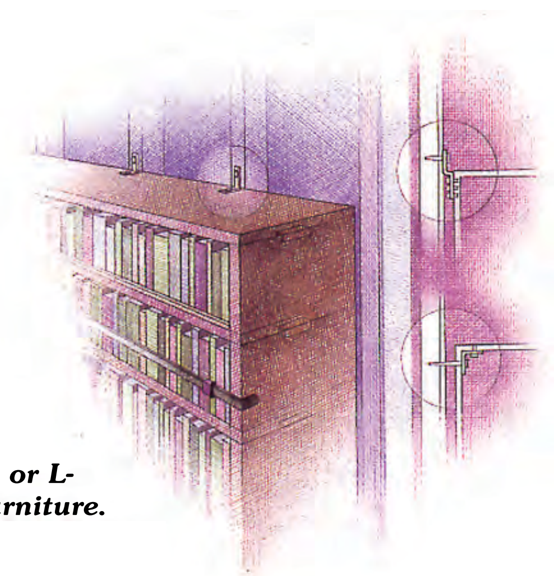


Protecting yourself from broken glass

Window glass can shatter during earthquakes and presents a significant hazard. Windows made from safety glass or covered with a strong mylar film are much safer. Be sure you use safety film and not just a solar filter.

Anchoring your furniture

Secure the tops of all top-heavy furniture, such as bookcases and file cabinets, to the wall. Be sure to anchor to the stud, not just to plasterboard. Flexible fasteners such as nylon straps allow tall objects to sway without falling over, reducing the strain on the studs.



Use nylon straps or L-braces for tall furniture.

Artwork by Todd Connor

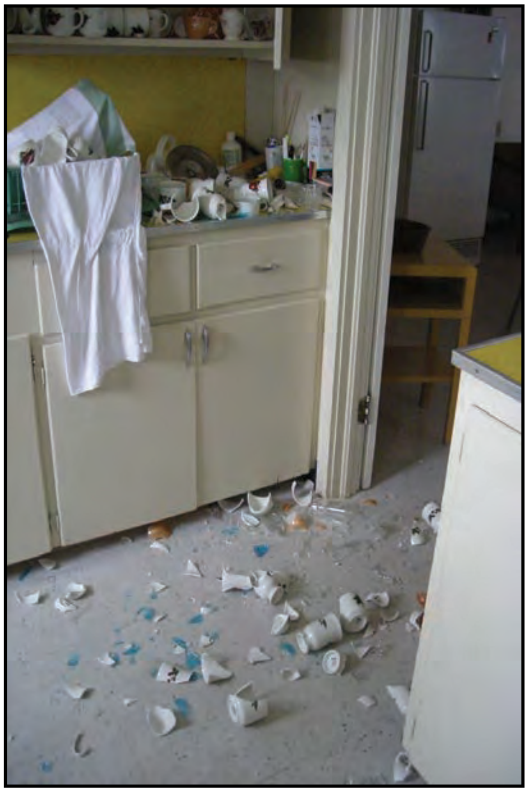


Photo by Wells resident

Content damage from the 2008 Wells, Nevada earthquake. Note the broken glass.

By conducting a hazard hunt, securing dangerous items, and rearranging furniture to avoid hazards and create safety spots, you will minimize your injuries, losses, and the amount you have to clean up from an earthquake.

Chimneys

Many chimneys are built of unreinforced brick or stone and can collapse or fall over during earthquakes, potentially injuring people, and damaging houses and cars. The 2008 Wells, Nevada earthquake damaged 10–15% of all chimneys in town. A house and a masonry chimney are essentially separate and very different structures, and tend to respond to earthquake motions by pounding and pulling apart. Thus, chimneys must be well tied to the frame of the building, preferably with long steel straps that are embedded in the masonry and nailed to joists in the building. The most dangerous chimneys are those that extend five or more feet above the roof; these may go through the roof if they fall toward the house. You can replace masonry chimneys with metal flues, especially the portion above the roof. One-inch-thick plywood panels can be installed in a house's attic or on the roof to help keep brick or stone from falling into a house. Do not locate patios, children's play areas, or parking spaces near a questionable chimney. **Tell your family members to get away from chimneys and fireplaces during earthquakes.**

Photo by C. dePolo

Damage to chimney from the 2008 Wells, Nevada earthquake. Everyone should be made aware that the areas around chimneys are dangerous during earthquakes.

Eliminating
Nonstructural Hazards

The term "nonstructural hazards" is used in the earthquake field for the contents in a building that can cause injury or damage if shaken. This section summarizes some of the earthquake remedies so that they can be applied to any kinds of objects.

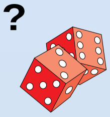
What is a Nonstructural Hazard?

Any object in a building that is not a part of the structural framework is a nonstructural component. This includes bookshelves, windows, televisions, computers, water heaters, lights, dishes, paintings, office equipment, file cabinets, and ventilation ducts, to name a few. Nonstructural components become hazards during an earthquake when they are thrown down, shaken down, or toppled. This hazard can be avoided by securing, relocating, replacing, removing, and taking cover from nonstructural hazards.

Why Should You Worry About Nonstructural Hazards?

Falling objects can injure or pin down your loved ones, your friends, or your customers. In areas of strong shaking from earthquakes, virtually all buildings and homes will have the potential for nonstructural damage. Nonstructural components can make up 75% to 80% of the original construction costs of a building, thus, nonstructural damage can cause high economic losses. Nonstructural damage can also cause a significant loss of function, rendering equipment temporarily or permanently useless. Mitigation is the solution. Strapping a computer down and protecting it from nonstructural hazards can save the computer and the records and information it contains.

What Can You Do About Nonstructural Hazards?



Secure Nonstructural Hazards

Straps, latches, Velcro, brackets, earthquake wax, earthquake putty, wire, and plumbers tape are some of the ways to secure a wide range of objects to avoid loss and damage during an earthquake.

Relocate Nonstructural Hazards

Relocate an object so that it is braced by other objects or poses no threat to injuring anyone. Objects should also be relocated to avoid blocking exits. If they do fall, they will not interfere with post-earthquake evacuation.

Replace Nonstructural Hazards

In some cases, objects can be replaced with lighter, more secure substitutes, reducing or eliminating a hazard. For example, new light fixtures might be considered in place of securing old heavier fixtures.

Remove Nonstructural Hazards

Removing the nonstructural object removes the hazard. Removing heavy objects from the top of book cases, shelves, or from over beds is an easy solution.

Take Cover from Nonstructural Hazards

Many of the safety maneuvers made during an earthquake are designed to protect you from nonstructural hazards. Taking cover under a desk can protect you from falling light fixtures, pictures, file cabinets, and other heavy or sharp objects. Facing away from windows or mirrors helps protect your face from flying glass. If there is an earthquake, take cover immediately to protect yourself from nonstructural hazards. Remember you will be largely on your own following a disastrous earthquake, so you need to survive the event as uninjured as possible. Make sure your home and office have safe spots to take cover and mitigate nonstructural hazards that may injure people, especially your family.

Further Reading:

Wiss, Janney, Elstner Assoc., Inc. (1994) Reducing the risks of nonstructural earthquake damage: A practical guide.

Avoid Earthquake Related Fires

Photo by Earthquake Engineering Research Institute

Fire following the 1995 Hyogoken-Nanbu, Japan earthquake.

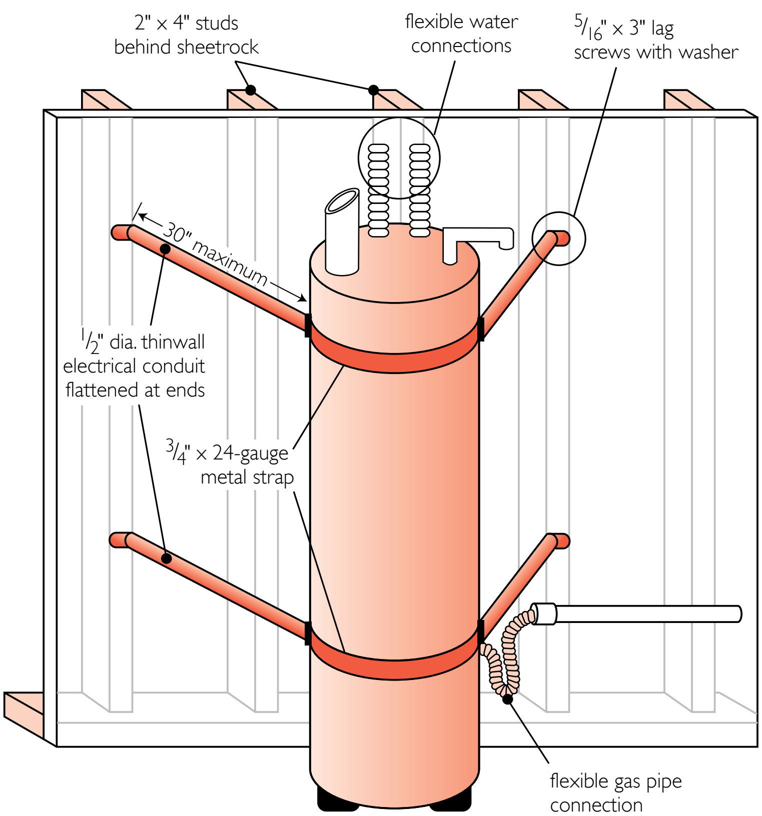
A fire caused by earthquake damage is a true emergency because the resources to fight fires may be spread out by a large number of fires, or access to a fire area may be limited or blocked. Further, following an earthquake, fire suppression systems such as water systems, water sprinklers, and sheetrock siding may be compromised. **Many earthquake fires totally destroy the structure of origin and spread to neighboring structures.** In the worst cases, fire storms are created. Fire prevention measures for earthquakes include:

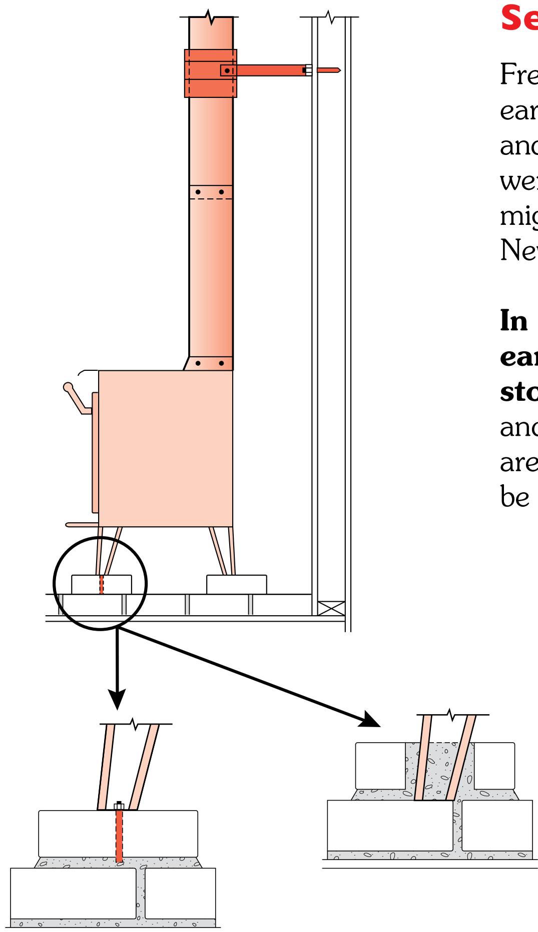
- using flexible gas hose lines
- securing water heaters, wood stoves, and propane tanks
- inspecting for gas leaks following an earthquake
- turning off the gas if there is a gas leak or significant damage
- not using any ignition source near potential fire areas; this includes matches, candles, and not turning on electrical switches
- inspect chimneys, flues, and stoves for damage before using following an earthquake

Anchoring Your Water Heater

Water heaters are heavy and can cause injury if they fall. They can cause fires when shaking of the heater breaks the gas line. Water heaters are also excellent emergency water supplies when they survive shaking and water lines are not broken. **Anchor unsecured water heaters with metal tubing, heavy metal strapping, and lag screws to wall studs.** Use flexible water and gas connections to help avoid breakage. Water heaters over 100 gallons—or more than 12" from a wall—require a designed system beyond this suggested anchoring.

- Use $\frac{3}{4}$" x 24-gauge metal strapping to hold water heater and attach support tubing (connect with a $\frac{1}{4}$" x 1" round-head machine screw with washers and a nut).
- Use $\frac{1}{2}$" diameter thinwall electrical conduit (pipe), flattened at ends to anchor the strapping that is holding the water heater to 2" x 4" studs in the wall. Connect the tubing to the studs using $\frac{5}{16}$" x 3" lag screws with washers.
- Install flexible gas pipe and water pipe connections.
- Keep water heater area clear for easy access.
- To use water heater for an emergency water supply, turn the water heater off first. When turning back on, follow procedures for turning on an empty water heater.





Securing Wood Burning Stoves

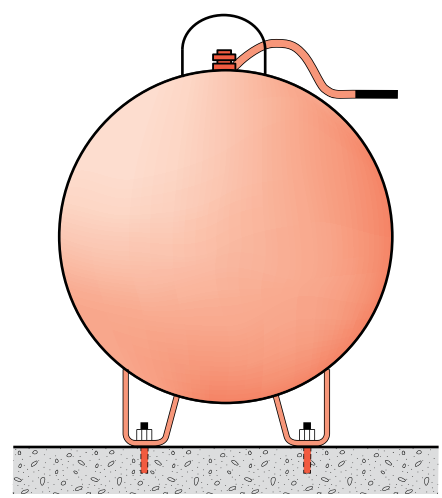
Free-standing wood burning stoves pose an additional risk in an earthquake. Many fire codes leave stoves unsupported on all four sides and vulnerable to sliding or overturning in an earthquake. If a stove were to tip and/or separate from the stove pipe, cinders or sparks might easily cause a fire in the home. This has happened during past Nevada earthquakes.

In order to reduce the potential fire hazard following an earthquake, the stove should be anchored to the floor and stove pipe sections secured. It is important that the seismic anchors or braces do not conduct heat from the stove. Although there are many types of stoves in use, the following recommendations can be used for common installations:

- Stoves resting on a brick hearth can be anchored using bricks and mortar.
- Mobile home approved units come with predrilled holes in the pedestals or legs and can be safely anchored to the underlying floor framing.
- Those resting on a concrete slab on grade can be directly anchored into the concrete.
- Stove pipe should be anchored to the flue exit and the stovepipe segments should be fastened securely together.

Anchoring Propane Tanks

Many residents in Nevada have above-ground propane tanks. **Propane tanks may move, slide, or topple during heavy ground shaking and are potentially hazardous unless both the tank and the piping are properly secured and a flexible hose connection is used.** Liquid propane expands 270 times when it turns into a gas and can quickly form a dangerous vapor cloud if a propane leak develops. This happened in the 2008 Wells earthquake, and fortunately the propane cloud did not ignite. Gas leaks are frequently the cause of earthquake-related fires. The following recommendations can be used to reduce the post-earthquake fire hazard associated with propane tanks.



- Mount the tank on a 6" thick continuous concrete pad and using four ½" diameter bolts, attach the four legs to the pad with a minimum embedment of 3".
- Install flexible hose connection between tank, supply line, and entrance to home.
- Clear area of tall or heavy objects that can fall and rupture tank or supply line.
- Keep a wrench tied on a cord near the shut-off valve and make sure family members know how to use it.
- For large tanks (such as farm and commercial use), seismic shut-off valves are available.

The Anatomy of a Safe Building

Although many considerations of building safety are economic, some structural problems, such as unreinforced masonry construction, are potential life safety issues. Even though structural problems in homes, if they exist, are usually more economic risks than safety issues, some of these risks can be substantial and should be addressed in earthquake country.

A safe building is one that can withstand the sideways push of an earthquake. Buildings are built to withstand the downward pull of gravity. Earthquakes push on a building in all directions—up and down, but most of all, sideways.

A safe building is built on a firm foundation. The foundation should be solid, with a continuous perimeter. The house should be securely fastened to the foundation with bolts or plates that anchor the sill plate to the foundation.

A safe building is securely connected together. Mortar in brick and masonry fails under even moderate shaking and should not be considered a structural element. A house with a crawl space (not a slab foundation) may have a small, wood-frame wall that surrounds the crawl space between the bottom of the house and the foundation, known as a cripple wall or pony wall. Cripple walls need bracing to resist the sideways push. The opening for a garage door can be a weak part of a wall and other walls must compensate if garage doors are located in the first floor of a multistory building.

A safe building is built of strong materials. Damaged concrete and rotten wood undermine the integrity of the building.

A safe building protects the plumbing. Broken water pipes will cause water damage and broken gas pipes are a great fire hazard. Pipes need some, but not too much, room to sway. Long spans of pipe need to be secured to a wall or floor. Gas connections should be the flexible type to avoid breakage during earthquakes from movement of the appliance.

Many houses in Nevada are not as safe as they could be. The box to the right presents some common structural problems and how to recognize them. To fix them, you will need to obtain more information.

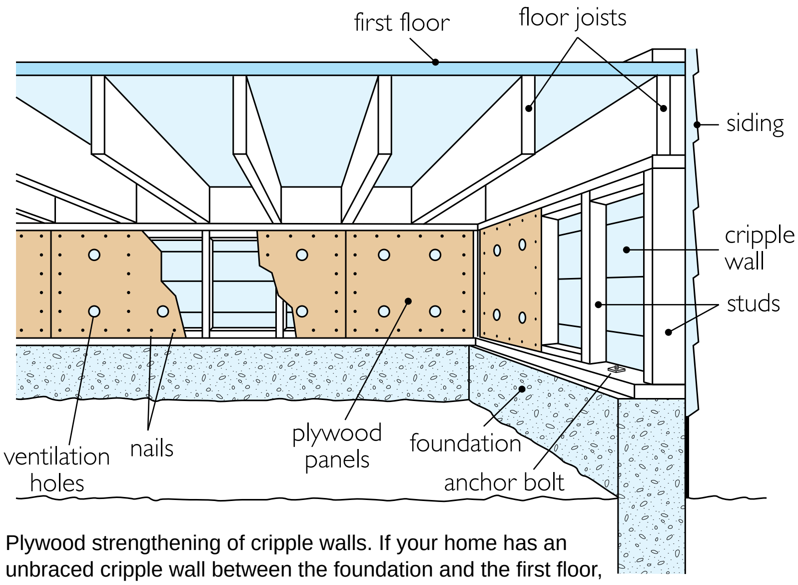
Common Structural Problems

Inadequate foundations or foundation anchorage. Go into your crawl space and look at your foundation. If the foundation is damaged or built in the "pier and post" style, consult a contractor or engineer about replacing it with a continuous perimeter foundation. Look for bolts in the mudsills. They should be no more than 6 feet apart in a single story and 4 feet apart in a multistory buildings and have large, heavy plate washers. Adding bolts or steel plates to unsecured houses is one of the most important steps toward earthquake safety. This can be done by a contractor or by someone moderately adept at home maintenance.

Unbraced cripple walls. Go into your crawl space and look for panels of plywood or diagonal wood sheathing connecting the studs of the cripple walls. You or a contractor can strengthen the cripple walls relatively inexpensively (see adjacent figure).

Soft first stories. Look for large openings in the lower floor, such as a garage door or a hillside house built on stilts. Consult a professional to determine if your building is adequately braced.

Unreinforced masonry. If your house is built of brick or rock, and it is an older home, it may be unreinforced. Solid bricks or rocks with mortar between them that lack reinforcement may not have adequate shear resistance to shaking. Chimneys are a common unreinforced masonry element of homes. Consult a professional to determine if your building is adequately reinforced.



Plywood strengthening of cripple walls. If your home has an unbraced cripple wall between the foundation and the first floor, it may collapse and shift off its foundation during an earthquake.

Further Reading:

Yanev (1991) Peace of mind in earthquake country
Smith and Furukawa (2000) Introduction to earthquake retrofitting
Ambrose and Vergun (1999) Design for earthquakes (technical)
Association of Bay Area Goverments website:
www.abag.ca.gov/bayarea/eqmaps

For professional contractors and engineers, see the yellow pages of the telephone book under *Engineering and General Contracting* and *Engineers—Structural*.

What if I rent?

As a renter, you have less control over the structural integrity of your building, but you do control which building you rent. Remember these points as you look for rental housing:

- Apartment buildings have the same structural requirements as houses.
- Structures made of unreinforced masonry and with soft first stories have caused the greatest loss of life in earthquakes.
- Foundation and cripple wall failures have led to expensive damage but less loss of life.
- Objects attached to the sides of buildings, such as staircases and balconies, have often broken off in earthquakes, injuring those below.

Ask your landlord, or potential landlord, these questions:

- Is this building built with earthquake resistance?
- What retrofitting has been done on this building?
- Have the water heaters been strapped to the wall studs?
- Can I secure furniture to the walls?
- What is their earthquake plan?

When was your house built?

Regulations for safety in building construction are codified in the Uniform Building Code (UBC), first issued in 1927 by a nonprofit, independent organization called the International Conference of Building Officials (ICBO). Now the International Building Code (IBC), it is updated every three years. It is up to local jurisdictions (cities, towns, counties) to adopt and enforce building codes in Nevada.

1927 First Uniform Building Code (UBC) issued, primarily about fire safety.

1935 UBC requires foundation bolting and reinforcement of masonry foundations.

1946 UBC requires some reinforcement of masonry chimneys.

1961 UBC requires all structural members to resist earthquake forces.

1973 UBC requires bracing of cripple walls.

1976 UBC requires 50% increase in earthquake design forces for box-type structures and stronger force loads for hospitals and concrete-moment frame buildings

1988 UBC adds a new soil profile type for considering site resonance for tall or long-period structures.

1991 UBC increases bracing requirements for cripple walls and requires bracing of water heaters.

1997 UBC requires testing of steel welds and increased design forces for concrete tilt-up wall anchorage. Heavy plate washers required for foundation anchor bolts.

2000 IBC uses new earthquake hazard maps and ground acceleration as input into seismic forces. Further changes "Zones" to seismic design categories which include soils considerations enhancing accuracy and providing better engineering data.

2003 IBC revised seismic redundancy, equivalent lateral force procedures, seismic force resisting designs, and enhanced mechanical and electrical component designs.

2006 IBC updated seismic hazard maps to include new maximum considered earthquakes.

2009 IBC increases minimum base shears, building to building distance requirements were added, new provisions for high-rise buildings in categories III (example: schools) and IV (example: hospitals).

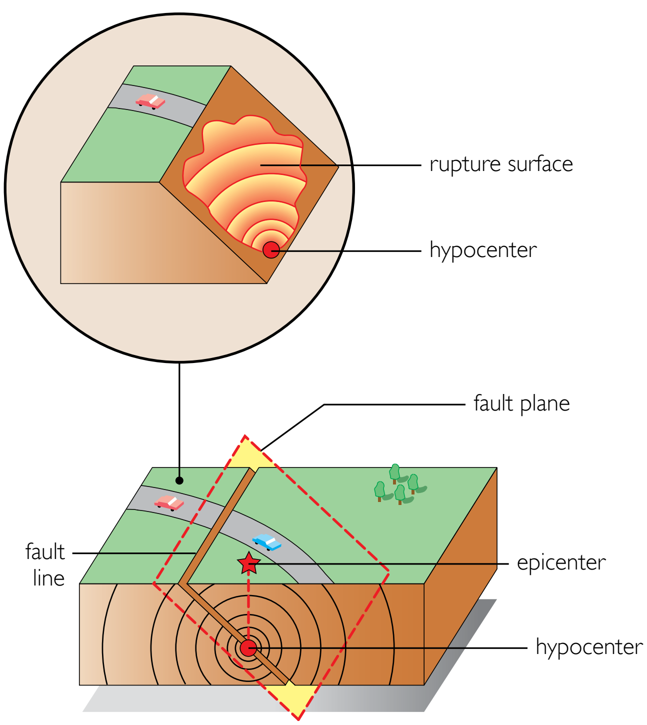
Reviewing the Basics

People use a lot of words when they talk about earthquakes. Magnitude, intensity, epicenter, fault, liquefaction. What do these terms mean? This section describes how earthquakes happen, how they are measured, and what the shaking feels like.

What is an Earthquake?

An earthquake is caused by sudden slip on a fault, much like what happens when you snap your fingers. Before the snap, you push your fingers together and sideways. Because you are pushing them together, friction keeps them from moving to the side. When you push sideways hard enough to overcome friction, your fingers move suddenly and you hear a snap.

A similar process goes on in an earthquake. Forces within the Earth and the weight of the Earth's crust push the two sides of a fault together. The friction across the surface of the fault holds the rocks together so they do not slip immediately when pushed sideways. Eventually enough stress builds up and the rocks slip suddenly, releasing energy in waves that travel through the Earth and causing the shaking that we feel from an earthquake.



Just as you snap your fingers with the area between your finger tip and thumb, earthquakes happen over the area of a fault, called the rupture surface. In a small earthquake, the ***rupture surface*** may be only a small part of the entire fault, whereas during a large earthquake, the entire fault may slip. The whole fault plane does not slip at once, however. The rupture begins at a point on the fault plane called the ***hypocenter,*** which is usually deep down on the fault (see lower left). The ***epicenter*** is the point on the surface directly above the hypocenter. The earthquake rupture keeps spreading until something stops it (exactly how this happens is one of the hot research topics in seismology).

What is a Fault?

Earthquakes occur on faults. A ***fault*** is a break in the Earth's crust having relative movement of the two sides. Faults can be any length, from inches to hundreds of miles. When an earthquake occurs on one of these faults, the rock on one side of the fault rapidly slips past the other. The fault surface can be vertical, horizontal, or at some angle to the Earth's surface.

Although many of the larger earthquakes rupture faults all the way to the Earth's surface, some faults do not intersect the surface. Some of these are termed blind faults because they cannot be easily identified at the surface. The ground above blind faults bends rather than breaks, and these faults may only be expressed at the surface as a warp or fold that erosion reduces to hills or a broad range front. Nevertheless, large earthquakes along blind faults can be quite destructive. The 1994 magnitude 6.7 Northridge earthquake in California occurred along a blind fault. Some faults can also be rapidly buried by sediment and be difficult to detect.

Movements on a Fault

The slip on a fault can be in any direction. We classify faults into two basic categories: strike-slip and dip-slip motion.

Strike-slip earthquakes commonly occur along vertical fault plane as one side of the fault slides horizontally past the other. If the far side of the fault shifts to the right, it is termed a right-lateral fault; if it shifts to the left, it is left-lateral fault. With ***dip-slip earthquakes,*** the fault is usually at an angle with the earth's surface and the movement is up or down. For faults that make an angle with the Earth's surface, names are given for the two sides of the fault. The top side of the fault is known as the hanging wall and the bottom side is the footwall. The walls are so named by their appearance in mines: miners hung their lanterns on the hanging wall and walked on the footwall.

On a ***normal-slip fault,*** the hanging wall moves down and the footwall up; on a ***reverse-slip fault,*** the reverse happens—the hanging wall moves up and the footwall moves down. A common feature along normal-slip faults is for the hanging wall to collapse and create a secondary fault that dips into the main fault. The area downdropped between these two faults is called a ***graben.*** If a fault has both strike-slip and dip-slip movement, it is known as an ***oblique-slip fault***.

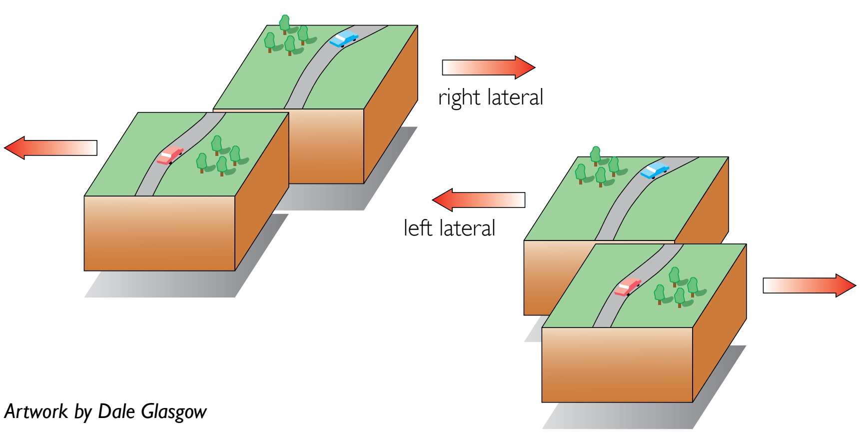
In Nevada, a majority of the faults are normal-slip faults. During an earthquake, one side of the fault drops abruptly. The side that falls down is commonly a valley and the side that remains or is uplifted slightly is a highland or mountain. This is how much of Nevada's picturesque mountain and valley landscape was formed.

Strike-slip faults are also very important in the state, especially in western Nevada where a majority of the earthquakes are strike-slip in nature. Small buried, blind, and undetected faults occur throughout Nevada—the most worrisome being those within basins where communities are located.

Further Reading:

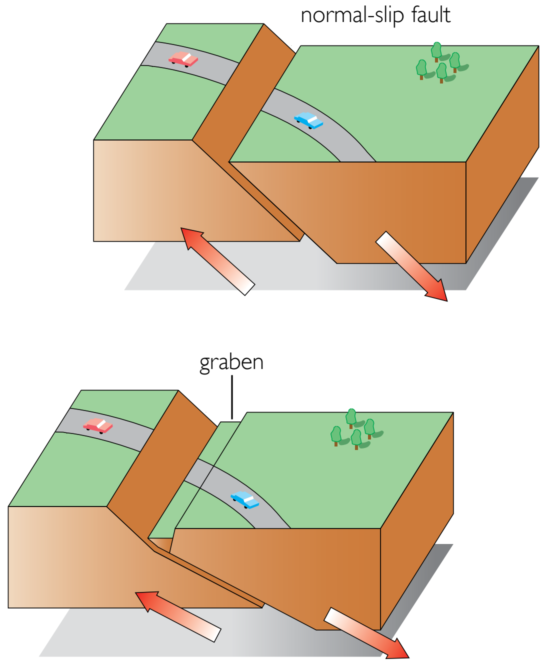
Gere and Shah (1984) Terra non firma
Association of Engineering Geologists (1998) Suggested guidelines for evaluating potential surface fault rupture
Tarbuck and Lutgens (1999) Earth
Yeats and others (1997) Geology of earthquakes (technical)

Strike-Slip Faults



Artwork by Dale Glasgow

Dip-Slip Faults



Ground Rupture From Earthquakes

Earthquakes larger than magnitude 6.5 are so big that they tend to rupture the ground surface. The length and size of this surface rupture is proportionately larger with increasing magnitude. The surface rupture is usually not a clean single break, but occurs as a larger rupture surrounded by smaller breaks within about 50 feet (~15 m) of it. The surface offset usually reflects what occurs at depth. For example, a normal-slip earthquake might leave a small escarpment in the surface over the place where the hanging wall drops. Fortunately, earthquakes rarely cause features at the surface that might be characterized as gaping holes that swallow people and cows alike. A person caught out in the open next to surface faulting is likely in for an experience-of-a-lifetime, but is unlikely to be swallowed by the fault. Buildings across surface faulting fare less well. Few buildings are strong enough to resist faulting through the structure. Those across ruptures have been ripped apart or horribly distorted. It is considered good practice to avoid building across faults that might move from earthquakes, thus avoiding this potential hazard. Setting back 50 feet (~15 m) from a fault helps avoid the smaller breaks that might occur.

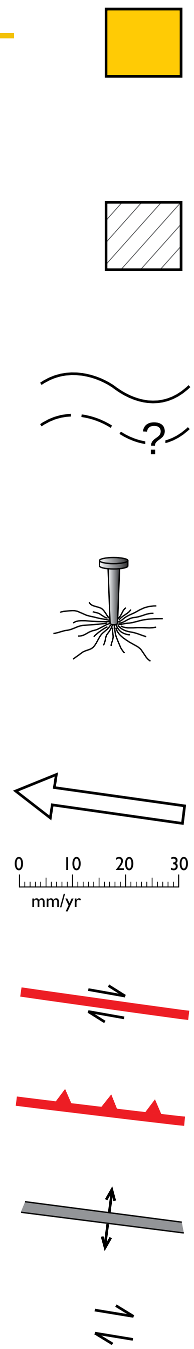
The BIG Picture

Major earthquakes are caused by the movement of huge blocks of the Earth's crust. These blocks are pulled apart and wrenched by larger tectonic forces that are caused ultimately by heat escaping from the deep interior of the Earth.

The outer portion of the Earth is made up of plates that move in different directions over the hotter interior. These plates can slide sideways, pull apart, or collide with one another. Huge systems of faults develop to accommodate the motions between the plates. When these faults move abruptly in the cooler, brittle, outermost part of the Earth's crust, called the seismogenic zone, earthquakes are produced. Most earthquakes occur along plate boundaries.

The western United States is on top of a broad boundary between the North American and Pacific Plates. The North American Plate extends east to Iceland; the Pacific Plate extends west to Japan. The Pacific Plate is moving northwest, scraping horizontally past North America at a rate of about 2 inches per year (5 cm/yr). The most famous fault within this mostly strike-slip plate boundary is the San Andreas Fault in California, which moves on average 1 1/3 inches every year (3 1/3 cm). More than a fifth of this overall plate boundary motion (greater than 1 cm) occurs east of the Sierra Nevada. Between the Sierra Nevada and Colorado Plateau is the Basin and Range Province, a large area of the North American Plate that is extending or spreading out. This extension, which began over 20 million years ago, has produced a mountain and valley topography, and many faults. Some of these faults are still active today.

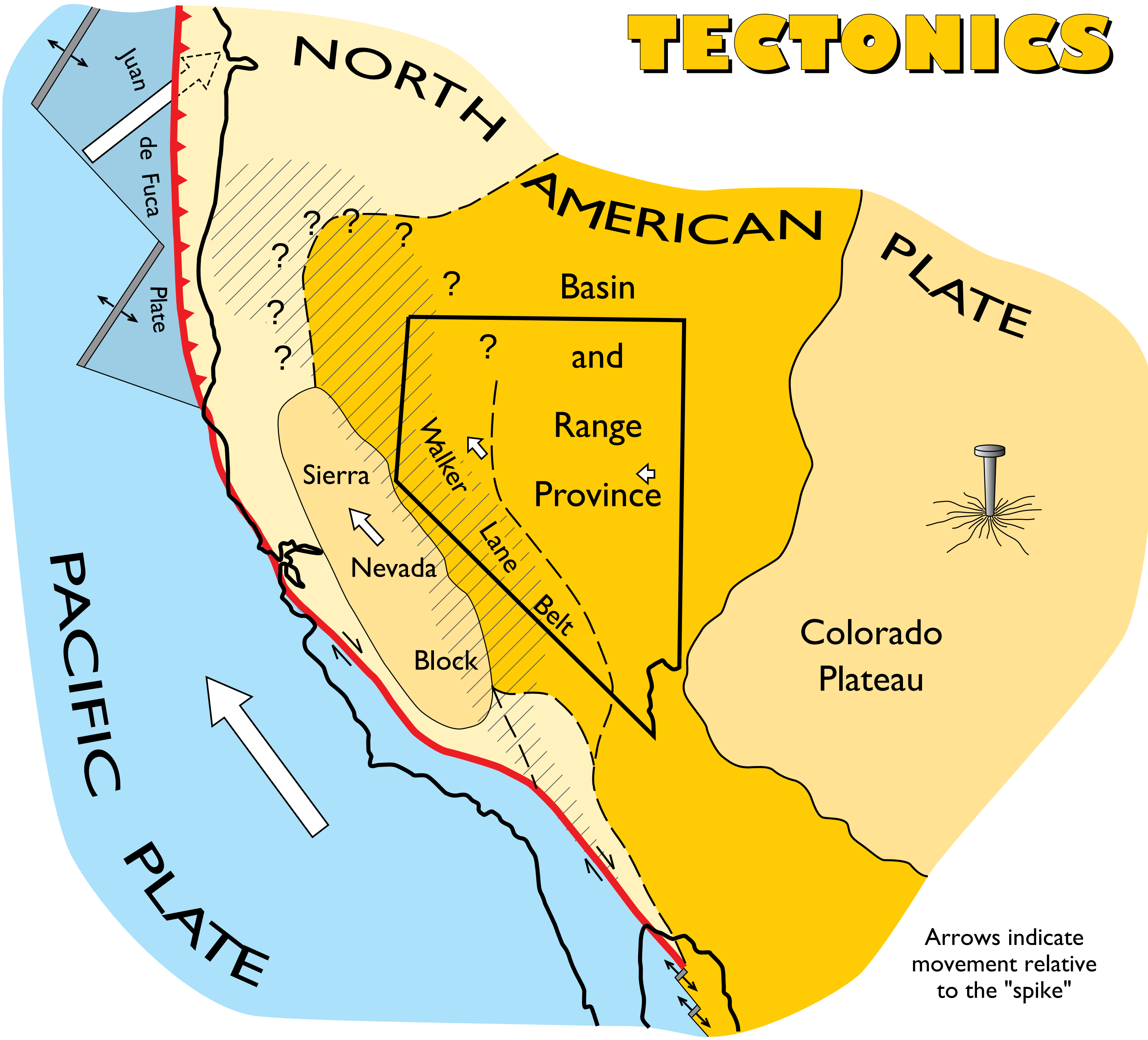
Located entirely in the Basin and Range Province, Nevada is a region of high average elevation, relatively thin continental crust, high levels of heat flowing out of the Earth, and a distinct mountain and valley topography. The crust in Nevada is both extending and shearing, largely in response to the motion between the Pacific and North American



- Basin and Range Province; area that is being extended or pulled apart
- Region of active strike-slip faulting in the western Basin and Range Province
- Boundaries of tectonic provinces; dashed where inferred, queried where uncertain
- Spike is part of the North American Plate held fixed as a reference point for relative movement
- Arrows show plate motion relative to the reference point ("spike") on the North American Plate. Length of arrow indicates the rate.
- San Andreas Fault Zone
- Cascadia Subduction Zone
- Oceanic spreading ridge
- Local relative motion across a fault

Plates. The extension is resulting in normal-slip faults that bound down-dropped blocks (basins), uplifted blocks (mountains), and tilted blocks (combination mountain and basin). Strike-slip faults also occur in this extending region but are fewer in number than the normal-slip faults. Why this region is pulling apart or extending is debated. Some suggest that hot upwelling from below causes the spreading. Others conclude that the elevation is so high that this area may be simply collapsing under its own weight. The white arrows show the relative motion with respect to the eastern part of the figure (the "spike"

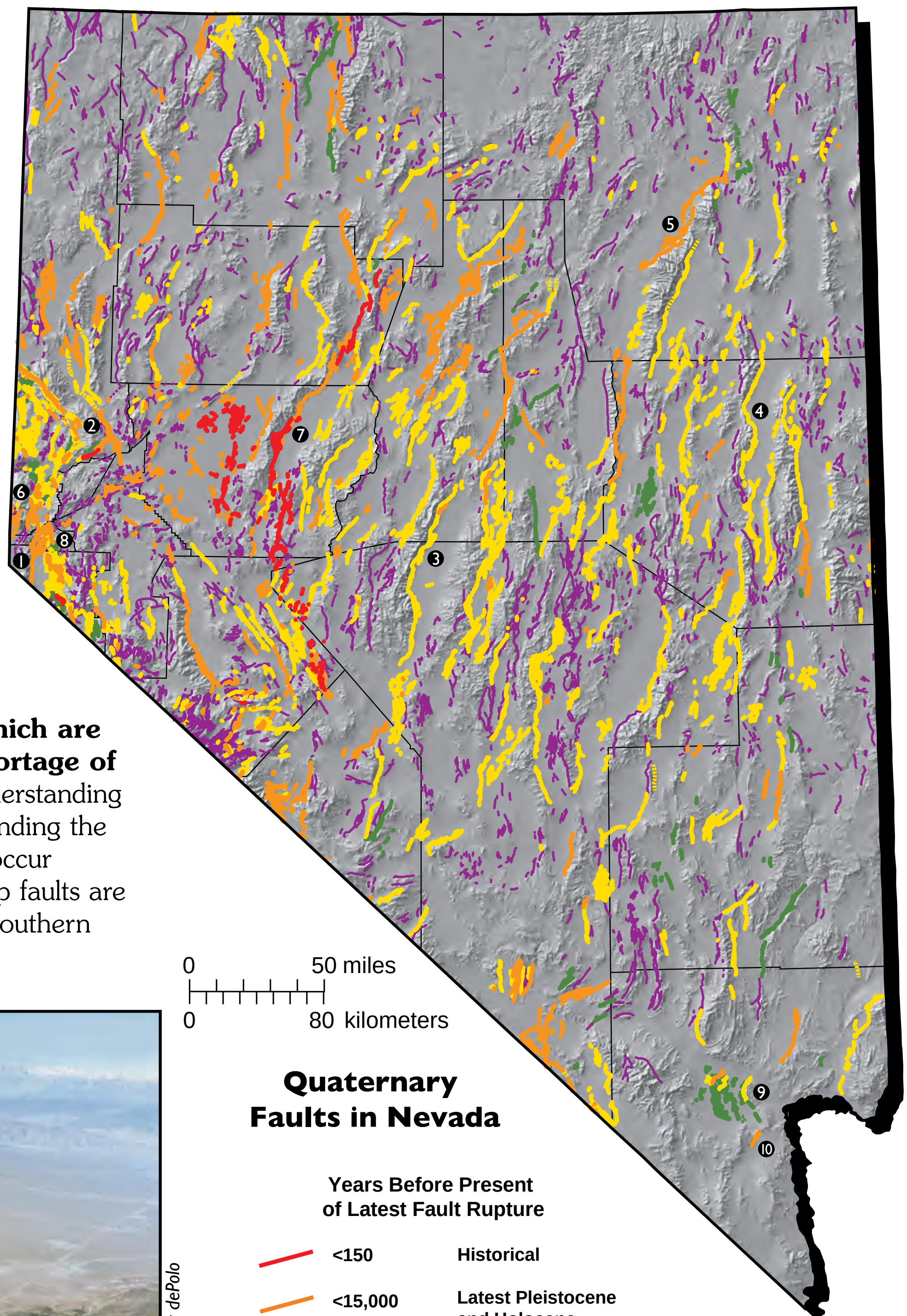
NEVADA TECTONICS



pictured in the Colorado Plateau), which corresponds to the stable part of North America. In eastern Nevada, the relative motion is about 1⁄6 of an inch (4 mm) per year westward. The Sierra Nevada block is moving about ½ inch (12 mm) per year to the northwest. The Walker Lane belt is a northwest-trending region in western Nevada and eastern California of diverse orientations of mountain ranges and faults, many strike-slip faults, and high relative levels of background earthquake activity. The Walker Lane belt is a transition zone between the strike-slip plate boundary system and extensional tectonics of the Basin and Range Province. The belt contains many strike-slip faults and has had major strike-slip earthquakes, such as the 1932 Cedar Mountain earthquake (magnitude 7.1). Western Nevada appears to have a higher earthquake hazard than the rest of the state because of the strike-slip activity in addition to the normal-slip faults.

Faults in Nevada

In Nevada, faults occur along many of the range fronts, within ranges, and within valleys. Normal-slip faults commonly appear as steps in the landscape related to the vertical offset, whereas strike-slip faults usually are expressed by linear features, such as small valleys, and alignments of features, such as springs. Historical earthquakes have ruptured both kinds of faults in Nevada. The Earth's crust in Nevada has countless faults formed through the geologic ages. The youngest faults are the most likely to cause future earthquakes, even though older faults can fail sometimes. Scientists studying earthquakes commonly limit their studies to Quaternary-age faults (those that have moved in the last 1.8 million years). **Nevada has thousands of Quaternary faults, hundreds of which are major faults. Thus, there is no shortage of potential earthquake sources.** Understanding the fault setting is essential to understanding the earthquake hazard. Normal-slip faults occur throughout the state, whereas strike-slip faults are most notable in western, central, and southern Nevada.



0 50 miles

0 80 kilometers

Quaternary Faults in Nevada

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

Modified from NBMG Map 167

Photo by Craig dePolo

View to the south of the White Mountains which are bounded by a major normal-slip and normal-oblique-slip fault zone (located at the base of the mountains).

Estimating the Size of Earthquakes

To predict the potential size of an earthquake that might occur along a fault, we estimate the length of potential earthquake rupture and how much the ground might be offset during an event. We compare these lengths and offset measurements with those from historical earthquakes to estimate the magnitude of a possible future earthquake. In general, the greater the length and/or the offset during an event, the greater the earthquake magnitude. Based on fault studies, the largest earthquakes we expect in Nevada are in the magnitude 7–8 range.

Estimating How Often Earthquakes Occur

The best way for scientists to tell how often earthquakes occur along a fault is to dig a trench across a fault, identify prior earthquakes (which might appear as offsets in soil layers), and find some material related to these earthquakes for which an age can be determined. From this, scientists compile a history of earthquakes along a fault. After determining when earthquakes occurred in the past, one can determine the average time between earthquakes along a fault, and ultimately what the chances are that an earthquake might occur. Unfortunately, getting this information takes a lot of resources and effort for each fault, and there are hundreds of faults. For faults for which we lack a detailed history of fault activity, an estimated rate of movement (slip rate) is commonly used. The faster a fault moves, the shorter a period of time it

How do we know a fault is active?

- If a large earthquake has broken the fault since we began keeping records.
- If earthquakes on the fault have left surface evidence, such as fault scarps (surface ruptures made by earthquakes).
- If earthquakes have left geologic evidence (such as young units that are broken).
- If it is a fault that produces small earthquakes that we record with the seismographic network.
- If geodetic deformation shows fault movement.
- If geophysical data indicate recent fault offsets.

Some Major Faults in Nevada

Fault	Potential Earthquake Magnitude	Length in Miles (km)	Slip Rate Millimeters Per Year*	Average Time Between Earthquakes (years)**
❶ Genoa fault	7.4	47 (75)	1 – 3	1,500 – 4,000
❷ Pyramid Lake fault zone	7.3	47 (75)	0.4 – 1.1	1,800 – 4,000
❸ Toiyabe Range fault zone	7.3	69 (110)	0.1 – 0.8	2,000 – 15,000
❹ Steptoe Valley fault zone	7.2	87 (139)	0.04 – 0.1	18,000 – 45,000
❺ Ruby Mountains fault zone	7.2	62 (99)	0.05 – 0.3	10,000 – 100,000
❻ Mt. Rose fault zone	7.1	25 (40)	0.2 – 0.4	2,000 – 10,000
❼ Dixie Valley fault zone	7.1	60 (96)	0.3 – 0.6	6,000 – 12,000
❽ Carson City fault	6.8	9 (14)	0.4 – 1	1,500 – 8,000
❾ Frenchman Mountain fault zone	6.8	16 (26)	0.02 – 0.2	5,000 – 50,000
❿ Black Hills fault	6.8	17 (27)	0.05 – 0.2	5,000 – 20,000

* Scientists usually use metric values, particularly millimeters per year, for slip rates of faults. To convert to inches per year, multiply by 0.039.

** Because we lack detailed studies, in many cases these values are approximations that cover wide ranges of potential values.

takes a fault to store up the energy for an earthquake. As might be expected from Mother Nature, earthquakes don't occur at regular time intervals, but occur at variable time intervals and can occur in groups.

The time between large earthquakes along individual faults in Nevada is typically from thousands of years to tens of thousands of years. This is a long time between earthquakes, and if there was only one of these faults in Nevada, perhaps we wouldn't worry so much. But there are hundreds of faults in Nevada that can produce earthquakes. Even though there are long periods of time between earthquakes on an individual fault, we expect large earthquakes every few decades because of this large number of faults.

Photo by Craig dePolo

The fault plane is usually covered over with rocks and dirt, or erodes away. This aerial view of a quarry shows the Genoa fault plane with vertical grooves caused by normal-slip movement. Exposed fault plane is about 100 feet high.

Unknown Faults

Nevada has been through hundreds of millions of years of geological processes that have pulled it apart and pushed it together, creating a severely faulted crust. There are many faults throughout the state that are unknown because of a lack of geological study or because the surface effects are minor, buried, or absent. Geophysical techniques might detect some of the larger faults, but minor faults escape detection unless tunneled into.

Further Reading:

McCalpin (1996) Paleoseismology (technical)
Keller and Pinter (1996) Active tectonics, earthquakes, uplift, and landscape (technical)
Reiter (1990) Earthquake hazard analysis (technical)
Kramer (1996) Geotechnical earthquake engineering (technical)

Shaking causes other kinds of hazards to occur in certain settings.

- **Landslides** — Block of soil and rock loosened by shaking may slide a short distance or, on steep slopes, may slide onto shallower slopes below.
- **Rockfall/boulders falling** — Rocks and boulders dislodged from steep, barren slopes with rocks exposed. Rocks and boulders may slide, roll, or bounce down the slope for considerable distances.
- **Ground liquefaction** — Temporary transformation of water-saturated sandy deposits from a solid state to a liquid state due to shaking.

How do we study faults?

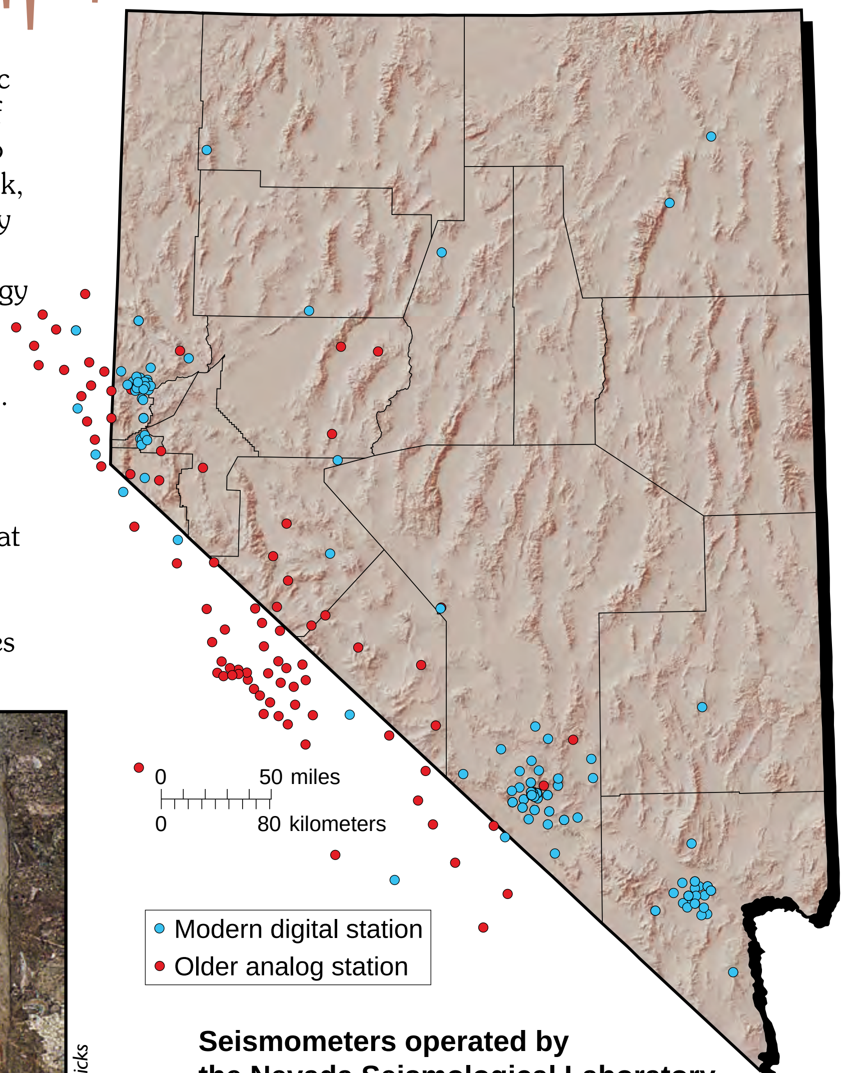
Scientists study faults by examining aerial photographs, making detailed geologic maps, and looking at different layers of geologic units in trenches across a fault. They are interested in exactly where the fault is located, how large the fault is, the history of earthquakes along the fault, and how much the fault moved during recent earthquakes. This information can be quite difficult to obtain without detailed studies.

Surface features that have been broken and offset by the movement of faults are used to determine how fast the faults move and thus how often earthquakes are likely to occur. For example, we might determine that sedimentary deposits have been offset 300 feet (91m) across a fault, and that these deposits are 75,000 years old. Thus, this fault would be moving at an average speed of 1.2 mm (0.048 inches) per year. We might further determine by measurements at the surface or made in trenches dug across the fault that the last earthquake offset the ground 3 feet (0.9 m). If we assume that all the earthquakes along this fault offset the ground 3 feet as well, then we will have earthquakes on average every 750 years (36 inches divided by 0.048 inches per year equals 750 years). This does not mean earthquakes will occur along this fault exactly 750 years apart. The well-studied San Andreas Fault in California has an average of 130 years between events, but actual times between earthquakes have ranged from 45 years to 300 years.

Measuring an Earthquake

Where was it?

How big was it?



Seismometers operated by the Nevada Seismological Laboratory

Earthquakes are recorded by a network of seismic stations. Each station measures the movement of the ground. Many things can cause the ground to move: an earthquake, the wind, or a passing truck, for examples. Therefore seismometers are usually placed in quiet locations. The slip of a block of rock past another in an earthquake releases energy that makes the rock near the fault vibrate. That vibration pushes the adjoining rocks, and thus energy travels out from the earthquake in a wave. As the wave passes by a seismic station, the ground vibrates and a signal is recorded. Earthquakes produce two types of waves — the P-wave (primary wave), a compressional wave that travels fast but is not as large; and the S-wave (secondary wave), a shear wave that is slower but larger and does most of the damage. These waves are usually clear on seismograms, but people can tell them apart too. If you have an estimate of the number of seconds between the P-wave and the S-wave, multiply by 5 miles (8 km) per second to get the distance to the earthquake. **Knowing how fast the waves travel, seismologists calculate a time and location of the earthquake that gives the pattern of shaking that was recorded.** They measure the time of the wave that arrives first. That is the wave traveling from the hypocenter, the first part of the fault to slip. Arrival times and locations can be determined by a computer within minutes. Determining the location of the rest of the fault plane, beyond the hypocenter, requires more complicated procedures and can take several hours to days.

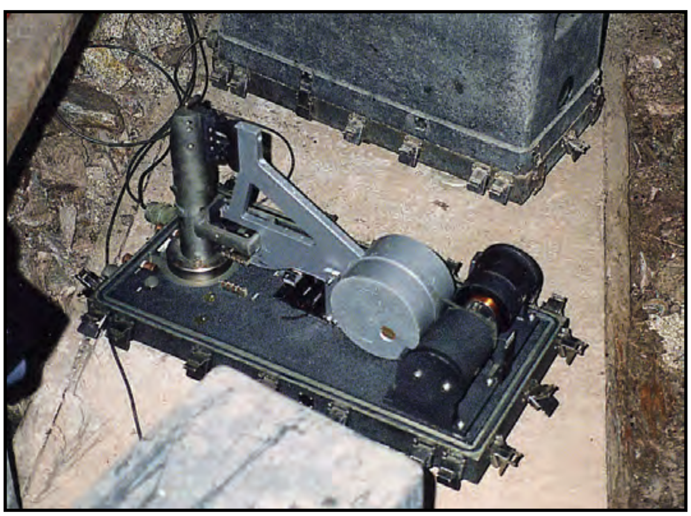
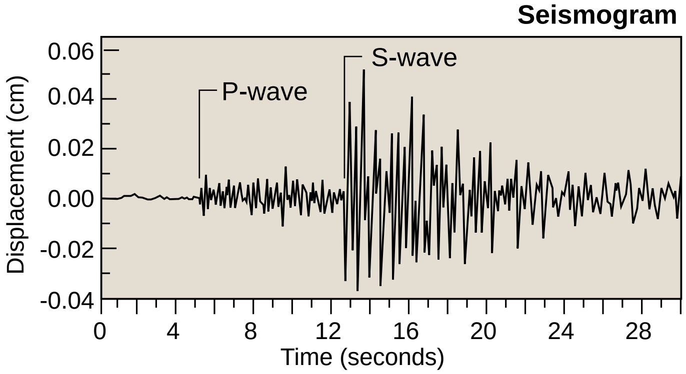


Photo by Wally Nicks

Horizontal Motion Seismograph

Seismogram



Measuring the Size of Earthquakes

How big was the earthquake? That should be easy. Why do scientists have problems coming up with a simple answer to a simple question? Many Nevadans have felt this frustration after earthquakes, as seismologists often seem to contradict one another. In fact, earthquakes are very complex. Measuring their size is something like trying to determine the "size" of an abstract modern sculpture with only the use of a tape measure. Which dimension do you measure? **Magnitude is the most common measure of an earthquake's size.** In the 1930s, Beno Gutenberg and Charles Richter borrowed the idea of a magnitude scale from astronomers and defined it in terms of how big the signal was on a particular seismograph, at a particular distance from the earthquake. The size of the signal is related to how much the ground moved. Each time the magnitude scale increases by one unit, for example from 4 to 5 or from 5 to 6, it means the ground moved 10 times more.

Gutenberg and Richter also showed that magnitude is related to the energy released in the earthquake. A magnitude 6 earthquake has about 32 times more energy than a magnitude 5 and almost 1000 times more energy than a magnitude 4 earthquake. This does not mean that there will be 1000 times stronger shaking at your home. A bigger earthquake will last longer and release its energy over a much larger area.

Seismologists measure different earthquake "dimensions" with different magnitude scales. Each scale measures how much the ground moves at a different distance and in a different frequency band of vibration. Each scale has its uses, but all are limited because they measure only a part of the ground motion.

In recent years, seismologists have developed a new scale, called moment magnitude. Moment is a physical quantity related to the area of the fault that moved during an earthquake and the average amount that it slipped. It can be estimated by geologists examining the geometry of a fault in the field or by seismologists analyzing a seismogram. The moment is a cumbersome number to work with. It has been converted to a magnitude scale (moment magnitude) for better communication to the public.

Moment magnitude has many advantages over other magnitude scales. First, we can measure all earthquakes, large and small, near and distant, with the same scale. Second, because it can be determined either from instruments or from geology,

"Where was the earthquake?"

This is a question that seems reasonable, but any answer can be misleading.

We define the epicenter of an earthquake with the latitude and longitude of a point, but the earthquake is bigger than that point. The fault's rupture surface can be hundreds of miles long and several miles wide, and even the epicenter can only be determined within a few tenths of a mile, at best. Giving the location of an earthquake in terms of its epicenter is like giving the location of Las Vegas by the address of City Hall.

We name earthquakes after map locations near epicenters to have a convenient way to refer to them. We could, for example, say "the earthquake of 12:23, September 12, 1994," but it's easier to say the "Double Spring Flat Earthquake."

Describing Magnitude

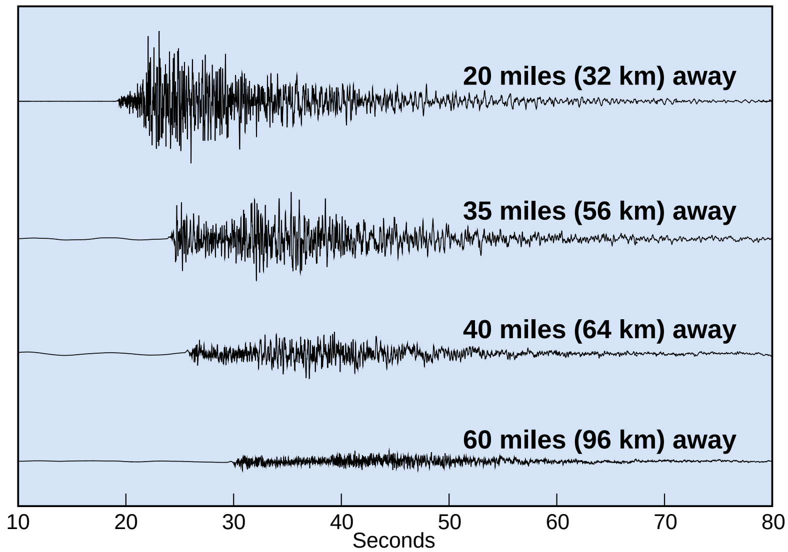
When scientists refer to a "great" earthquake, they do not mean the earthquake was fabulous, they mean it was huge. Informally, earthquakes are classified according to their size.

Magnitude	Type of Earthquake	Characteristics
< 3	micro-earthquake	generally not felt, but recorded
3–4	small earthquake	sometimes felt, but rarely causes damage
4–5	moderate earthquake	often felt, but rarely causes damage
5–6	strong earthquake	at most, slight damage to well designed buildings, possible damage to poorly constructed buildings over small areas
6–7	major earthquake	can be destructive in areas up to 60 miles (100 km) across
7–8	large earthquake	can cause serious damage over large areas
> 8	great earthquake	can cause serious damage several hundred miles across

we can use it to measure old earthquakes and compare them to the instrumentally recorded events. Third, because it is more reliable, we can compare the size and energy of different earthquakes with more confidence, and better estimate what might happen in the future.

Measuring Earthquake Waves

Earthquake waves vary greatly in size, from very tiny to several feet, and it has been difficult to design a single instrument that could measure this wide range. Such instruments are available now, but they weren't in the past. A common way to measure the weaker ground motions that are generated by small, everyday earthquakes is with an instrument that measures the displacement or velocity of the ground. For larger earthquakes with strong ground motion, it is easier to measure the ground acceleration. These different types of recordings can be related to each other, as shown in the box in the lower right. Engineers subject computer models of buildings to these different representations of earthquake waves to see how the building would perform. If there is a problem, they can adjust their design and feel confident the building can withstand certain levels of earthquake motion.



Four seismograms showing waves getting smaller with distance from the earthquake epicenter

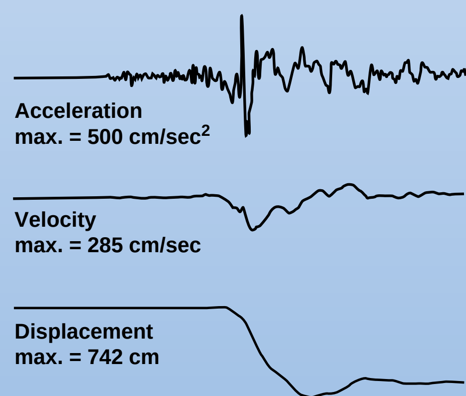
Further Reading:
Bolt (1999) Earthquakes
Brumbaugh (1999) Earthquakes, Science, and Society
Shearer (1999) Introduction to Seismology (technical)

Photo by Alan Ramelli

Dust from the ground shaking and rock falls created near the epicenter of the 1986 Chalfant Valley, California earthquake.

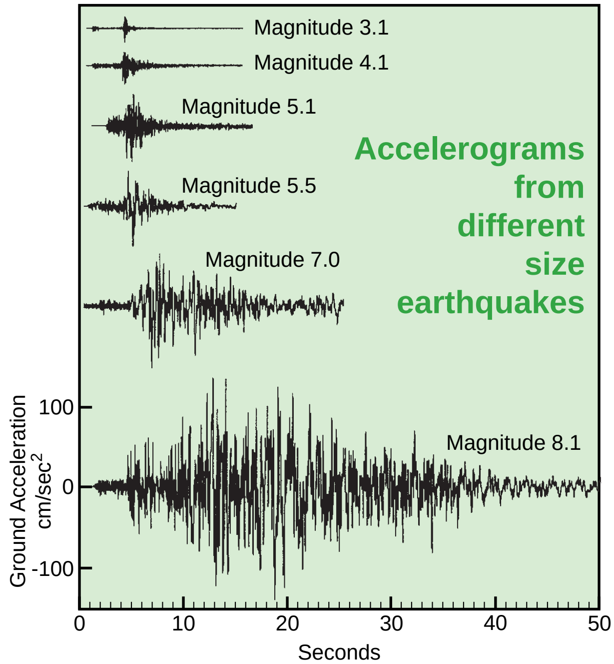
Types of Measurement of Ground Movement

Below are three representations of ground motion during the 1999 Taiwan earthquake (M7.6) from a seismograph near the fault. The acceleration is the measured record. Analysis of this record gives the velocity and displacement of the ground. Permanent displacement of the ground as shown on the record below happens only close to the fault.



Larger earthquakes produce more intense and longer-lasting shaking.

Some of the main differences in shaking between earthquakes of different magnitudes can be seen in the six seismograms to the right from earthquakes ranging from magnitude 3.1 to 8.1. These earthquakes were recorded in Mexico on solid rock about 15 miles (25 km) away from each event. The strong shaking from bigger earthquakes commonly overwhelms seismometers at such close distances, but these seismograms are from "strong-ground motion instruments." They measure motion in acceleration, which can be more easily kept on scale. The most obvious differences are that with increasing magnitude, the shaking is stronger (you're moved further from side to side) and lasts much longer. The magnitude 3.1 earthquake has a short, sharp jolt lasting only about a second, whereas the seismogram from the magnitude 8.1 earthquake indicates strong side-to-side shaking for over 45 seconds.



Earthquake moment (p. 28) increases with longer fault lengths, thus larger magnitude earthquakes tend to occur along longer faults, as shown in the table below. The longer a fault is, the longer it takes an earthquake to rupture it, so the longer the duration of shaking is (also indicated on the table). Also, as shown above, longer faults can produce larger amplitude and longer-period seismic waves.

A longer fault can produce a larger earthquake that lasts longer.

Magnitude	Date	Location	Length miles	(km)	Duration seconds
7.8	January 9, 1857	Fort Tejon, CA	224	(360)	130
7.7	April 18, 1906	San Francisco, CA	249	(400)	110
7.5	July 21, 1952	Kern County, CA	47	(75)	27
7.3	June 28, 1992	Landers, CA	43	(70)	24
7.3	October 15, 1915	Pleasant Valley, NV	38	(61)	19
7.2	December 16, 1954	Fairview Peak, NV	40	(64)	12
7.1	December 21, 1932	Cedar Mtn., NV	40	(65)	21
7.1	December 16, 1954	Dixie Valley, NV	29	(46)	11
7.0	October 17, 1989	Loma Prieta, CA	25	(40)	7
6.7	February 9, 1971	San Fernando, CA	10	(16)	8
6.7	January 17, 1994	Northridge, CA	9	(14)	7
6.6	July 6, 1954	Rainbow Mtn., NV	11	(18)	11
6.4	October 15, 1979	Imperial Valley, CA	19	(30)	13
6.0	August 16, 1966	Caliente, NV	9	(11)	6
5.9	September 12, 1994	Double Spring Flat, NV	10	(16)	5

Foreshocks, Mainshocks, and Aftershocks

Part of living with earthquakes is living with aftershocks. **Earthquakes usually come in clusters called an earthquake sequence and although foreshocks may or may not occur, aftershocks are a certainty.** In any earthquake sequence, the largest event is called a mainshock; anything before that is called a foreshock and anything after is an aftershock. Foreshocks and aftershocks can be large enough to be damaging—particularly aftershocks that can additionally damage structures that are weakened by the mainshock. Following a large earthquake we must be seriously mindful of aftershocks to avoid preventable injuries and damage.

Foreshocks

A mainshock becomes a foreshock if a later event is larger. This happens about 6 percent of the time in Nevada. The chance of it happening dies off quickly with time just like aftershocks. The most likely time for a mainshock is within the first hour (a quarter of all mainshocks happen within an hour of their foreshock) and after three days this hazard is reduced back to normal levels.

Scientists have tried to find ways to tell if an earthquake is a foreshock *before* the mainshock would appear . . . in other words, to use them to predict earthquakes. A valid earthquake prediction must specify the location, magnitude, and the beginning and end of the time window for an earthquake. Depending on the length of the time window, predictions can be "long " or "short term." Long-term predictions (for example, in the next 30 years) can be based on studies of the behavior of individual faults and the interactions of nearby faults. Even that is very complicated and results have significant uncertainty.

Earthquakes, which could be short-term precursors, are so far indistinguishable from earthquake sequences with smaller magnitude mainshocks. Sometimes, however, advisories are issued to remind people that there is the chance that an ongoing earthquake sequence might turn out to be a foreshock sequence. Such reminders are justified because **there are foreshocks before many large earthquakes in Nevada, although only a small fraction of earthquakes turn out to be foreshocks.**

Aftershocks

Aftershocks usually occur near their mainshock. The stress on and around the mainshock's fault changes during the mainshock and produces most of the aftershocks. Sometimes the change in stress is great enough to trigger aftershocks on nearby faults as well.

An earthquake large enough to cause damage will produce several felt aftershocks within the first hour. The rate of aftershocks dies off quickly—the decrease is proportional to the inverse of time since the mainshock. This simply means that the second day after the mainshock has about one-half and the tenth day about one-tenth the number of aftershocks of the first day. **Aftershocks can continue for weeks to decades.**

Larger earthquakes have more and larger aftershocks. The difference in magnitude between the mainshock and the largest aftershock can be 0.1 to 3 or more, but averages about 1.2. There are many more small aftershocks than large ones. Aftershocks of all magnitudes die off at the same rate—magnitude 5 aftershocks are one-tenth as common by day 10 as day one, as are magnitude 2 aftershocks. Large aftershocks can occur months or even years after the mainshock.

What will the SHAKING Feel Like?

What influences how strong the shaking is?

Magnitude is a measurement of the energy produced by the earthquake but is not enough to predict what you feel during an event. **What you feel is very complex—hard or gentle, long or short, jerky or rolling—and not describable with one number.** Aspects of the ground motion are described by the peak velocity (how fast the ground is moving), peak acceleration (how quickly the speed of the ground is changing), frequency content (energy is released in waves and these waves vibrate at different frequencies just like sound waves), and duration (how long the strong shaking lasts).

Three factors are the most important to determine what you feel in an earthquake. These are

- magnitude,
- distance from the fault, and
- local soil conditions.

Magnitude

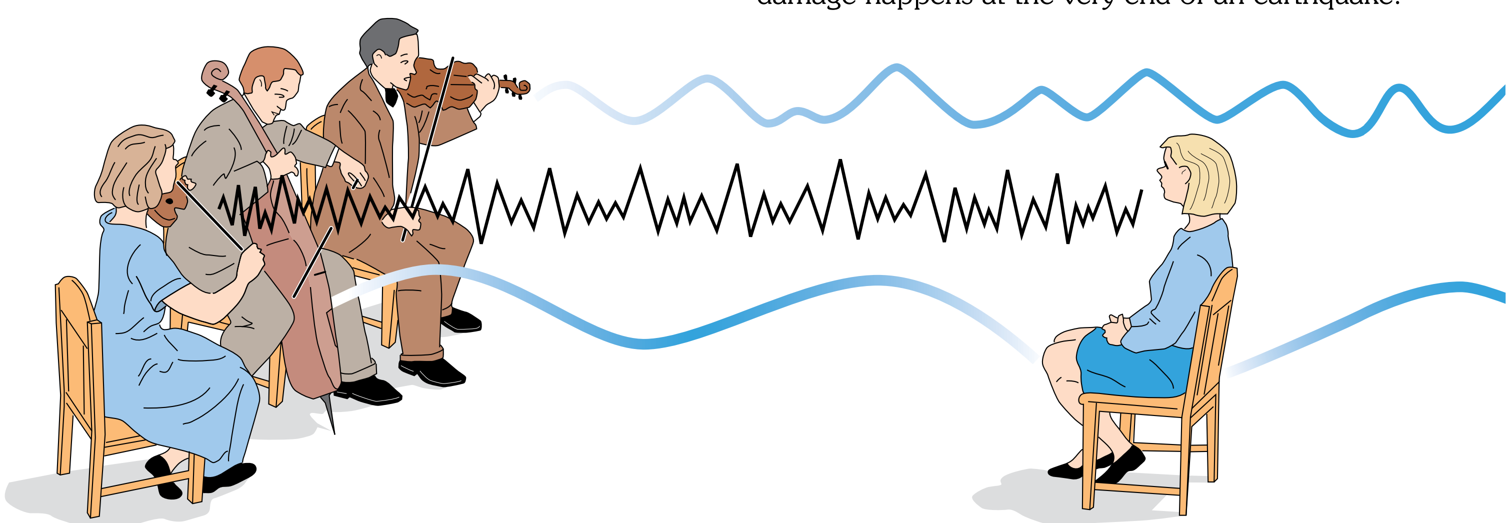
At a given distance from a fault, you will generally feel more intense shaking from a big earthquake than from a small one. Big events also release their energy over a larger area and for a longer period of time.

An earthquake begins at a hypocenter, and from there the rupture front travels along the fault, producing waves all the time it is moving. That rupture front cannot travel faster than the speed of sound in rock—about four miles (~6 km) per second because this is the first possible earthquake trigger. Every point crossed by the rupture front gives off shaking, so longer faults can produce bigger earthquakes that have longer durations. You can therefore use the duration to guess the magnitude of an earthquake you feel.

The actual durations (how long the Earth gave off energy) for 15 Nevada and California earthquakes are shown on page 30. For a magnitude 5 event, the actual process of rupturing the fault is over in a few seconds, although you might continue to feel shaking longer because some waves reach you after they bounce and echo within the earth.

The magnitude 7.8 earthquake on the San Andreas Fault in California (labeled Fort Tejon) in 1857 ruptured almost 230 miles (370 km) of the fault. At 2 miles (~3 km) per second, it took two minutes for that length of fault to rupture, so you would have felt the shaking for several minutes. If you are close to the fault, only 10 to 20 seconds of shaking originates from the part of the fault nearest you and will be very strong. Many of the rest of the waves you feel will be traveling from as far as 200 miles (~320 km) away.

Each cycle of shaking stresses buildings and can add to the damage. Because this is cumulative, the most damage happens at the very end of an earthquake.



Distance

Earthquake waves die off as they travel through the Earth, so earthquake shaking becomes less intense farther from the fault.

Low-frequency waves die off less rapidly with distance than do high-frequency waves (just as you can hear low-pitched noises from farther away than you can hear high-pitched noises). If you are near the earthquake, you will experience all the frequencies produced by the earthquake and feel "jolted." Farther away, the high frequencies will have died away and you will feel a rolling motion.

The amount of damage to a building does not depend solely on how hard it is shaken. Different structures respond differently to the various frequencies. In general, smaller buildings, such as houses, respond more to higher frequencies, so closeness to the fault is a very important factor. Larger structures, such as bridges and high-rise buildings, are more responsive to lower frequencies and will be more noticeably affected by the largest earthquakes. The shaking dies off with distance more quickly in Nevada than in the older, more rigid crust of the eastern United States (we are lucky in that respect), but Nevada is about the same as most regions that have large numbers of earthquakes.

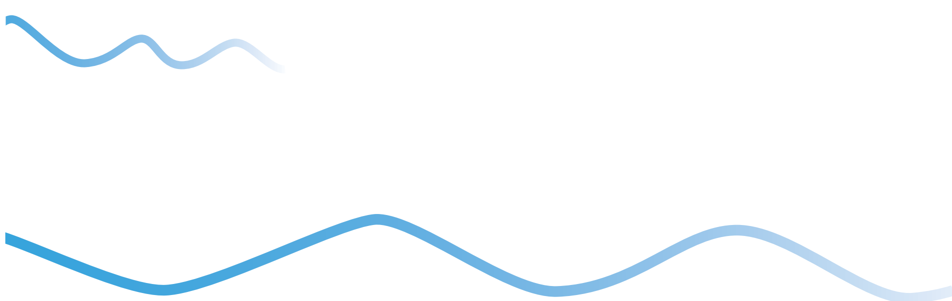
Soil Conditions

Certain soils greatly amplify the shaking in an earthquake. Just as sound carries differently in water than in air, seismic waves travel at different speeds in different types of rock and soil. Passing from rock to soil, the waves slow down but get bigger. **A soft, loose soil will shake more intensely than hard rock at the same distance from the same earthquake.** The looser the soil is, the greater the amplification will be. An extreme example of this type of amplification was in Oakland and San Francisco during the 1989 Loma Prieta earthquake. That earthquake was 60 miles (~100 km) from San Francisco, and most of the Bay Area escaped serious damage. However, some sites in the Bay Area on soft soils experienced severe shaking, exemplified by the collapse of the elevated Nimitz freeway in Oakland and many homes and apartments in the Marina District in San Francisco. Ground motion at those sites was more than 10 times stronger than at neighboring sites on rock.

Other Factors Affecting Shaking

Several other factors can affect the shaking. Earthquake waves do not travel evenly in all directions from the rupture surface; the orientation of the fault and the direction of slip will change characteristics of the waves in different directions. This is called a radiation pattern. When the earthquake rupture moves along the fault, it focuses energy in the direction it is moving so that a site in that direction will receive more shaking than a site at the same distance from the fault but in the opposite direction. This is called rupture, or ground motion, directivity.

The valleys or basins that many of our communities are in also can modify earthquake waves in many ways, including collecting and amplifying waves from distant large earthquakes, sometimes to damaging levels. These are called basin effects.



Artwork by Min Jae Hong

The Quake Lab

Take a plastic bowl of Jell-O and a block of wood. Hit each one gently with a rubber hammer. The block of wood sits there but the bowl of Jell-O slops back and forth. The softer material amplified the shaking.

Recovering from a Damaging Earthquake

Devastating earthquakes affect businesses, communities, and people's lives. Recovery depends on many factors but is most successful if prompt action is taken. The most important components to a speedy recovery from an earthquake are a positive, proactive attitude towards cleaning up, restoring your house or business, and/or rebuilding, and having earthquake insurance to limit financial losses. Securing and mitigating potential hazards before an event will result in fewer losses when an earthquake strikes, reducing the amount of recovery effort needed. Other elements to recovery from an earthquake are described below:

► Financial Assistance

There is commonly some financial assistance made available following a damaging earthquake, but this assistance is usually limited in nature and does not cover all the losses or rebuilding. Earthquake recovery aid can come in the form of public and private donations of goods, services, and money; small recovery-fund grants; and disaster assistance loans. In some cases, there are prescribed protocols that must be followed in order to apply for financial assistance; some professional guidance and lots of patience helps in this process. The amount of funding available depends on the size of the disaster and whether disaster declarations are made at state and federal levels. Earthquake insurance can help cover major investment losses, such as a house or business.

► Emotional Response

The initial shock and pain of a disastrous earthquake may be numbing, and the immediate needs of caring for your family, finding a place to stay, initial clean up and repairs, and filing financial application forms may occupy most of your time. As the immediate shock wears off, and you start to rebuild and put your life back together, you may experience strong emotional reactions such as anger, hopelessness, exhaustion, headaches, loss of appetite or nausea, sleeplessness, inability to concentrate, or nightmares. It is common for disaster victims to experience one or more of these or other stress-related emotions. The first step in emotional recovery is to acknowledge these feelings, discuss them with others, and seek the help of trained counselors if necessary. Try to maintain a positive outlook and cooperate with neighbors to rebuild homes and communities.

► Earthquake Disaster Recovery Plans

Communities and businesses should prepare earthquake disaster recovery plans before an earthquake occurs. Recovery plans lay out the first steps to be taken to restore infrastructure, clean up debris, and resume commerce and other community activities. Businesses must obtain a safety inspection clearance, resume sales, communicate that they are open for business, assess and replenish inventory, and possibly reassess short-term business models to adapt to the new situation. Recovery plans help create rapid, effective community and business recovery.

The Road to Earthquake Safety

We would all be better prepared for earthquakes if we knew when the next one was coming. However, unlike the storm front that must travel to you before rain can begin, there are usually no warning signs for earthquakes. We currently have no scientifically verifiable way to predict earthquakes. Taking the time to secure your home and office, and being prepared are key to surviving and being able to mentally cope with such an "instantaneous" event.

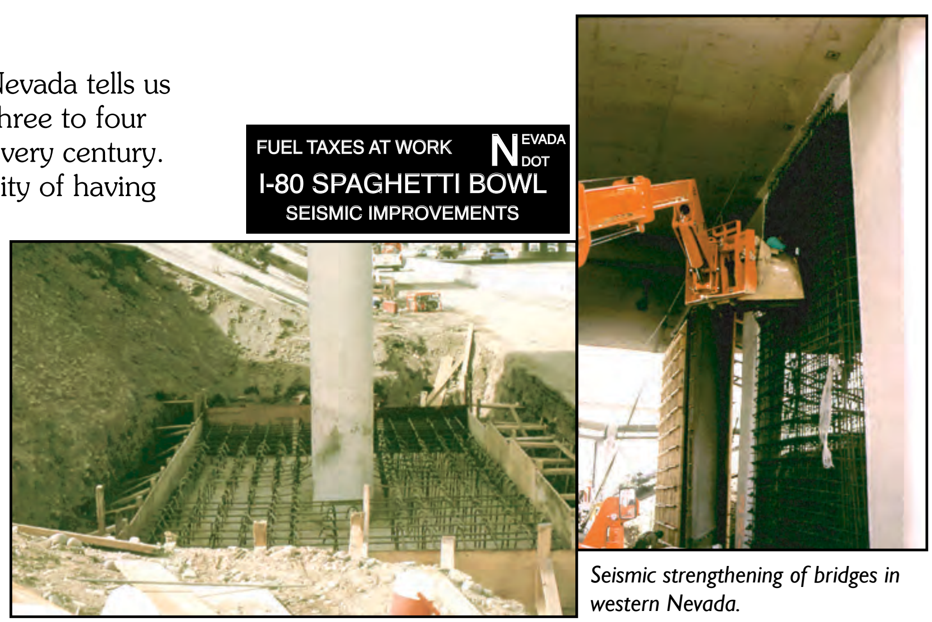
Even though we cannot predict the time of the next earthquake, science can help us live safely with earthquakes. The road to earthquake safety follows many steps. First, we must estimate what size earthquakes are likely to occur (geology). Given those earthquakes, we then estimate what the shaking will be (seismology). Given that shaking, we estimate the response of different kinds of buildings (earthquake engineering). Only with all these steps completed can we take the steps as a society to enact building codes and retrofitting programs to make our community safer.

Before we had radar to see an approaching storm front, we could look at the historical record and see that rain was likely at certain times of the year. We also recognized that the larger storms caused flash floods, particularly in the bottom of canyons. In the same way, we can analyze our average rate of earthquakes, what the effect of those earthquakes will be, and where the safest places to build are.

For instance, the earthquake record in Nevada tells us to expect an average of approximately three to four earthquakes of magnitude 7 or greater every century. From that, we can calculate the probability of having another major quake in any given period of time. Knowing that such an earthquake is likely, we use our knowledge of the fault locations and the soil conditions to estimate the likely patterns of shaking. We describe this shaking by its frequency content, intensity, and duration. Understanding what kind of shaking can be expected, we can use our knowledge of the behavior of buildings and their contents to estimate the probable damage. News reports after earthquakes often dwell on what surprised the scientists because what is new is news. However, the damage from most earthquakes is not a great surprise.

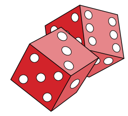
Much of the damage in earthquakes is predictable and preventable. We must all come together in our communities to apply our knowledge to building codes, hazard hunts, and neighborhood and family emergency plans. Many of the safety measures taken for earthquakes will help prevent other accidents or damage from other natural hazards as well. After your house and its contents are secured, being earthquake ready consists of knowing what to do during an earthquake and maintaining earthquake plans and earthquake kits. You will be well on the road to earthquake safety.

What must be done immediately is personal preparedness. Know your potential safety spots at home, work, and school; talk to your kids about earthquake safety; make an earthquake plan (use the following pages); remove or secure nonstructural hazards that immediately threaten you, your loved ones, your friends, or your customers. **Action on all our parts can put the odds of surviving an earthquake with minimal losses in our favor.**



Photos by Craig dePolo

Seismic strengthening of bridges in western Nevada.

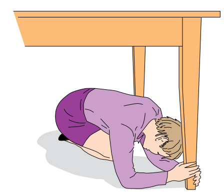


Five Steps for Putting the Odds in Your Favor When Earthquakes Occur

▶ **Step 1: Know how to react safely when an earthquake occurs** **(pp. 8–10)**

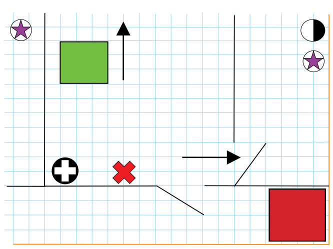
DUCK UNDER, COVER YOUR HEAD, and HOLD ON

Do not run in or out of buildings in panic! If outside, stay outside. If inside, immediately take cover under sturdy furniture to protect yourself from falling objects. After a strong earthquake, do not panic; carefully check for injuries, damage, or fire; proceed cautiously; check on your neighbors; listen to the radio for advice; use telephones only for emergencies.



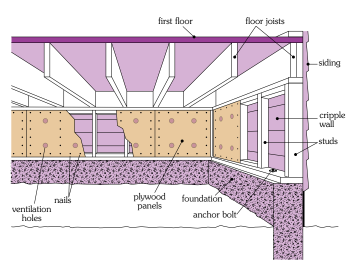
▶ **Step 2: Identify potential earthquake hazards within your home and workplace, and begin to fix them** **(pp. 11–17).** After first addressing life-safety hazards, protect what possessions are valuable to you. Recognize specific safety hazards, such as chimneys and heavy objects on shelves and walls. Plan and discuss how to avoid these hazards and how to secure or eliminate them.

▶ **Step 3: Prepare a disaster kit** **(p. 10).** This includes water, food, safety supplies, medications, pet food, and other supplies to sustain you and your family for at least 5 days.



▶ **Step 4: Create a disaster-preparedness plan** **(pp. 8, 10, 37, and 38).** This plan will help you navigate the uncertain and unfamiliar aftermath of an earthquake and can solve some common problems following earthquakes, such as reuniting the family. Have a family discussion to review the plan.

▶ **Step 5: Identify your building's earthquake weaknesses and begin to fix them** **(pp. 18 and 19).** Many earthquake fixes can be done during building repairs and upgrades. Protect your investment.



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

6 Make your home earthquake safe.

Inside your home:

- ❑ Water heater
- ❑ Bookcases
- ❑ Cabinet latches
- ❑ TV sets
- ❑ Armoire
- ❑ Lamps
- ❑ File cabinets
- ❑ Vases and trophies
- ❑ Microwave
- ❑ Computers
- ❑ Mirrors
- ❑ Artwork
- ❑ Appliances
- ❑ Glassware
- ❑ Shelf items

The structure of your home:

- ❑ House foundation
- ❑ Chimney
- ❑ Cripple wall
- ❑ Masonry

7 Know where to find vital documents and account numbers.

	Account/Policy Number	*Where is Copy?*	*Original?*
Insurance policies:			
Home			
Auto			
Health			
Life			
Disability			
Driver's License/ID			
Green Card			
Credit Cards:			
Bank Accounts:			
Passport			

	Location of Papers
Household inventory	
Tax returns	
Contracts	
Property deeds	
Medical consent forms	
Immunization records	

	Location of Papers
Birth and death certificates	
Marriage certificate	
Critical phone numbers	
Stocks and bonds	
Safe deposit box key	
Treasured pictures	

8 Jobs after an earthquake. Assign responsibility for the following jobs.

Safety Action	*Person Responsible*
Search for injured/trapped	
Check for gas leaks	
Check plumbing	
Care for children/dependents	
Inspect for damage	
Prepare for evacuation	

Safety Action	*Person Responsible*
Check on neighbors	
Ensure sipping/snacking	
Prepare first meal	
Supervise clean-up	
Ensure medications taken	
Corral pets	

Consent to treat a minor

This form should include the following information about the child: name, birthdate, allergies or special medical conditions, and name of physician and dentist. It should contain the following statement and should be signed and dated by the parent or legal guardian:

I, being the parent of the above-named minor, do hereby appoint:

____

to act in my behalf in authorizing any X-ray, anesthetic, medical, dental, or surgical diagnosis or treatment and hospital care for the above-named minor during my absence.

This document may be relied on by any licensed physician, surgeon, dentist, or appropriate hospital representative. I authorize any hospital that has treated the above-named minor to surrender physical custody of the minor to my above-named agent.

Authorized signature: ____________________

Date: ____________________

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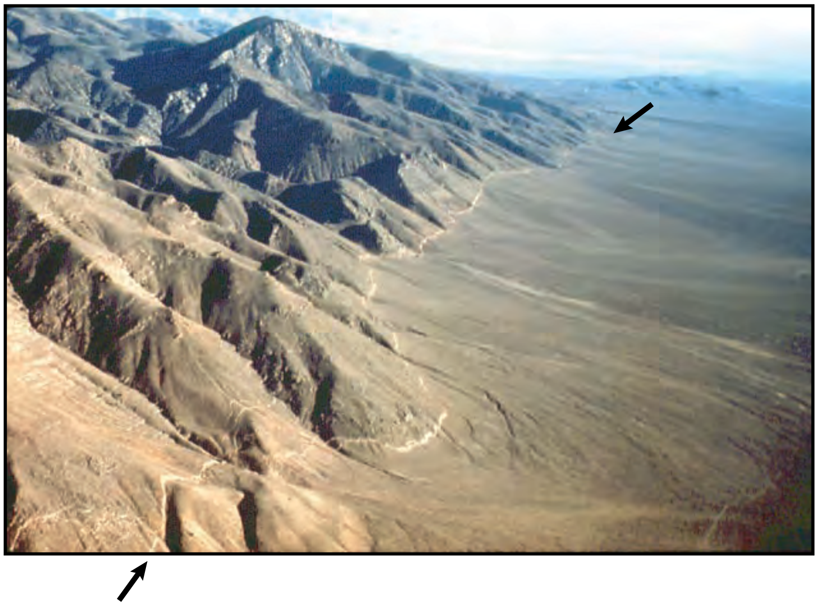

Light-colored line along the base of the Tobin Range (between the arrows) is an 8- to 15-foot vertical offset of the ground that occurred during the 1915 Pleasant Valley, Nevada earthquake. *Photo by Burt Slemmons.*

Setback of homes away from a Quaternary fault in Las Vegas. The fault is located in the central part of the grassy belt, near where the trees are located, and the homes are set at least 50 feet away from it. This setback helps avoid potential surface rupture from earthquakes, potential earth fissures related to groundwater pumping, and groundwater discharge along the fault. *Photo by Craig dePolo.*

Late afternoon view of the eastern side of the Black Hills, southeast of Las Vegas. A shadowed offset of the ground that is about seven feet high crosses near the base of the range (between the arrows). This Holocene-age (≤10,000 years old) fault scarp is a relict of a magnitude ~7 earthquake. *Photo by Larry Anderson.*