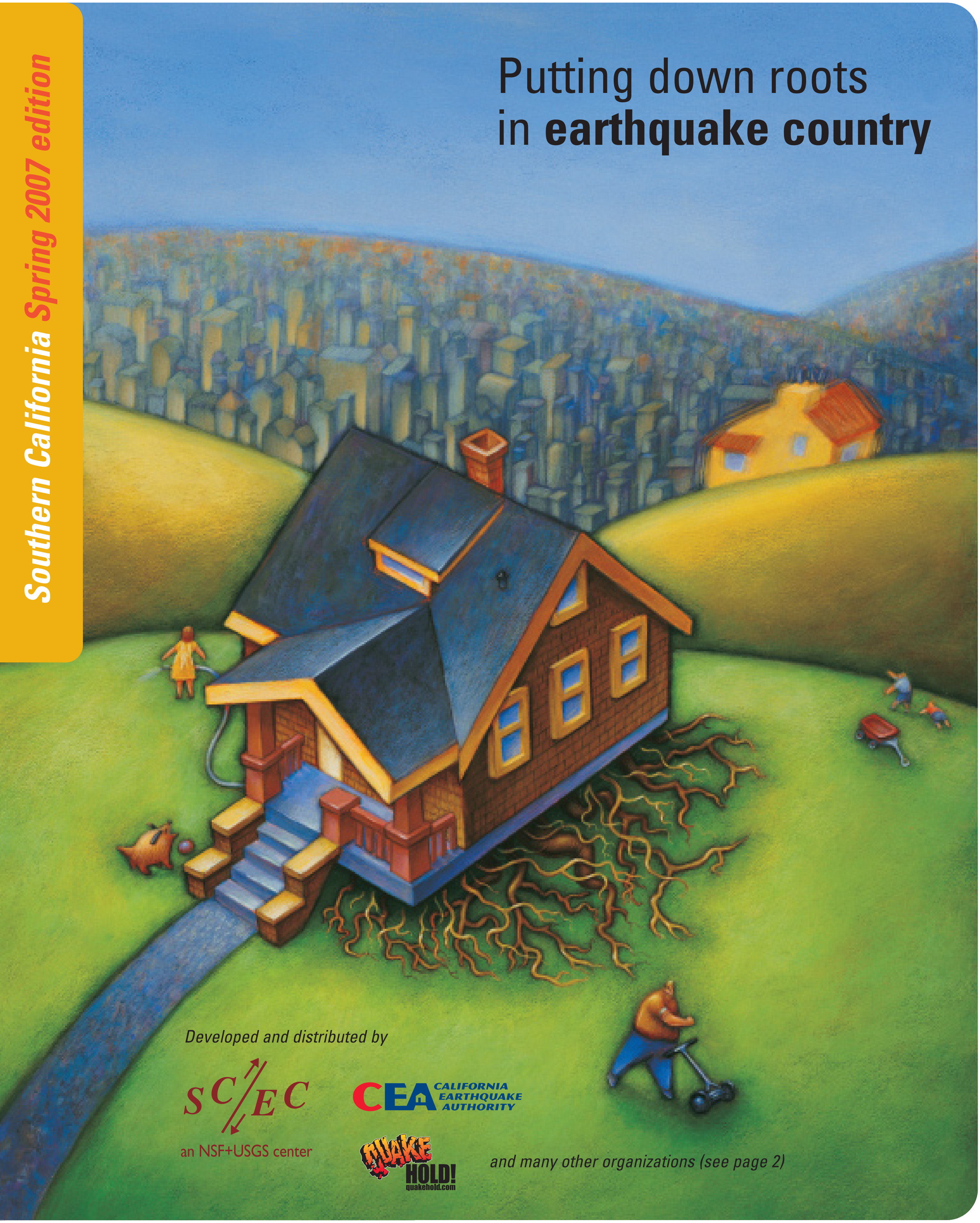
Southern California Spring 2007 edition

Putting down roots in **earthquake country**



Developed and distributed by

SCEC
an NSF+USGS center

CEA CALIFORNIA EARTHQUAKE AUTHORITY

QUAKE HOLD! quakehold.com

and many other organizations *(see page 2)*

Introduction

SCEC is a research consortium supported by the National Science Foundation and the United States Geological Survey, headquartered at the University of Southern California.

"Every day is earthquake season in California" is a service mark of the California Earthquake Authority and is used with permission.

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Prepared by the Southern California Earthquake Center (SCEC) and the Department of the Interior United States Geological Survey (USGS), in cooperation with the National Science Foundation (NSF), the Department of Homeland Security Federal Emergency Management Agency (FEMA), and the California Earthquake Authority (CEA), with contributions from many members of the Earthquake Country Alliance

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Special thanks to members of the **1906 Earthquake Centennial Alliance** for improvements implemented in the San Francisco Bay Region version of this handbook, many of which now have been adopted in this Southern California edition.

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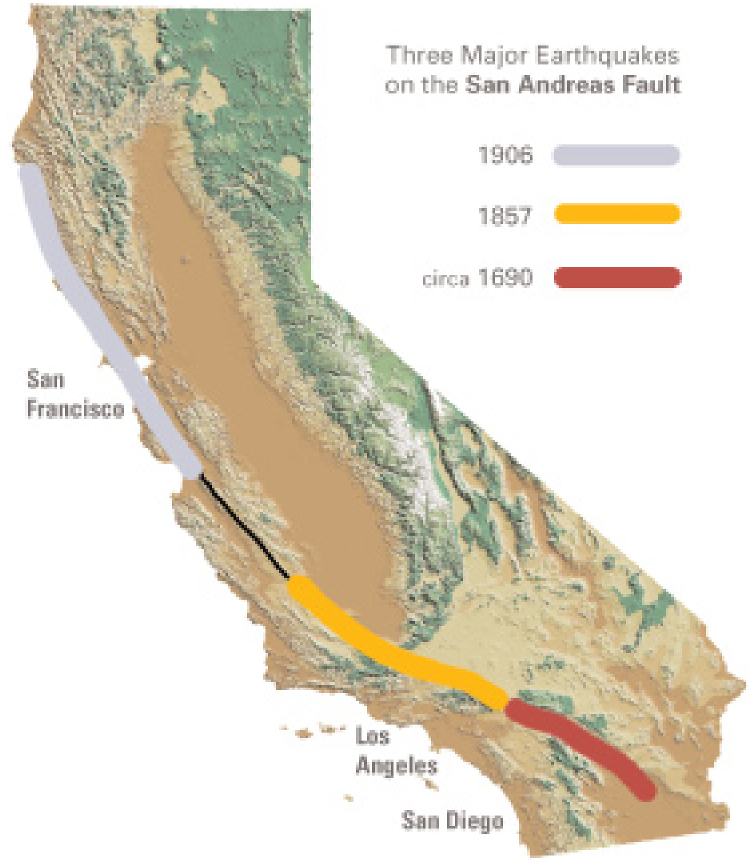


Why should I **care?**

Southern California *is* Earthquake Country

Generations of Californians have been "putting down roots" along one of the world's most famous faults—the San Andreas. However, few Californians have experienced a major San Andreas earthquake. In Northern California, the last major earthquake was 100 years ago in 1906. Over 3,000 people were killed and 225,000 people were left homeless. In Southern California, the last major earthquake on the San Andreas fault was 150 years ago (1857), rupturing the fault from Central California to San Bernardino. Few people lived in the area, so there was very little damage.

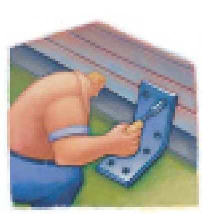
Further south along the San Andreas fault, from San Bernardino through the Coachella Valley to the Salton Sea, over 300 years have passed since the last major earthquake (around 1690). Another major earthquake is likely to happen on this section of the fault within our lifetime. When it does, all of Southern California will be shaken and many areas may be heavily damaged.

There are hundreds of other faults throughout Southern California that could also cause damaging earthquakes. Some may happen before the next major San Andreas earthquake. Southern California is earthquake country, and every day is earthquake season.

This handbook provides information about why we should **care** about earthquakes in Southern California, what we should **do** to be safe and reduce damage, and also what we should **know** about earthquake basics.

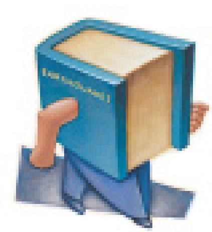
What should I **do?**

The Seven Steps to Earthquake Safety



What should I **know?**

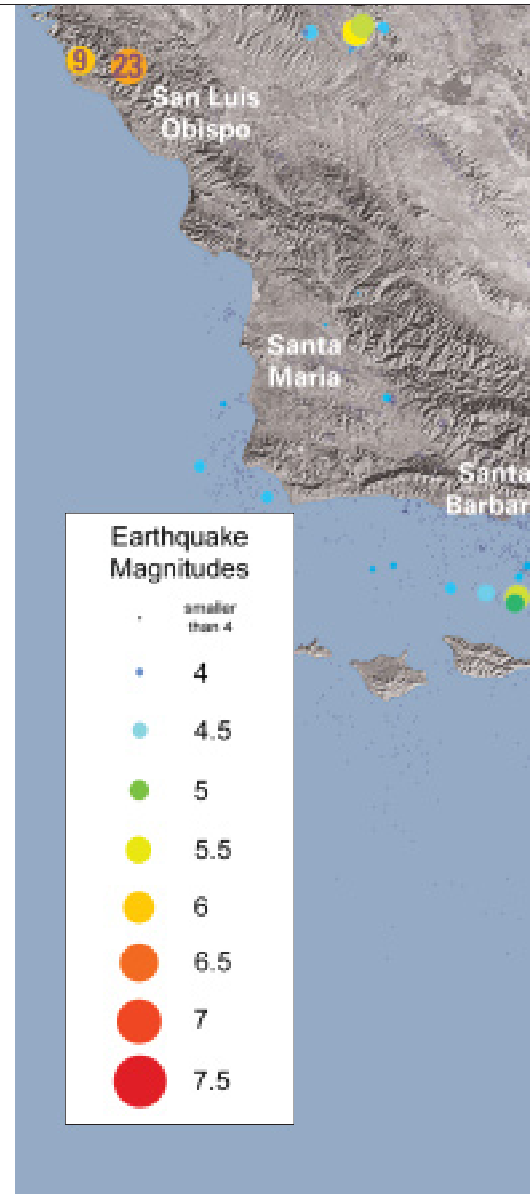
Earthquake Basics



The Resource Mine

SOUTHERN CALIFORNIA *IS* EARTHQUAKE COUNTRY

We know that the San Andreas fault produces large earthquakes and that many other faults are also hazardous. However, it is often difficult to understand how to incorporate this information into our lives. Should we care only if we live near the San Andreas fault? Is every place just as dangerous? This section describes where and how often earthquakes happen in Southern California. It also explains how earthquakes will shake the ground and cause other hazards such as liquefaction and landslides.



MYTH #1 Don't be fooled!

"BIG EARTHQUAKES ALWAYS HAPPEN IN THE EARLY MORNING."

This myth may be so common because we want it to be true. Several recent damaging earthquakes have been in the early morning, so many people believe that all big earthquakes happen then. In fact, earthquakes occur at all times of day. The 1933 Long Beach earthquake was at 5:54 pm and the 1940 Imperial Valley event was at 8:37 pm. More recently, the 1992 Joshua Tree earthquake was at 9:50 pm and the 2003 San Simeon event was at 11:15 am. It is easy to notice the earthquakes that fit the pattern and forget the ones that don't.

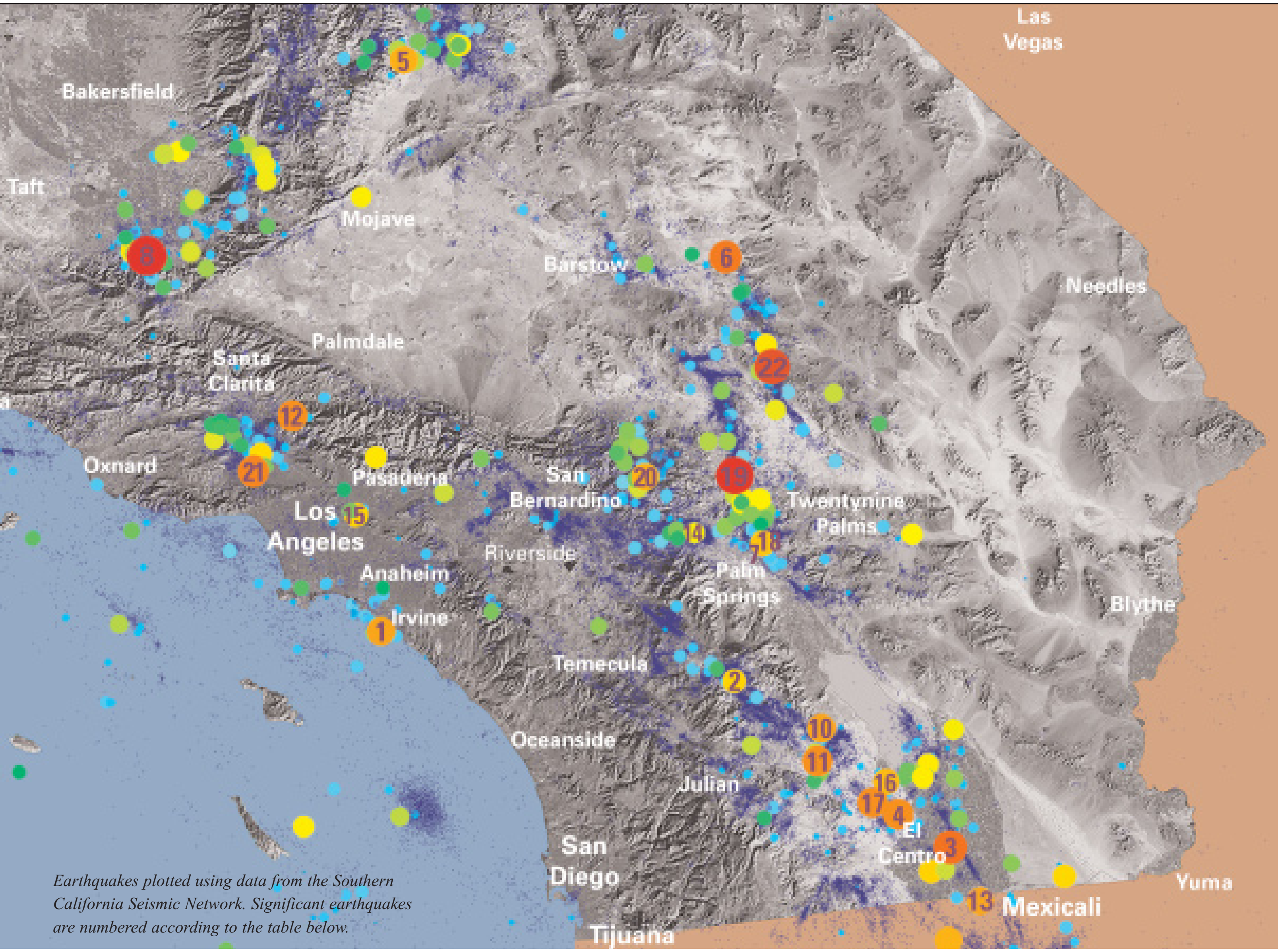
What does it mean?

To become familiar with earthquake vocabulary, you may want to read the "What Should I Know" section first.

SOUTHERN CALIFORNIA EARTHQUAKES

Southern California has thousands of earthquakes every year. A few are damaging, but most are not even felt. However, almost none are on the San Andreas fault. The last significant earthquake on the Southern California stretch of this fault was in 1857. It is still storing energy for some future earthquake. Other faults produce most of our earthquakes.

The Southern California Seismic Network (operated jointly by the U.S. Geological Survey and the California Institute of Technology) recorded several hundred



Earthquakes plotted using data from the Southern California Seismic Network. Significant earthquakes are numbered according to the table below.

thousand earthquakes greater than magnitude 1 in Southern California between 1981 and 2003. The epicenters of these earthquakes are shown by the dark blue dots on the map of Southern California on this page. The colored circles are earthquakes larger than magnitude 4 since 1932, with the size of the circle increasing with magnitude. Small earthquakes are much more common — the map shows 360,000 earthquakes smaller than magnitude 4 in 22 years, but less than 1600 earthquakes above magnitude 4 in 70 years. The largest earthquakes (in red) are the 1992 magnitude 7.3 Landers and 1999 magnitude 7.1 Hector Mine earthquakes in the Mojave Desert and the 1952 magnitude 7.5 Kern County earthquake near Bakersfield.

By comparing this map with the fault map on the next page, we can see that there are very few small earthquakes along many of the major faults, including the San Andreas, Garlock, and Elsinore fault. Other major faults, such as the San Jacinto fault, have both small and large earthquakes. This shows how difficult it can be to predict future earthquakes from patterns of earthquakes.

Significant Southern California earthquakes since 1933

	Date	*Time (local)*	*Location*	*Magnitude*
1.	03.10.1933	5:54 pm	Long Beach	6.4
2.	03.25.1937	8:49 am	San Jacinto	6.0
3.	05.18.1940	8:37 pm	Imperial Valley	6.9
4.	10.21.1942	9:30 am	Fish Creek Mountains	6.6
5.	03.15.1946	5:49 am	Walker Pass	6.0
6.	04.10.1947	7:58 am	Manix	6.5
7.	12.04.1948	3:43 pm	Desert Hot Springs	6.0
8.	07.21.1952	3:52 am	Kern County	7.5
9.	11.21.1952	11:46 pm	Bryson	6.2
10.	03.19.1954	1:54 am	Arroyo Salada	6.4
11.	04.09.1968	6:29 pm	Borrego Mountain	6.5
12.	02.09.1971	6:01 am	San Fernando	6.6
13.	10.15.1979	4:54 pm	Imperial Valley	6.4
14.	07.08.1986	2:21 am	North Palm Springs	5.9
15.	10.01.1987	7:42 am	Whittier Narrows	5.9
16.	11.23.1987	5:54 pm	Elmore Ranch	6.2
17.	11.24.1987	5:15 am	Superstition Hills	6.6
18.	04.22.1992	9:50 pm	Joshua Tree	6.1
19.	06.28.1992	4:57 am	Landers	7.3
20.	06.28.1992	8:05 am	Big Bear	6.3
21.	01.17.1994	4:30 am	Northridge	6.7
22.	10.16.1999	2:46 am	Hector Mine	7.1
23.	12.22.2003	11:15 am	San Simeon	6.5

THE RESOURCE MINE: To learn more see the web resources listed on page 32.

MYTH #2 Don't be fooled!

"BEACHFRONT PROPERTY IN ARIZONA"

The idea of California falling into the ocean has had an enduring appeal to those envious of life in the Golden State. Of course, the ocean is not a great hole into which California can fall, but it is itself land at a somewhat lower elevation with water above it. The motion of plates will not make California sink — western California is moving horizontally along the San Andreas fault and up around the Transverse ranges.

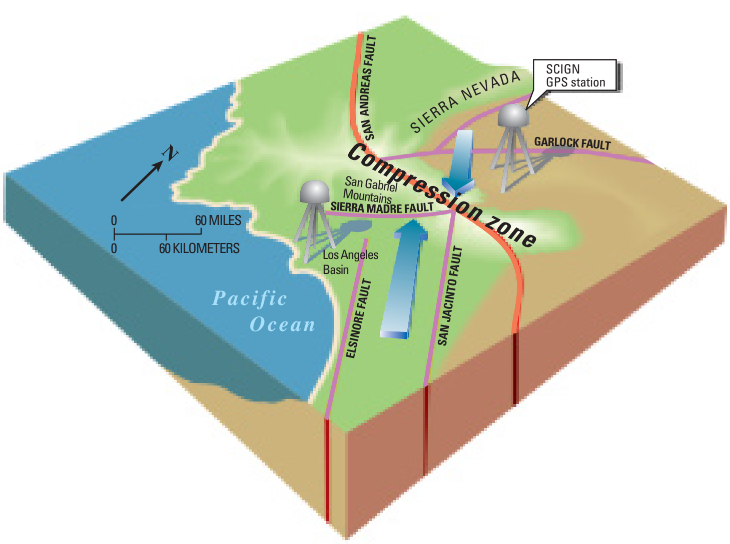
SOUTHERN CALIFORNIA FAULTS

The earthquakes of California are caused by the movement of huge blocks of the earth's crust. Southern California straddles the boundary between the Pacific and North American plates. These large sections of the earth's crust (the North American plate extends east to Iceland while the Pacific plate extends west to Japan) are moving past each other. The Pacific plate is moving northwest, scraping horizontally past North America at a rate of about 50 millimeters (2 inches) per year.

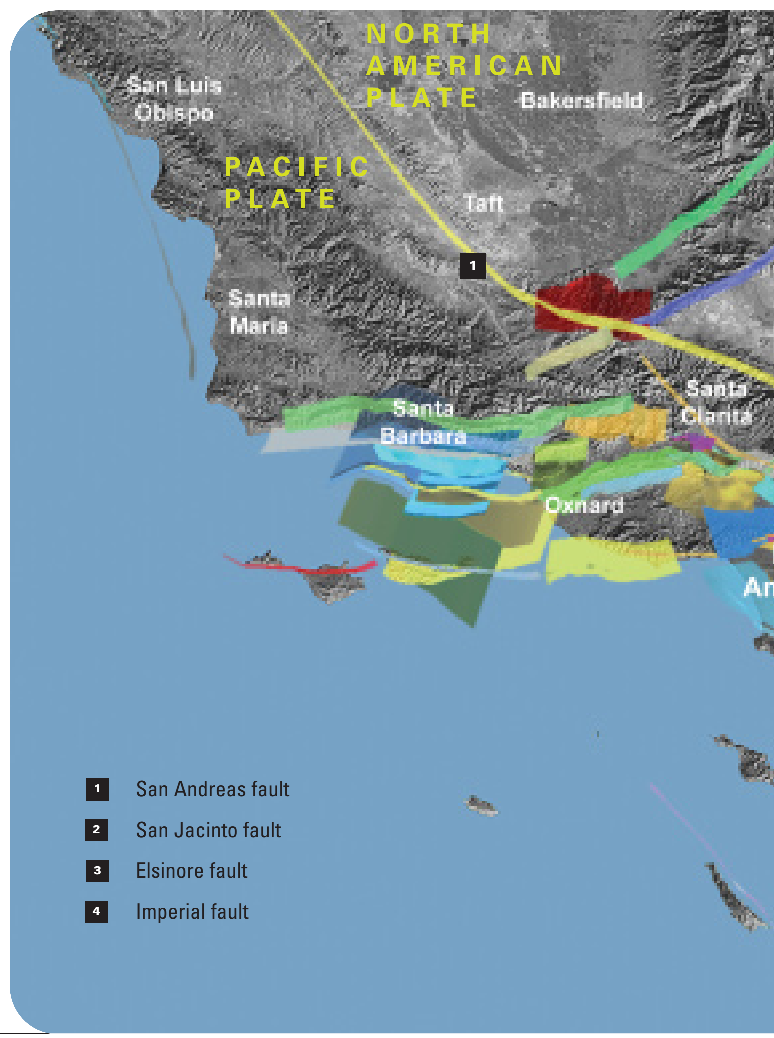
About two-thirds of this 50 millimeters per year occurs on the San Andreas fault and some parallel faults — the San Jacinto, Elsinore, and Imperial faults (see map). These four faults are among the fastest moving, and therefore most dangerous, in Southern California. Over time, these four faults produce about half of the significant earthquakes of our region.

However, this is not the whole picture. Unlike Central and Northern California, much of the plate movement in Southern California is not parallel to the San Andreas fault. Between the southern end of the San Joaquin Valley and the San Bernardino mountains, in the so-called "big bend," the San Andreas fault runs in a more westerly direction.

Where the fault bends, plate motion is complex. The Pacific and North American plates push into each other, compressing the earth's crust into the mountains of Southern California and producing faults and earthquakes. While these 300 or so faults are generally much shorter and slower moving than the four faults mentioned previously, over half



▲ A schematic block model of Southern California showing the motion of the Pacific and North American plates, and the big bend of the San Andreas fault where the plates squeeze together.



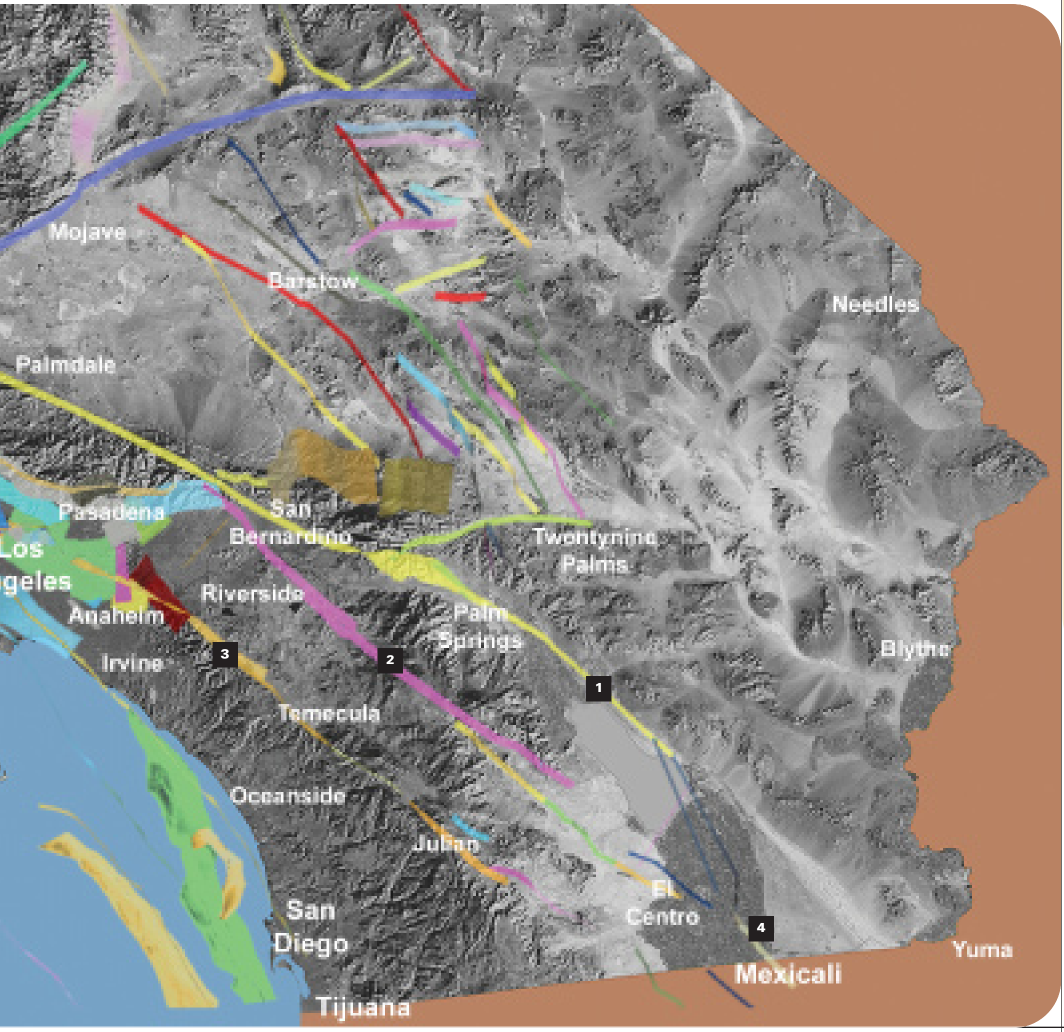
of the significant earthquakes in Southern California occur on these faults.

The greatest concentration of these faults is in and near the mountains that have formed around the big bend of the San Andreas fault (the San Bernardino, San Gabriel, and Santa Ynez mountains). These mountains, like most mountains in California, are there because earthquakes are pushing them up. Many of these faults can be seen at the earth's surface, though some are buried beneath the sediments of the Los Angeles basin and the inland valleys.

Geologic rates

The rate of plate movement along the San Andreas fault, 33 millimeters (1.3 inches) each year, is about how fast your fingernails grow. As a result, Los Angeles City Hall is now 2.7 meters (9 feet) closer to San Francisco than when it was built in 1924. It would take a mere (geologically speaking) 2 million years for your nails to extend 100 kilometers (60 miles) from San Bernardino to Palmdale. It took many millions of years of movement on faults (earthquakes) to shape Southern California's current landscape.

▼ **SCEC Community Fault Model.** This map shows the 3-dimensional structure of major faults beneath Southern California. Vertical faults such as the San Andreas (yellow band from top left to bottom right) are shown as a thin strip. Faults that are at an angle to the surface are shown as wider ribbons of color. The nearest fault to you might be a few miles beneath your home. Areas that seem to have few faults can still experience strong shaking from earthquakes on unmapped faults or from large earthquakes on distant faults.



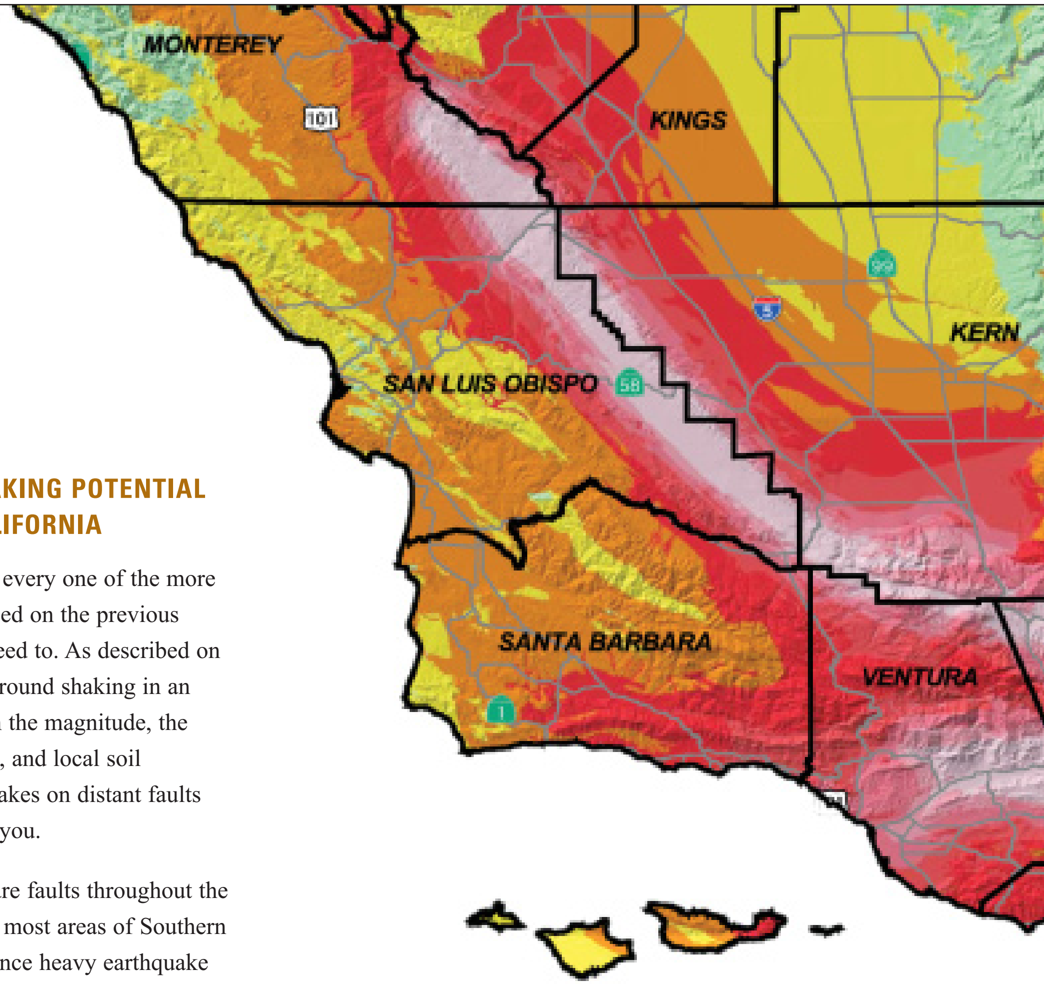
SCIGN station located in Elysian Park near downtown Los Angeles

Unknown faults

As the Northridge earthquake confirmed, some faults are not known until they move in large and damaging earthquakes. What do we do about these unknown faults we can't see and don't know about yet? Do we still have to wait until the next earthquake reveals them?

Not necessarily. In 2001, scientists of the Southern California Earthquake Center completed the Southern California Integrated GPS Network (SCIGN), an advanced system of 250 Global Positioning System (GPS) receivers. With this network the positions of locations throughout Southern California can be precisely measured. This network is now a part of an even larger system, the Plate Boundary Observatory, which is measuring movement throughout the western United States.

By measuring these locations for several years, we can see how different sites are moving relative to each other—for instance, Palos Verdes is moving toward Pasadena at about 4 millimeters (5/32 inch) per year. If movement between two locations is greater than the movement on known faults, then we have a reasonable idea that there may be another fault in the area, perhaps buried by sediment. This can lead to focused research using other methods to identify the unknown fault.

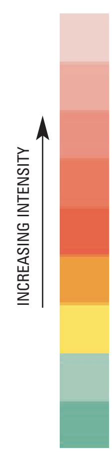


EARTHQUAKE SHAKING POTENTIAL IN SOUTHERN CALIFORNIA

We could worry about every one of the more than 300 faults described on the previous page. But we do not need to. As described on pages 28 and 29, the ground shaking in an earthquake depends on the magnitude, the distance from the fault, and local soil conditions. So earthquakes on distant faults may not be a threat to you.

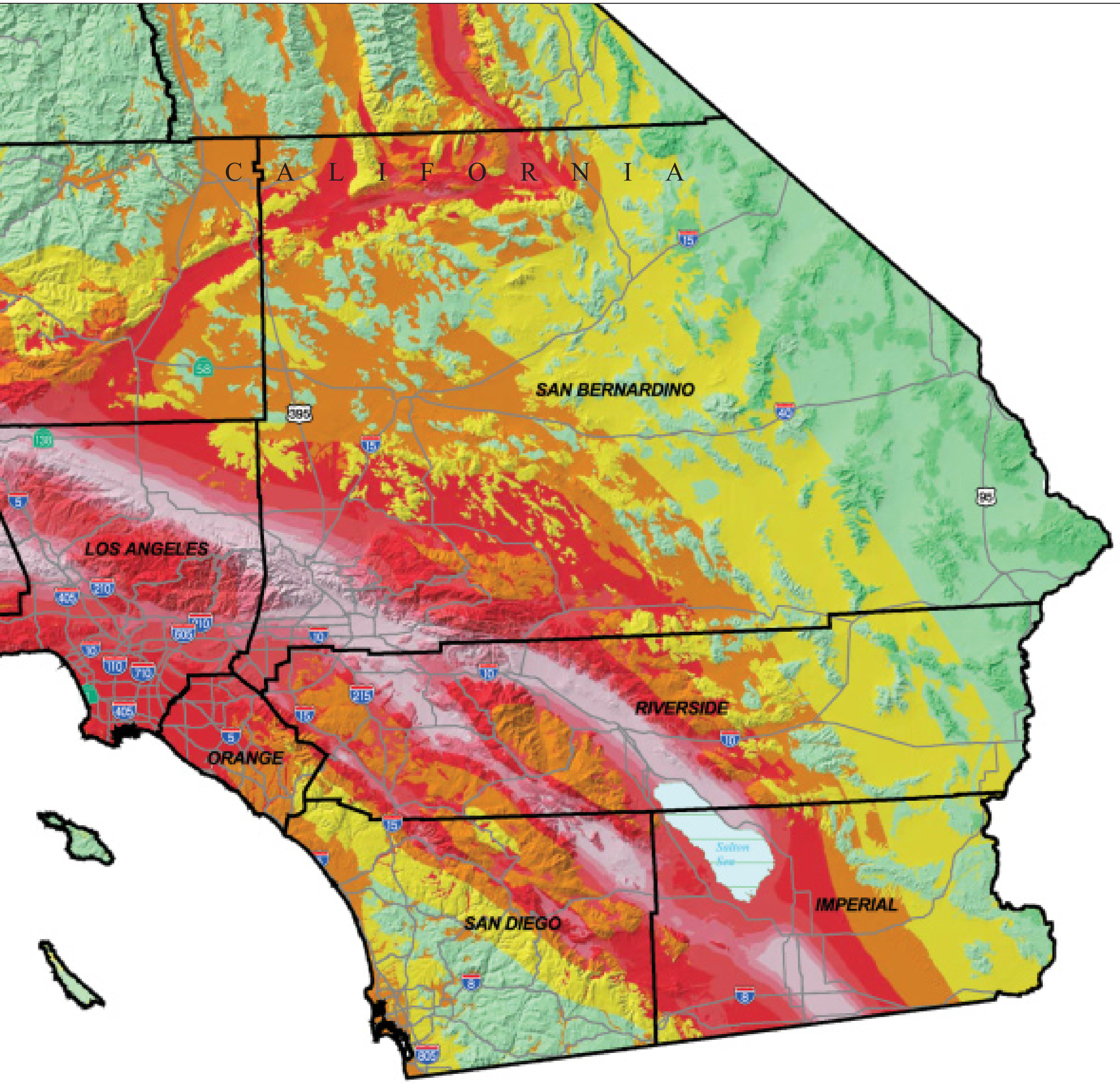
However, since there are faults throughout the region, in the long run most areas of Southern California will experience heavy earthquake shaking. Some locations will experience such shaking more frequently because they are closer to more faults or have local soil conditions that amplify earthquake shaking (see pages 28 and 29 for more information).

Unfortunately, scientists do not yet have the information needed to predict which earthquakes will happen first, so we must be ready for the shaking in our area from any possible earthquake. To help, scientists have combined the probable shaking from all our known faults to create the large map above. It shows the relative intensity of ground shaking in California from all anticipated future earthquakes. Areas in red and pink are nearer major, active faults and on average experience stronger earthquake shaking more frequently. Although the greatest hazard is in these areas, no region within the state is immune from the potential for earthquake damage.



These regions are near major, active faults and will on average experience stronger earthquake shaking more frequently. This intense shaking can damage even strong, modern buildings.

These regions are distant from known, active faults and will experience lower levels of shaking less frequently. In most earthquakes, only weaker masonry buildings would be damaged. However, very infrequent earthquakes could still cause strong shaking here.



C A L I F O R N I A
SAN BERNARDINO
LOS ANGELES
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL
Salton Sea

OTHER EARTHQUAKE-RELATED HAZARDS IN SOUTHERN CALIFORNIA

The previous pages have described where earthquakes have happened, the many faults in Southern California capable of large earthquakes, and the expected shaking from future earthquakes. In addition to these regional aspects of the earthquake hazard, there are location-specific hazards that can cause additional damage: surface rupture, liquefaction, and landslides. The California Geological Survey produces maps that identify Earthquake Fault Zones and Seismic Hazard Zones where these hazards may occur. State laws require that every person starting to "put down roots" by buying a home or real property in California be told if the property is in one of these zones.

Earthquake Fault Zones (EFZs) recognize the hazard of surface rupture that might occur during an earthquake where an active fault meets the earth's surface. Few structures can withstand fault rupture directly under their foundations. The law requires that within an EFZ most structures must be set back a safe distance from identified active faults. The necessary setback is established through geologic studies of the site. EFZs are narrow strips along the known active surface faults wherein these studies are required prior to development. Being located in an EFZ does not necessarily mean that a building is on a fault. Most of the important known faults in California have been evaluated and zoned, and modifications and additions to these zones continue as we learn more.

Seismic Hazard Zones (SHZs) identify areas that may be prone to liquefaction or landsliding triggered by earthquake shaking. Liquefaction is a temporary loss of strength in the ground that can occur when certain water saturated soils are shaken during a strong earthquake. When this occurs buildings can settle, tilt, or shift. Landsliding can occur during an earthquake where shaking reduces the strength of the slope. These hazards can usually be reduced or eliminated through established engineering methods. The law requires that property being developed within these zones be evaluated to determine if a hazard exists at the site. If so, necessary design changes must be made before a permit is granted for residential construction. Being in an SHZ does not mean that all structures in the zone are in danger. The hazard may not exist on each property or may have been mitigated. Mapping new SHZs in urban and urbanizing areas is ongoing statewide.

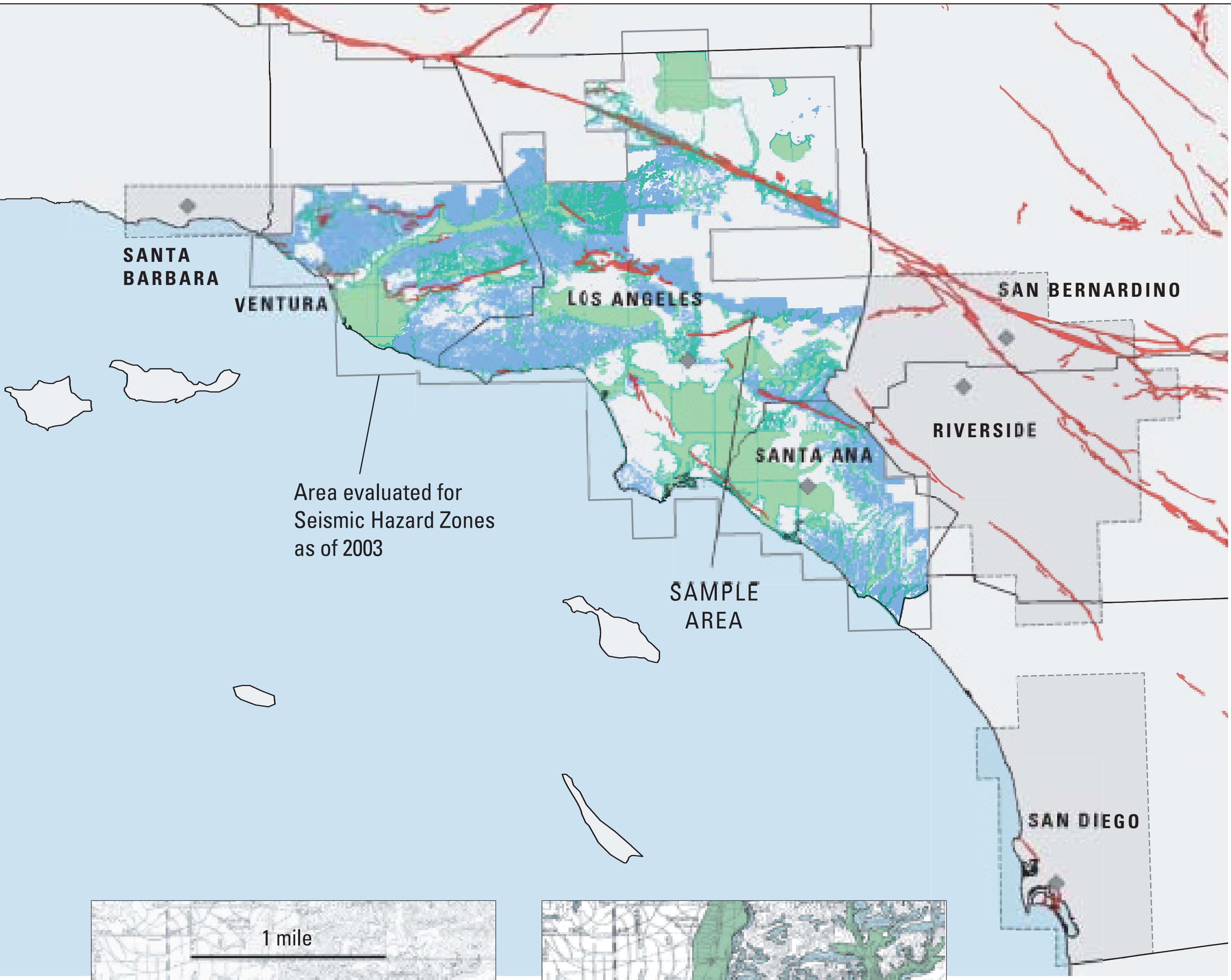
Current zones, as established by the California Geological Survey, are indexed at www.consrv.ca.gov/cgs.

LA County Juvenile Hall, Sylmar, California, damaged by liquefaction during the magnitude 6.6 San Fernando earthquake of February 9, 1971. The broken floor is due to settling of the earth and is not the fault itself. Photo by Jack Meehan, structural engineer.

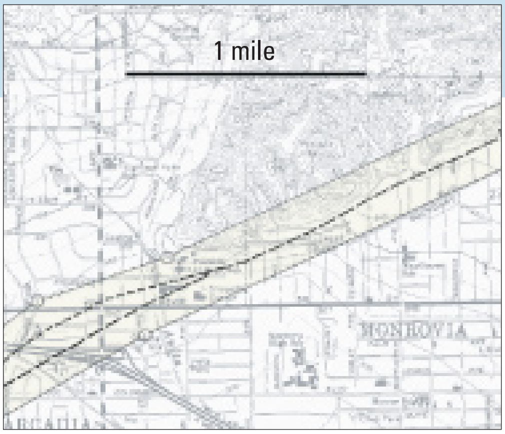
MYTH #3 Don't be fooled!

"AND THE EARTH OPENED…"

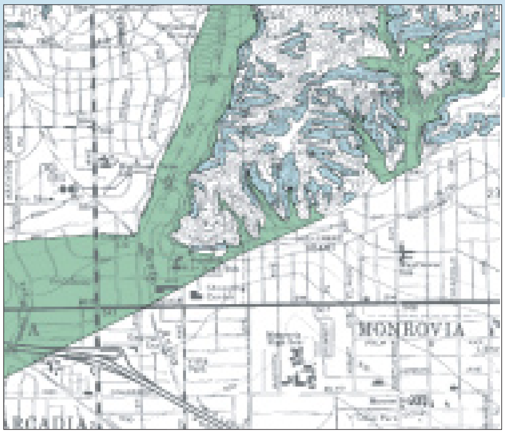
A popular literary device is a fault that opens during an earthquake to swallow up an annoying character. But unfortunately for principled writers, gaping faults exist only in novels. The ground moves across a fault during an earthquake, not away from it. If the fault could open, there would be no friction. Without friction, there would be no earthquake.



▲ Red zones are Earthquake Fault Zones with potential for surface faulting. Blue and green zones are Seismic Hazard Zones with a potential for landslides and liquefaction, respectively. Shaded areas indicate future Seismic Hazard evaluation and zoning.



Earthquake Fault Zone (EFZ):
see "sample area" above



Seismic Hazard Zone (SHZ)
see "sample area" above

THE SEVEN STEPS TO EARTHQUAKE SAFETY

Earthquakes are inevitable, but the damage from earthquakes is not. Many people think the destruction caused by earthquakes is unavoidable, and that our only option is to pick up the pieces after the shaking stops. No! Earthquake damage and loss can be limited by steps you take before, during, and after. Many also think that all the damage and injuries from earthquakes comes from collapsing buildings. Again, no! As buildings are designed better, more of the losses in earthquakes are from objects that break or fall on people causing injury.

The seven steps described in this section show how we can be safer by knowing what to do before, during, and after earthquakes. The steps may also save a lot of money when structures and contents are not damaged. In addition to following the steps at home, they should also be followed in schools, workplaces, and other facilities. If we all follow these steps, we may save billions of dollars in the next large earthquake. Most importantly, we can reduce the risk of being injured or killed.

These steps were developed by members of the Earthquake Country Alliance, which includes leading earthquake professionals, emergency managers, government officials, business and community leaders, and others. The recommendations are based on many existing resources and the advice of many organizations.

The members of the Earthquake Country Alliance all have specific roles before, during, and after earthquakes, to reduce earthquake damage and injuries, and to speed recovery. Do your part. Dare to prepare by following the seven steps described in this section.

Follow these seven steps to prepare your home, your school, and your workplace for our next earthquake.

start here...

THE RESOURCE MINE: To learn more see the web resources listed on page 32.

#1 IDENTIFY POTENTIAL HAZARDS IN YOUR HOME AND BEGIN TO FIX THEM.

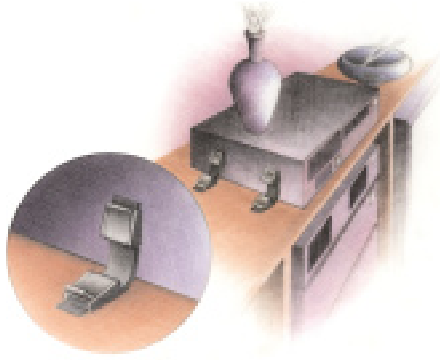
Earthquake safety is more than minimizing damage to buildings. We must also secure the contents of our buildings to reduce the risk to our lives and our pocketbooks.

Several people died and thousands were injured in the Northridge earthquake because of unsecured building contents such as toppling bookcases. Many billions of dollars were lost due to this type of damage. Much of this damage and injury could have been prevented in advance through simple actions to secure buildings and contents.

You should secure anything 1) heavy enough to hurt you if it falls on you, or 2) fragile or expensive enough to be a significant loss if it falls. In addition to contents within your living space, also secure items in other areas, such as your garage, to reduce damage to vehicles or hazardous material spills.

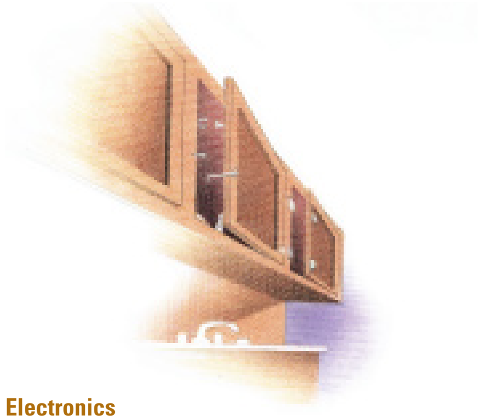
There may be simple actions you can do right now that will protect you if an earthquake happens tomorrow. START NOW by moving furniture such as bookcases away from beds, sofas, or other places where people sit or sleep. Move heavy objects to lower shelves. Then begin to look for other items in your home that may be hazardous in an earthquake.

Some of the actions recommended on this page may take a bit longer to complete, but all are relatively simple. Most hardware stores and home centers now carry earthquake safety straps, fasteners, and adhesives.



In the kitchen

Unsecured cabinet doors fly open during earthquakes, allowing glassware and dishes 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. Secure refrigerators and other major appliances to walls using earthquake appliance straps.

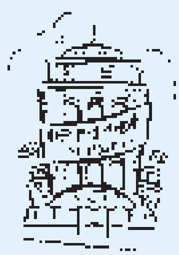


Electronics

Televisions, stereos, computers and microwaves and other electronics are heavy and costly to replace. They can be secured with flexible nylon straps and buckles for easy removal and relocation.

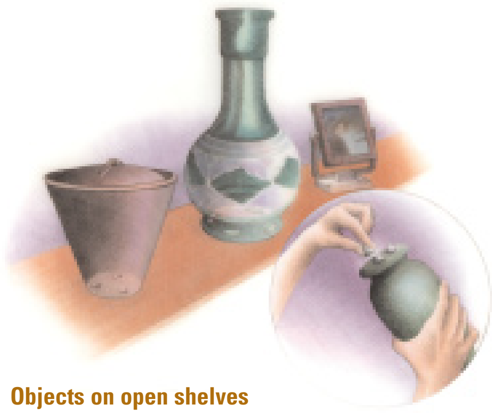
Additional information, including how-to instructions, is available at
www.daretoprepare.org

MYTH #4 Don't be fooled!



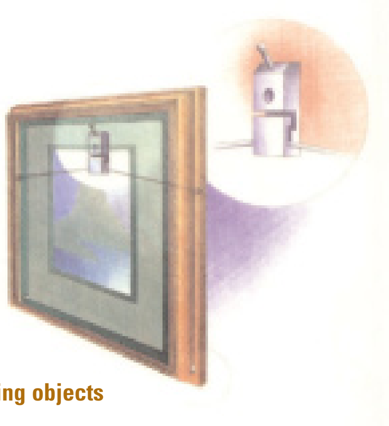
"WE HAVE GOOD BUILDING CODES SO WE MUST HAVE GOOD BUILDINGS."

The best building codes in the world do nothing for buildings built before a code was enacted. While the codes have been updated, the older buildings are still in place. Fixing problems in older buildings — retrofitting — is the responsibility of the building's owner.



Objects on open shelves and tabletops

Collectibles, pottery objects, and lamps can become deadly projectiles. Use either hook and loop fasteners on the table and object, or non-damaging adhesives such as earthquake putty, clear quake gel, or microcrystalline wax to secure breakables in place. Move heavy items and breakables to lower shelves.



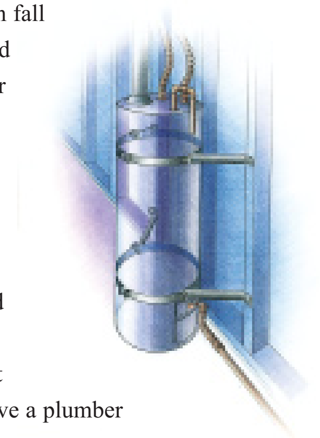
Hanging objects

Mirrors, framed pictures, and other objects should be hung from closed hooks so that they can't bounce off the walls. Pictures and mirrors can also be secured at their corners with earthquake putty. Only soft art such as tapestries should be placed over beds or sofas.

Furniture

Secure the tops of all top-heavy furniture, such as bookcases and file cabinets, to a wall. Be sure to anchor to the stud, and not just to the drywall. Flexible fasteners such as nylon straps allow tall objects to sway without falling over, reducing the strain on the studs. Loose shelving can also be secured by applying earthquake putty on each corner bracket.

Water heater



Unsecured water heaters often fall over, rupturing rigid water and gas connections. If your water heater does not have two straps around it that are screwed into the studs or masonry of the wall, then it is not properly braced. This illustration shows one method of bracing a water heater. Bracing kits are available that make this process simple. Have a plumber install flexible (corrugated) copper water connectors, if not already done.

In the garage or utility room

Items stored in garages and utility rooms can fall, causing injuries, damage, and hazardous spills or leaks. They can also block access to vehicles and exits. Move flammable or hazardous materials to lower shelves or the floor.

→ **Move on to #2**

once you have identified potential hazards, have fixed some, and have a plan for fixing the rest. → → → → → →

The seven steps to earthquake safety

BEFORE:

- **#1 Identify and fix hazards in your home.**
- #2 Create a disaster-preparedness plan. (Page 16)
- #3 Prepare disaster supplies kits. (Page 17)
- #4 Identify and fix your building's weaknesses. (Page 18)

DURING:

- #5 Drop, cover, and hold on. (Page 19)

AFTER:

- #6 Check for injuries and damage. (Page 20)
- #7 When safe, continue to follow your disaster plan. (Page 21)

#2

CREATE A DISASTER-PREPAREDNESS PLAN.

Will everyone in your household do the right thing during the violent shaking of a major earthquake? Before the next earthquake, get together with your family or housemates to plan now what each person will do before, during and after.

Once the earthquake is over, we will have to live with the risk of fire, the potential lack of utilities and basic services, and the certainty of aftershocks. By planning now, you will be ready. This plan will also be useful for other emergencies.

Plan NOW to be safe during an earthquake:

- ☐ Practice “drop, cover, and hold on.” *(See Step 5, page 19)*
- ☐ Identify safe spots in every room, such as under sturdy desks and tables.
- ☐ Learn how to protect yourself no matter where you are when an earthquake strikes.

Plan NOW to respond after an earthquake:

- ☐ Keep shoes and a working flashlight next to each bed.
- ☐ Teach everyone in your household to use emergency whistles and/or to knock three times repeatedly if trapped. Rescuers searching collapsed buildings will be listening for sounds.
- ☐ Identify the needs of household members and neighbors with special requirements or situations, such as use of a wheelchair, walking aids, special diets, or medication.
- ☐ Take a Red Cross first aid and cardiopulmonary resuscitation (CPR) training course. Learn who else in your neighborhood is trained in first aid and CPR.
- ☐ Know the location of utility shutoffs and keep needed tools nearby. Make sure you know how to turn off the gas, water, and electricity to your home. Only turn off the gas if you smell or hear leaking gas.
- ☐ Get training from your local fire department in how to properly use a fire extinguisher.
- ☐ Install smoke alarms and test them monthly. Change the battery once a year, or when the alarm emits a "chirping" sound (low-battery signal).
- ☐ Check with your city or county to see if there is a Community Emergency Response Team (CERT) in your area. If not, ask how to start one.

Plan NOW to communicate and recover after an earthquake:

- ☐ Select a safe place outside of your home to meet your family or housemates after the shaking stops.
- ☐ Designate an out-of-area contact person who can be called by everyone in the household to relay information.
- ☐ Provide all family members with a list of important contact phone numbers.
- ☐ Determine where you might live if your home cannot be occupied after an earthquake or other disaster.
- ☐ Know about the earthquake plan developed by your children's school or day care. Keep your children's school emergency release card current.
- ☐ Keep copies of essential documents, such as identification, insurance policies, and financial records, in a secure, waterproof container, and keep with your disaster supplies kits. Include a household inventory (a list and photos or video of your belongings).

Have occasional earthquake “drills” to practice your plan. Share your plan with people who take care of your children, pets, or home.

→ **Move on to #3**

once you have your plan, create your disaster supplies kits that you’ll use when you follow your plan after an earthquake. → → → → →

The seven steps to earthquake safety

BEFORE:

- #1 Identify and fix hazards in your home. (Page 14)
- #2 **Create a disaster-preparedness plan.**
- #3 **Prepare disaster supplies kits.**
- #4 Identify and fix your building’s weaknesses. (Page 18)

DURING:

- #5 Drop, cover, and hold on. (Page 19)

AFTER:

- #6 Check for injuries and damage. (Page 20)
- #7 When safe, continue to follow your disaster plan. (Page 21)

#3

PREPARE DISASTER SUPPLIES KITS.

Personal disaster supplies kits

Everyone should have personal disaster supplies kits. Keep them where you spend most of your time, so they can be reached even if your building is badly damaged. The kits will be useful for many emergencies.

Keep one kit in your **home**, another in your **car,** and a third kit at **work**. Backpacks or other small bags are best for your disaster supplies kits so you can take them with you if you evacuate. Include at least the following items:

- ☐ Medications, prescription list, copies of medical cards, doctor's name and contact information
- ☐ Medical consent forms for dependents
- ☐ First aid kit and handbook
- ☐ Examination gloves (non-latex)
- ☐ Dust mask
- ☐ Spare eyeglasses or contact lenses and cleaning solution
- ☐ Bottled water
- ☐ Whistle (to alert rescuers to your location)
- ☐ Sturdy shoes
- ☐ Emergency cash
- ☐ Road maps
- ☐ List of emergency out-of-area contact phone numbers
- ☐ Snack foods, high in water and calories
- ☐ Working flashlight with extra batteries and light bulbs, or light sticks
- ☐ Personal hygiene supplies
- ☐ Comfort items such as games, crayons, writing materials, teddy bears
- ☐ Toiletries and special provisions you need for yourself and others in your family including elderly, disabled, small children, and animals.
- ☐ Copies of personal identification (drivers license, work ID card, etc.)

Household disaster supplies kit

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 unable to provide you with immediate assistance. Providing first aid and having supplies will save lives, will make life more comfortable, and will help you cope after the next earthquake.

In addition to your personal disaster supplies kits, store a **household** disaster supplies kit in an easily accessible location (in a large watertight container that be easily moved), with a **three-day to one-week** supply of the following items:

- ☐ Wrenches to turn off gas and water supplies
- ☐ Work gloves and protective goggles
- ☐ Heavy duty plastic bags for waste, and to serve as tarps, rain ponchos, and other uses
- ☐ Portable radio with extra batteries
- ☐ Additional flashlights or light sticks
- ☐ Drinking water (minimum one gallon per person, per day)
- ☐ Canned and packaged foods
- ☐ Charcoal or gas grill for outdoor cooking and matches if needed
- ☐ Cooking utensils, including a manual can opener
- ☐ Pet food and pet restraints
- ☐ Comfortable, warm clothing including extra socks
- ☐ Blankets or sleeping bags, and perhaps even a tent
- ☐ Copies of vital documents such as insurance policies

Use and replace perishable items like water, food, medications and batteries on a yearly basis.

→ **Move on to** #4

to consider how to reduce damage to your home and serious injury from building collapse. → →

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 of 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 developing your disaster plan, prepare disaster supplies kits, and practice "drop, cover, and hold on." Consider simulating post-earthquake conditions by going without electricity or tap water.

After the earthquake, remember that children will be under great stress. They may be frightened, their routine will probably be disrupted, and the aftershocks won't let them forget the experience. Adults tend to leave their children in order to deal with the many demands of the emergency, but this can be devastating to children. Extra contact and support from parents in the early days will pay off later. Whenever possible, include them in the recovery process.

#4

IDENTIFY YOUR BUILDING'S POTENTIAL WEAKNESSES AND BEGIN TO FIX THEM.

Buildings are designed to withstand the downward pull of gravity, yet earthquakes shake a building in all directions — up and down, but most of all, sideways. There are several common issues that can limit a building's ability to withstand this sideways shaking.

Additional information, including how-to instructions, is available at **www.daretoprepare.org**

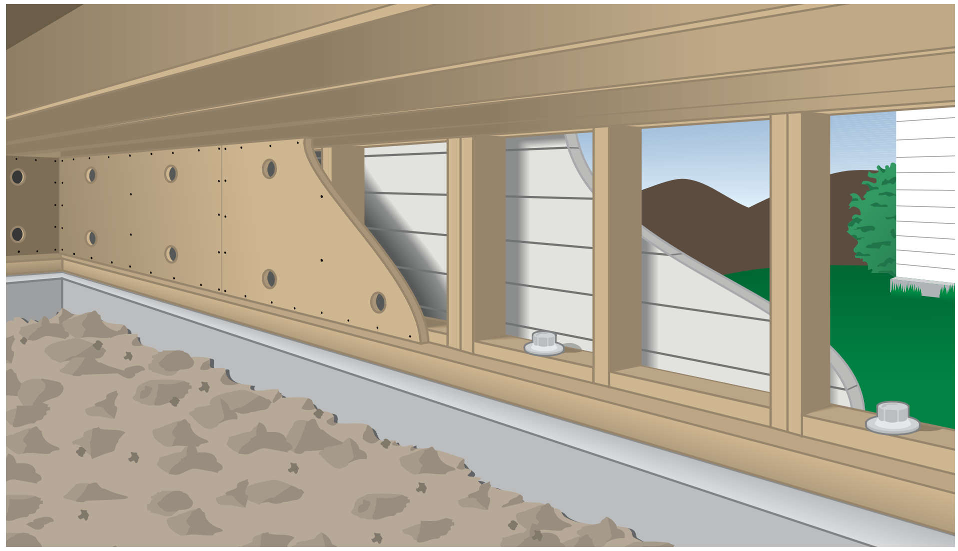
For those who rent

As a renter, you have less control over the structural integrity of your building, but you *do* control which apartment or house you rent:

- Structures made of unreinforced brick or block walls can collapse and cause great loss of life.
- Apartment buildings with "tuck-under" parking space openings can also collapse.
- Foundation and cripple wall failures can cause expensive damage but less loss of life.
- Objects attached to the sides of buildings, such as staircases, balconies, and decorations, can break off in earthquakes.

Ask your landlord these questions:

- 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?



▲ This cutaway diagram shows how weak cripple walls can be strengthened by properly attached plywood sheets.

Common building problems

Most houses are not as safe as they could be. The following presents some common structural problems and how to recognize them. Once you determine if your building has one or more of these problems, prioritize how and when to fix them, and get started.

Inadequate foundations. Look under your house 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 1.8 meters (6 feet) apart in a single story and 1.2 meters (4 feet) apart in a multistory building. Adding bolts to unsecured houses is one of the most important steps toward earthquake safety. This can be done by a contractor or by someone skilled at home maintenance.

Unbraced cripple walls. Homes with a crawl space should have panels of plywood connecting the studs of the short "cripple" walls (see figure). You or a contractor can strengthen the cripple walls relatively inexpensively.

Soft first stories. Look for larger 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. All masonry (brick or block walls) should be reinforced. Some communities have a program for retrofitting buildings made of unreinforced masonry. If your house has masonry as a structural element consult a structural engineer to find what can be done. Inadequately braced chimneys are a more common problem. Consult a professional to determine if your chimney is safe.

If you live in a mobile home...

Look under your home. If you only see a metal or wood "skirt" on the outside with concrete blocks or steel tripods or jacks supporting your home, you need to have an "engineered tie-down system" or an "earthquake-resistant bracing system" (ERBS) installed. An ERBS should have a label on the bracing that says, "Complies with the California Administrative Code, Title 25, Chapter 2, Article 7.5."

#5

PROTECT YOURSELF DURING EARTHQUAKE SHAKING— DROP, COVER, AND HOLD ON.

The previous pages have concentrated on getting ready for the next earthquake. What should you do during and after earthquakes?

During earthquakes, drop to the floor, take cover under a sturdy desk or table, and hold on to it firmly. Be prepared to move with it until the shaking stops.

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

MYTH #5 Don't be fooled!

"HEAD FOR THE DOORWAY."

An enduring earthquake image of California is a collapsed adobe home with the door frame as the only standing part. From this came our 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. You are safer under a table.

If you are...

Indoors: **Drop, cover, and hold on.** If you are not near a desk or table, drop to the floor against the interior wall and protect your head and neck with your arms. Avoid exterior walls, windows, hanging objects, mirrors, tall furniture, large appliances, and kitchen cabinets with heavy objects or glass. Do not go outside!

In bed: If you are in bed, hold on and stay there, protecting your head with a pillow. You are less likely to be injured staying where you are. Broken glass on the floor has caused injury to those who have rolled to the floor or tried to get to doorways.

In a high-rise: Drop, cover, and hold on. 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, 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 stadium or theater: Stay at your seat and 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 in the aftershocks.

Near the shore: Drop, cover and hold on until the shaking stops. Estimate how long the shaking lasts. If severe shaking lasts 20 seconds or more, immediately evacuate to high ground as a tsunami might have been generated by the earthquake. Move inland 3 kilometers (2 miles) or to land that is at least 30 meters (100 feet) above sea level immediately. Don't wait for officials to issue a warning. Walk quickly, rather than drive, to avoid traffic, debris and other hazards.

Below a dam: Dams can fail during a major earthquake. Catastrophic failure is unlikely, but if you live downstream from a dam, you should know flood-zone information and have prepared an evacuation plan.

The seven steps to earthquake safety

BEFORE: **DURING:** **AFTER:**

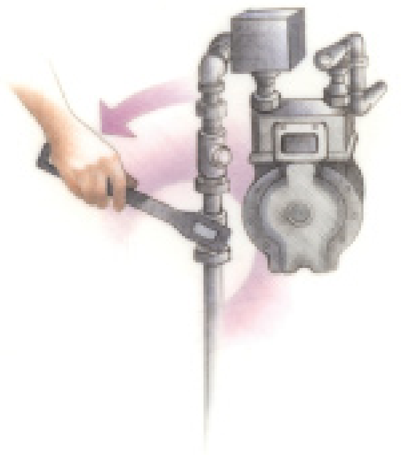
#4 **Identify and fix your building's weaknesses.**

#5 **Drop, cover, and hold on.**

#6 Check for injuries and damage. (Page 20)

#7 When safe, continue to follow your disaster plan. (Page 21)

#6 AFTER THE EARTHQUAKE, CHECK FOR INJURIES AND DAMAGE



First take care of your own situation. Remember your emergency plans. Aftershocks may cause additional damage or items to fall, so get to a safe location. Take your disaster supplies kit.

If you are trapped by falling items or a collapse, protect your mouth, nose, and eyes from dust. If you are bleeding, put pressure on the wound and elevate the injured part. Signal for help with your emergency whistle, a cell phone, or knock loudly on solid pieces of the building, three times every few minutes. Rescue personnel will be listening for such sounds.

Once you are safe, help others and check for damage. Protect yourself by wearing sturdy shoes and work gloves, to avoid injury from broken glass and debris. Also wear a dust mask and eye protection.

Check for injuries

- Check your first aid kit or the front pages of your telephone book for detailed instructions on first aid measures.
- If a person is bleeding, put direct pressure on the wound. Use clean gauze or cloth, if available.
- If a person is not breathing, administer rescue breathing.
- If a person has no pulse, begin CPR (cardiopulmonary resuscitation).
- Do not move seriously injured persons unless they are in immediate danger of further injury.
- Cover injured persons with blankets or additional clothing to keep them warm.
- Get medical help for serious injuries.
- Carefully check children or others needing special assistance.

Check for damage

- FIRE. If possible, put out small fires in your home or neighborhood immediately. Call for help, but don't wait for the fire department.
- GAS LEAKS. Shut off the main gas valve only if you suspect a leak because of broken pipes or the odor or sound of leaking natural gas. Don't turn it back on yourself — wait for the gas company to check for leaks. The phone book has detailed information on this topic.
- DAMAGED ELECTRICAL WIRING. Shut off power at the main breaker switch if there is any damage to your house wiring. Leave the power off until the damage is repaired.
- BROKEN LIGHTS AND APPLIANCES. Unplug these as they could start fires when electricity is restored.
- DOWNED POWER LINES. If you see downed power lines, consider them energized and stay well away from them. Keep others away from them. Never touch downed power lines or any objects in contact with them.
- FALLEN ITEMS. Beware of items tumbling off shelves when you open closet and cupboard doors.
- SPILLS. Use extreme caution. Clean up any spilled medicines, drugs, or other non-toxic substances. Potentially harmful materials such as bleach, lye, garden chemicals, and gasoline or other petroleum products should be isolated or covered with an absorbent such as dirt or cat litter. When in doubt, leave your home.
- DAMAGED MASONRY. Stay away from chimneys and walls made of brick or block. They may be weakened and could topple during aftershocks. Don't use a fireplace with a damaged chimney. It could start a fire or let poisonous gases into your home.

MYTH #6 Don't be fooled!

"EVERYONE WILL PANIC DURING THE BIG ONE!"

A common belief is that people always panic and run around madly during and after earthquakes, creating more danger for themselves and others. Actually, research shows that people usually take protective actions and help others both during and after the shaking. Most people don't get too shaken up about being shaken up!

The seven steps to earthquake safety

AFTER:

#6 Check for injuries and damage.

#7 When safe, continue to follow your disaster plan.

#7 WHEN SAFE, CONTINUE TO FOLLOW YOUR DISASTER-PREPAREDNESS PLAN.

Once you have met your and your family's immediate needs after an earthquake, continue to follow the plan you prepared in advance *(see Step 2, page 16)*. Aftershocks will continue to happen for several weeks after major earthquakes. Some may be large enough to cause additional damage. Always be ready to drop, cover, and hold on.

Your recovery period can take several weeks to months or longer. Take the actions listed below to be safe and to minimize the long-term effects of the earthquake on your life.

The first days after the earthquake…

Use the information you put together in your disaster plan and the supplies you organized in your disaster kits. Until you are sure there are no gas leaks, do not use open flames (lighters, matches, candles, or grills) or operate any electrical or mechanical device that can create a spark (light switches, generators, motor vehicles, etc.). Never use the following indoors: camp stoves, gas lanterns or heaters, gas or charcoal grills, or gas generators. These can release deadly carbon monoxide or be a fire hazard in aftershocks.

Be in communication

- Turn on your portable or car radio for information and safety advisories.
- Place all phones back on their cradles.
- Call your out-of-area contact, tell them your status, then stay off the phone. Emergency responders need to use the phone lines for life-saving communications.
- Check on the condition of your neighbors.

Food and water

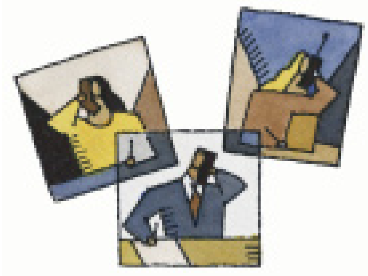
- If power is off, plan meals to use up refrigerated and frozen foods first. If you keep the door closed, food in your freezer may be good for a couple of days.
- Listen to your radio for safety advisories.
- If your water is off or unsafe, you can drink from water heaters, melted ice cubes, or canned vegetables. Avoid drinking water from swimming pools or spas.
- Do not eat or drink anything from open containers that are near shattered glass.

The first weeks after the earthquake…

This is a time of transition. Although aftershocks may continue, you will now work toward getting your life, your home and family, and your routines back in order. Emotional care and recovery are just as important as healing physical injuries and rebuilding a home. Make sure your home is safe to occupy and not in danger of collapse in aftershocks. If you were able to remain in your home or return to it after a few days, you will have a variety of tasks to accomplish:

- If your gas was turned off, you will need to arrange for the gas company to turn it back on.
- If the electricity went off and then came back on, check your appliances and electronic equipment for damage.
- If water lines broke, look for water damage.
- Locate and/or replace critical documents that may have been misplaced, damaged, or destroyed.
- Contact your insurance agent or company right away to begin your claims process.
- Contact the Federal Emergency Management Agency (FEMA) to find out about financial assistance (www.fema.gov/about/process/).

Once you have recovered from the earthquake, go back to Step 1 and do the things you did not do before, or do them more thoroughly. Learn from what happened during the earthquake so you will be safer next time.



If you cannot stay in your home…

If your home is structurally unsafe or threatened by a fire or other hazard, you need to evacuate. However, shelters may be overcrowded and initially lack basic services, so do not leave home just because utilities are out of service or your home and its contents have suffered moderate damage.

If you evacuate, tell a neighbor and your out-of-area contact where you are going. As soon as possible, set up an alternative mailing address with the post office. Take the following, if possible, when you evacuate:

- ☐ Personal disaster supplies kits
- ☐ Medications and eyewear
- ☐ Supply of water, food, and snacks
- ☐ Blanket/pillow/air mattress or sleeping pad
- ☐ Change of clothing and a jacket
- ☐ Towel and washcloth
- ☐ Diapers, food, and other supplies for infants
- ☐ A few family pictures or other comfort items
- ☐ Personal identification and copies of household and health insurance information.

Do not take to a shelter:

- Pets (Service animals for people with disabilities are allowed; take food for them. Have a plan for your pets in advance.)
- Large quantities of unnecessary clothing or other personal items
- Valuables that might be lost, stolen, or take up needed space

Once a Presidential Declaration has been issued, FEMA may activate the *Individuals and Households Program*. This program includes:

- Home-repair cash grants; the maximum Federal grant available (as of 2005) is $26,200
- Housing Assistance in the form of reimbursement for short-term lodging at a hotel
- Rental assistance for as long as 18 months in the form of cash payment
- If no other housing is available, FEMA may provide mobile homes or other temporary housing

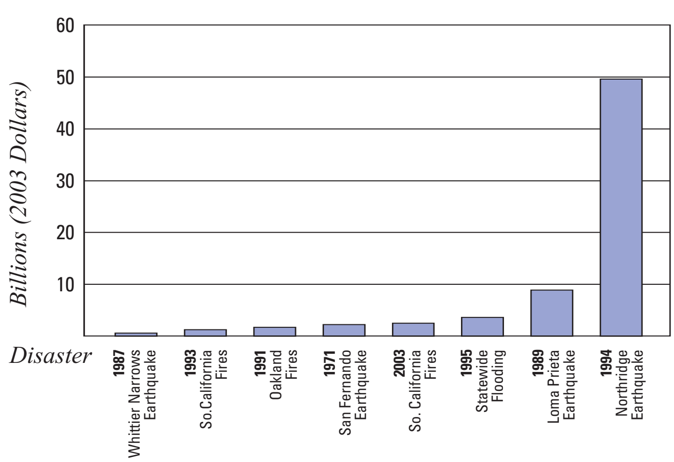
REDUCING THE COSTS OF EARTHQUAKES IN CALIFORNIA

Earthquakes are California's costliest disasters (see graph of disaster costs). They have produced over $60 billion in losses in California since 1971. These losses include building and bridge damage, destruction of building contents, and business interruption. Understanding where future damage is likely to occur can help us take actions now to reduce potential losses and assist in our recovery.

Damage caused by an earthquake depends on the pattern of intense shaking, how many structures are in the area, the quality of construction, and many other factors. If an earthquake the size of the magnitude 6.7 Northridge earthquake were to occur in a more densely populated area with older buildings, fatalities and damage would be much higher.

California's enhanced building codes, strengthened highway structures, and emergency management organizations have reduced the deaths, injuries and damage in recent earthquakes. However, to reduce losses in future earthquakes much more work is needed. Older buildings at risk from earthquakes must be strengthened or rebuilt, emergency managers must be equipped and ready to respond, and individuals must take responsibility for their safety and the protection of their property. Better building codes only apply to new construction, so in most cases it is up to you to strengthen your building by a seismic retrofit.

California's Costliest Disasters



Earthquakes are California's costliest disasters. This chart shows losses from several disasters since 1971, compared using 2003 dollars.

Understanding your potential earthquake risk

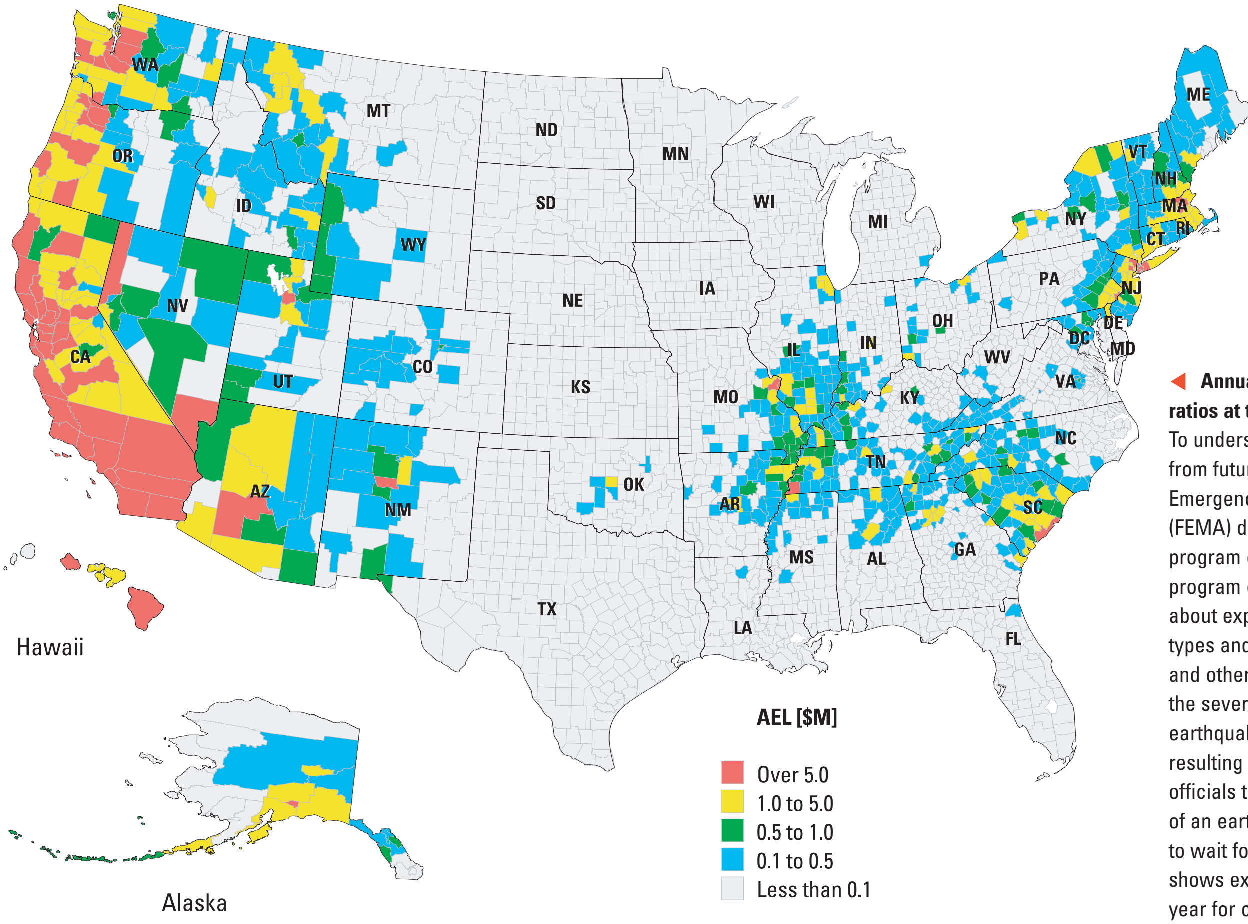
You are at risk for a loss if you own property in earthquake country. If you ask the right questions about your risks and take steps to prepare and protect yourself, you may be able to reduce your risk. This can limit the damage earthquakes may cause to your home and belongings. Here are some factors to consider:

- Consider the geographic location of your property in relationship to identified and active earthquake faults or areas that can have liquefaction or landslides. *(See page 10)*
- Know what type of soil your home is built on, and what risks the soil type might bring in the event of an earthquake. *(See page 29)*
- Are your belongings properly secured? *(See Step 1, page 14)*
- Consider the age and type of construction of your home. Do you have a raised foundation with a cripple wall, or is your home resting on a slab foundation? Learn what retrofitting programs are available and how they might benefit your property. *(See Step 4, page 18)*
- Consider the investment you have in your property, including your belongings. How much equity do you have in your property? If a devastating earthquake destroys your property, how would you recover and rebuild?

Individuals interested in estimating the potential losses to their home can follow the guidance suggested in *Understanding Your Risk–Identifying Hazards and Estimating Losses* available from FEMA.

Earthquake insurance in California

If you own your home it is probably your biggest single asset. You have worked hard to secure your piece of the American Dream by becoming a homeowner. In seconds, your dream can become a nightmare when an earthquake strikes and damages your home and personal belongings. Even if you follow the steps in this handbook, it is likely your home will still have some level of damage, and you will need to repair or replace belongings. One option for managing these potential costs is to buy earthquake insurance.



Annualized earthquake loss ratios at the county level
To understand potential losses from future disasters, the Federal Emergency Management Agency (FEMA) developed a software program called HAZUS. This program combines information about expected shaking, building types and locations, population, and other factors to calculate the severity of damage that an earthquake may cause and resulting costs. This allows officials to estimate the impacts of an earthquake without having to wait for it to occur. This map shows expected losses each year for counties in the United States, averaged over many years. Los Angeles County has the highest expected loss of any county in the country, at over $1 billion each year on average. In addition, the Southern California region contains almost half the Nation's $4.4 billion in projected annualized loss.

Earthquake insurance in California is typically not part of your homeowners insurance policy; it is generally a separate policy you can purchase when buying homeowners insurance. All insurance companies that sell residential property insurance in California are required by law to offer earthquake insurance to homeowners when the policy is first sold and then every two years thereafter.

The cost of the earthquake policy you are offered is based on a number of factors, including your home's location, age, construction type, and value. It is up to each homeowner to consider their individual risk factors and then weigh the cost of earthquake coverage against the benefits that coverage may offer after a devastating earthquake.

Many companies issue California Earthquake Authority (CEA) insurance policies, which are designed to rebuild your home if it suffers significant damage from an earthquake.

You may purchase a CEA policy only through the CEA's participating insurers. A complete list is on the CEA web site at www.earthquakeauthority.com, which has an online premium calculator.

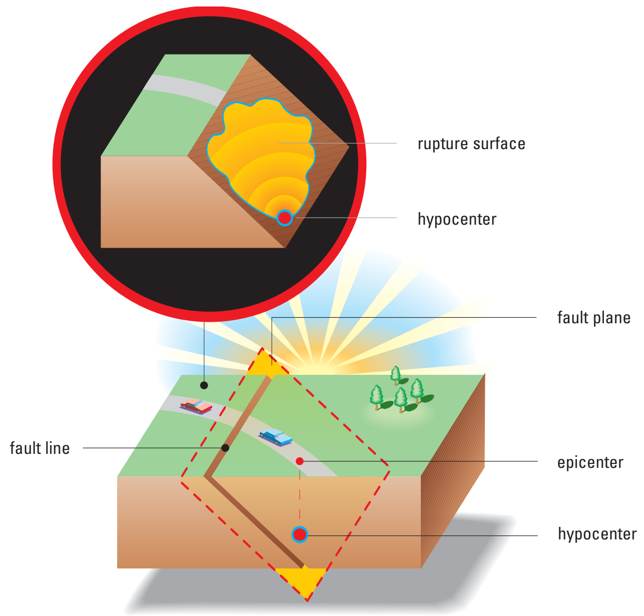
Contact your homeowners insurance company or agent to help you evaluate your earthquake risk factors and then consider whether earthquake insurance is a good choice for you.

EARTHQUAKE BASICS

Epicenter, hypocenter, aftershock, foreshock, fault, fault plane, seismograph, P-waves, magnitude, intensity, peak acceleration, amplification...

We hear them. After big earthquakes, we say them. But what do these terms mean? What do they mean for what we felt and what we will feel the next time? Do we really understand what seismologists are saying?

This section describes how earthquakes happen and how they are measured. It also explains why the same earthquake can shake one area differently than another area. It finishes with information we expect to learn after future earthquakes.



EARTHQUAKES AND FAULTS

What is an earthquake?

An earthquake is caused by a 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 this friction, your fingers move suddenly, releasing energy in the form of sound waves that set the air vibrating and travel from your hand to your ear, where you hear the snap.

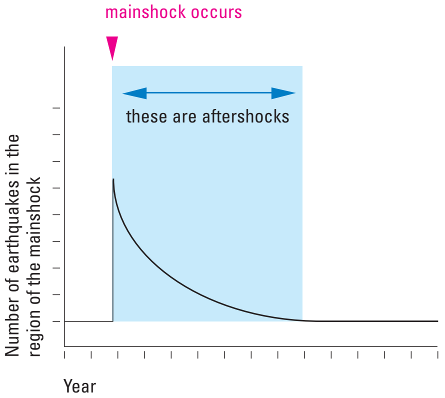
The same process goes on in an earthquake. Stresses in the earth's outer layer push the sides of the fault together. The friction across the surface of the fault holds the rocks together so they do not slip immediately when pushed sideways. Eventually enough stress builds up and the rocks slip suddenly, releasing energy in waves that travel through the rock to cause the shaking that we feel during an earthquake.

Just as you snap your fingers with the whole area of your fingertip and thumb, earthquakes happen over an area of the fault, called the rupture surface. However, unlike your fingers, the whole fault plane does not slip at once. The rupture begins at a point on the fault plane called the hypocenter, a point usually deep down on the fault. The epicenter is the point on the surface directly above the hypocenter. The rupture keeps spreading until something stops it (exactly how this happens is a hot research topic in seismology).

Aftershocks

Part of living with earthquakes is living with aftershocks. Earthquakes come in clusters. In any earthquake cluster, the largest one is called the mainshock; anything before it is a foreshock, and anything after it is an aftershock.

How do we know it's an aftershock?



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

An earthquake large enough to cause damage will probably produce several felt aftershocks within the first hour. The rate of aftershocks dies off quickly. The day after the mainshock has about half the aftershocks of the first day. Ten days after the mainshock there are only a tenth the number of aftershocks. An earthquake will be called an aftershock as long as the rate of earthquakes is higher than it was before the mainshock. For big earthquakes, this might go on for decades.

Bigger earthquakes have more and larger aftershocks. The bigger the mainshock, the bigger the largest aftershock, on average, though there are many more small aftershocks than large ones. Also, just as smaller earthquakes can continue to occur for many years after a mainshock, there is still a chance for a large aftershock long after an earthquake.

Foreshocks

Sometimes what we think is a mainshock is followed by a larger earthquake. Then the original earthquake is considered a foreshock. The chance of this happening dies off quickly with time just like aftershocks. After three days the risk is almost gone.

Sometimes, the chance that an event is a foreshock seems higher than average — usually because of its proximity to a major fault. The Governor's Office of Emergency Services will then issue an advisory based on scientists' recommendations. These are the only officially recognized short-term "predictions."

What is a fault?

Earthquakes occur on faults. A fault is a thin zone of crushed rock separating blocks of the earth's crust. When an earthquake occurs on one of these faults, the rock on one side of the fault slips with respect to the other. Faults can be centimeters to thousands of kilometers long. The fault surface can be vertical, horizontal, or at some angle to the surface of the earth. Faults can extend deep into the earth and may or may not extend up to the earth's surface.

How do we know a fault exists?

- Past fault movement has brought together rocks that used to be farther apart;
- Earthquakes on the fault have left surface evidence, such as surface ruptures or fault scarps (cliffs made by earthquakes);
- Earthquakes recorded by seismographic networks are mapped and indicate the location of a fault.

Some faults have not shown these signs and we will not know they are there until they produce a large earthquake. Several damaging earthquakes in California have occurred on faults that were previously unknown.

How do we study faults?

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, a streambed that crosses the San Andreas fault near Los Angeles is now offset 83 meters (91 yards) from its original course. The sediments in the abandoned streambed are about 2,500 years old. If we assume movement on the San Andreas has cut off that streambed within the last 2,500 years, then the average slip rate on the fault is 33 millimeters (1.3 inches) per year. This does not mean the fault slips 33 millimeters each year. Rather, it stores up 33 millimeters of slip each year to be released in infrequent earthquakes. The last earthquake offset the streambed another 5 meters (16 feet). If we assume that all earthquakes have 5 meters (5000 millimeters) of slip, we will have earthquakes on average every 150 years: 5000 millimeters divided by 33 millimeters per year equals 150 years. This does not mean the earthquakes will be exactly 150 years apart. While the San Andreas fault has averaged 150 years between events, earthquakes have occurred as few as 45 years and as many as 300 years apart.

Carrizo Plain National Monument along the San Andreas fault

THE RESOURCE MINE: To learn more see the web resources listed on page 32.

MYTH #7 Don't be fooled!

"IT'S HOT AND DRY — EARTHQUAKE WEATHER!"

Many people believe that earthquakes are more common in certain kinds of weather. In fact, no correlation with weather has been found. Earthquakes begin many kilometers below the region affected by surface weather. People tend to notice earthquakes that fit the pattern and forget the ones that don't. Also, every region of the world has a story about earthquake weather, but the type of weather is whatever they had for their most memorable earthquake.

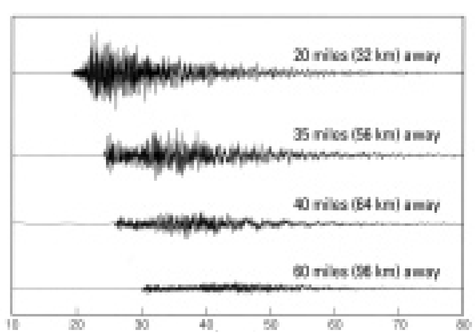
LOCATING AND MEASURING EARTHQUAKES

Where and when was the earthquake?

Earthquakes are recorded by a seismic network. Each seismic station in the network measures the movement of the ground at that site. In an earthquake, the slip of a block of rock over another releases energy that makes the ground vibrate. That vibration pushes the adjoining piece of ground, causing it to vibrate, and thus the energy travels out from the earthquake in a wave. As the wave passes by a seismic station, that piece of ground vibrates and this vibration is recorded.

Earthquakes produce two main types of waves — the P-wave (a compressional wave), and the S-wave (a shear wave). The S-wave is slower but larger than the P-wave and does most of the damage. Scientists have used knowledge of the differences between these and other seismic waves to learn a great deal about the interior of the earth.

Knowing how fast seismic waves travel through the earth, seismologists can calculate the time when the earthquake occurred and its location by comparing the times when shaking was recorded at several stations. This process used to take almost an hour when done manually.



▲ These seismograms show how the ground moved at four seismic stations during an earthquake. The time when ground starts shaking is the arrival of the P-wave. The ground starts shaking sooner and shakes more at sites nearer the earthquake.

Now computers determine this information automatically within minutes. Within a few more hours the shape and location of the entire portion of the fault that moved can be calculated.

We name earthquakes after map locations near epicenters to have a convenient way to refer to them, but this 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 kilometers long and several kilometers wide, and even the epicenter can only be determined within a few tenths of a kilometer. Therefore, giving the location of an earthquake in terms of city streets is like giving the location of your city by the address of City Hall.

How big was the earthquake?

Why do scientists have problems coming up with a simple answer to this simple question? Many people 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 one use of a tape measure. Which dimension do you measure?

Magnitude is the most common way of describing an earthquake's size. In the 1930s, Beno Gutenberg and Charles Richter at the California Institute of Technology developed a method to describe all sizes of earthquakes using a small range of numbers. Using recordings from seismographs, they measured how fast the ground moved at a set distance from earthquakes. If the maximum acceleration of the ground in one earthquake is 10 times the maximum acceleration in another earthquake, then the first earthquake is said to be one unit of magnitude larger than the second. The Richter Scale, as it became known, is not a device, but the range of numbers used to compare earthquakes.

A magnitude 6.0 earthquake has about 32 times more energy than a magnitude 5.0 and about 1,000 times more energy than a magnitude 4.0 earthquake. This does not mean there will be 1,000 times more shaking at your home. A bigger earthquake will last longer and release its energy over a much larger area.

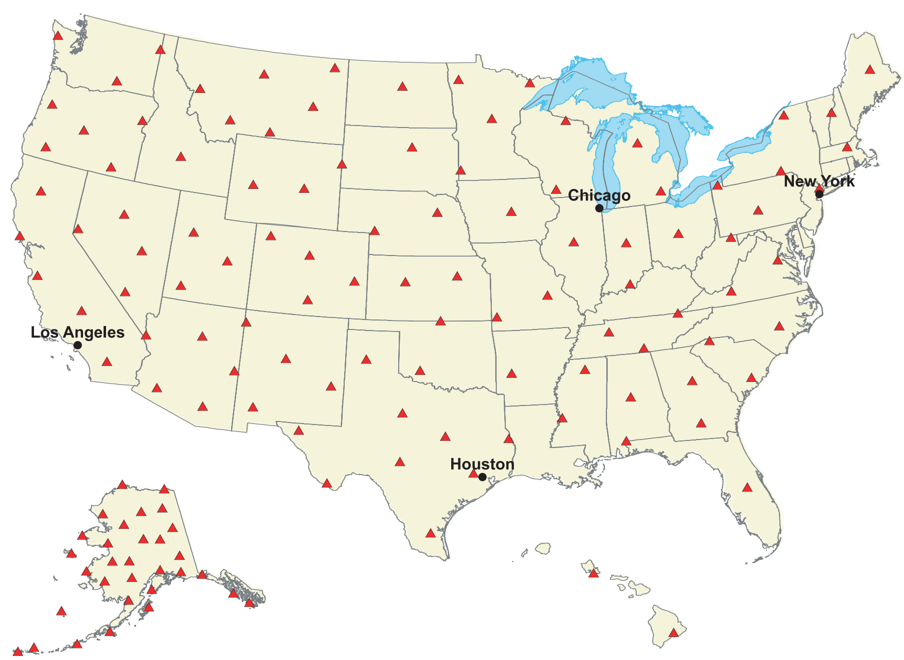
Seismologists have since developed a new measurement of earthquake size, called moment magnitude. Moment is a physical quantity more closely related to the total energy released in the earthquake than Richter magnitude. It can be estimated by geologists examining the geometry of a fault in the field or by seismologists analyzing a seismogram. Because the units of moment are very large, it has been converted to the more familiar range of magnitude values for communication to the public.

Moment magnitude has many advantages over other magnitude scales. First, all earthquakes can be compared on the same scale. (Richter magnitude is only precise for earthquakes of a certain size and distance from a seismometer.) Second, because it can be determined either instrumentally or from geology, it can be used to measure old earthquakes and compare them to instrumentally recorded earthquakes. Third, by estimating how large a section of fault will likely move in the future, the magnitude of that earthquake can be calculated with confidence.

A longer fault can produce a bigger earthquake that lasts a longer time.

Magnitude	Date	Location	Rupture Length (kilometers)	Duration (seconds)
9.2	March 27, 1964	Alaska	1,000	420
7.9	November 3, 2002	Denali, AK	300	90
7.9	January 9, 1857	Fort Tejon, CA	360	130
7.8	April 18, 1906	San Francisco, CA	400	110
7.2 - 7.8	February 7, 1812	New Madrid, MO	40–100	13–30
7.3	June 28, 1992	Landers, CA	70	24
7.3	August 17, 1959	Hebgen Lake , MT	44	12
7.0	October 17, 1989	Loma Prieta, CA	40	7
7.0	October 28, 1983	Borah Peak, ID	34	9
6.8	February 28, 2001	Nisqually, WA	20	6
6.7	January 17, 1994	Northridge, CA	14	7
6.4	March 10, 1933	Long Beach, CA	15	5
5.9	October 1, 1987	Whittier Narrows, CA	6	3
5.8	June 28, 1991	Sierra Madre, CA	5	2
5.2	September 3, 2001	Yountville (near Napa), CA	4	2

For comparison, the largest earthquake ever recorded was a moment magnitude 9.5 in Chile on May 18, 1960.

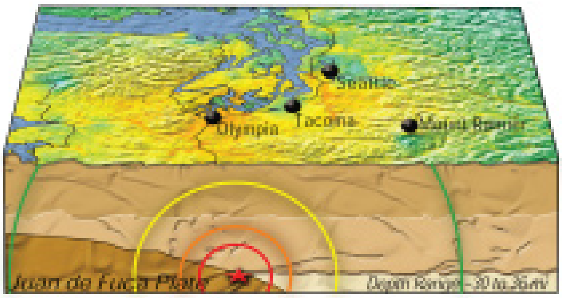


▲ Shown are the 100 stations of the Advanced National Seismic System's (ANSS) backbone network. When completed the ANSS will include 1,000 regional stations in areas of active seismicity and 6,000 strong motion stations in 26 urban areas at risk to damaging earthquakes. These stations will build upon the existing networks of seismographs already existing in high-seismic areas such as Southern California, and improve the accuracy of locating and measuring earthquakes throughout the country.

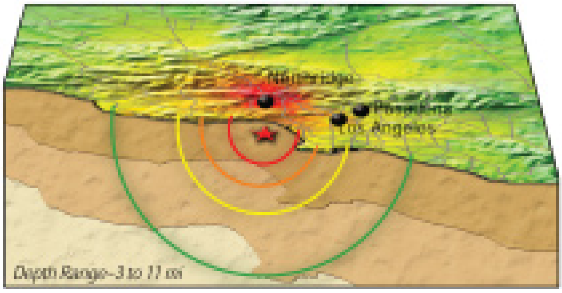
EARTHQUAKE SHAKING

Magnitude is a measurement of the energy produced by an earthquake and is not a measure of the shaking you feel. What you feel is very complex — hard or gentle, long or short, jerky or rolling — and is not describable with one number. Aspects of the motion are described by the velocity (how fast the ground is moving), acceleration (how quickly the speed of the ground is changing), the frequency (seismic waves vibrate at different frequencies just like sound waves), and the duration (how long the strong shaking lasts). What you feel in an earthquake is controlled by three main factors: magnitude, distance, and local soil conditions.

2001
M6.8 Nisqually
Earthquake



1994
M6.7 Northridge
Earthquake



▲ The 2001 Nisqually (M6.8) and 1994 Northridge (M6.7) earthquakes shown above provide an interesting example of how distance from an earthquake affects the level of shaking experienced. Even though the Nisqually earthquake was slightly larger than the Northridge earthquake on the magnitude scale, the resulting damage was far less. One reason is that the section of fault that moved was much deeper than the fault that moved in the Northridge earthquake. Therefore every house was at least 50 kilometers (30 miles) away from the fault.

Magnitude

Typically you will feel more intense shaking from a big earthquake than from a small one. Bigger earthquakes also release their energy over a larger area and for a longer period of time.

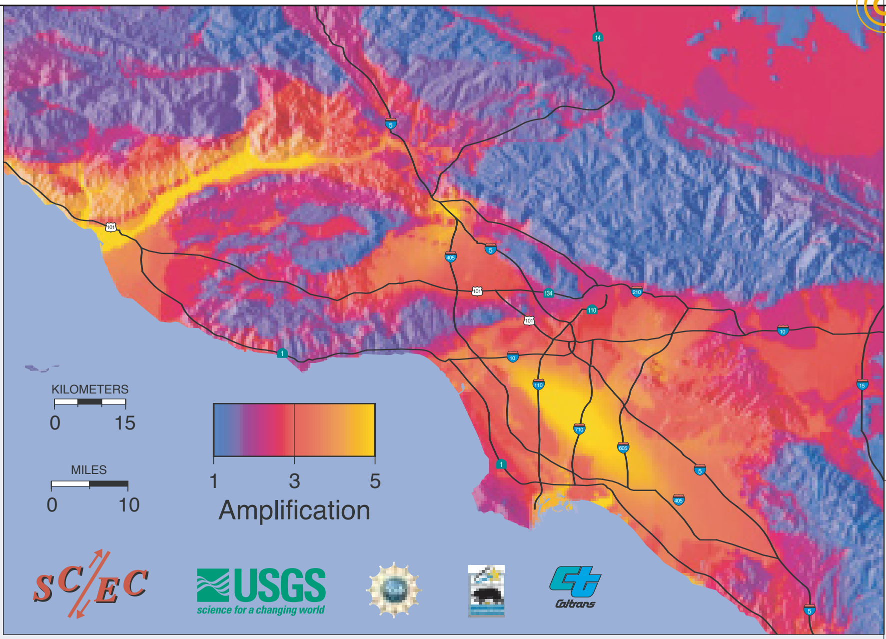
An earthquake begins at a hypocenter, and from there the rupture front travels along the fault, producing waves all the time it is moving. Every point crossed by the rupture front gives off shaking, so longer faults produce bigger earthquakes that have longer durations. The actual durations of 15 earthquakes are shown on the previous page. 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 for 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 1857 ruptured almost 360 kilometers (220 miles) of the fault. At 3 kilometers (2 miles) per second, it took two minutes for that length of fault to rupture, so you would have felt shaking for several minutes. If the idea of a two-minute earthquake frightens you, remember that some of the energy will be traveling from 400 kilometers (250 miles) away. In most cases, only the 10–15 seconds of shaking that originates from the part of the fault nearest you will be very strong.

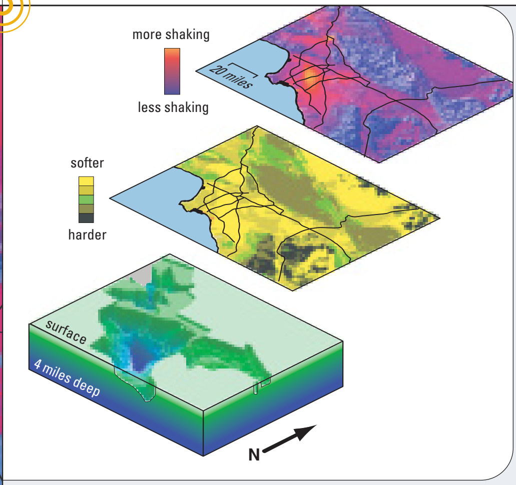
Distance

Earthquake waves diminish in intensity as they travel through the ground, so earthquake shaking is less intense farther from the fault.

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



Earthquake Ground-Motion Amplification in Southern California

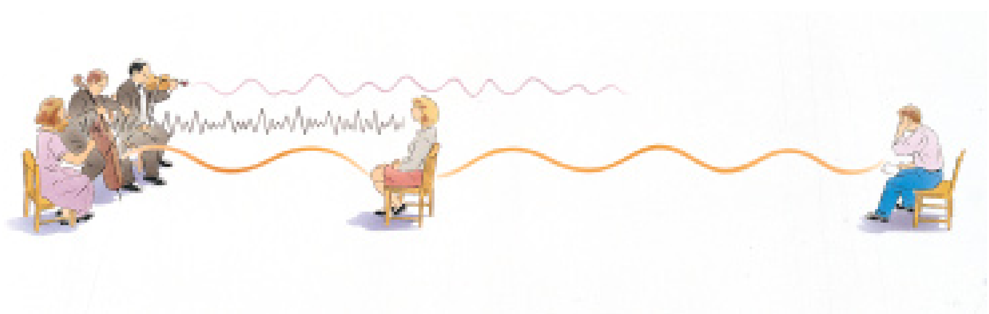


Relative Shaking in Future Earthquakes
In these images of the Los Angeles Basin, the lowest layer shows the depth of sedimentary basins, and the middle layer shows the softness of near-surface rocks and sediments. The top layer is the total amplification expected in future earthquakes because of these features.

The amount of damage to a building does not depend solely on how hard it is shaken. In general, smaller buildings such as houses are damaged more by higher frequencies, so usually houses must be relatively close to the hypocenter to be severely damaged. Larger structures such as high-rises and bridges are damaged more by lower frequencies and will be more noticeably affected by the largest earthquakes, even at considerable distances. The shaking dies off with distance more quickly in the western United States than in the older, more rigid crust of the eastern United States.

Local soil conditions

Soils can greatly amplify the shaking in an earthquake. Passing from rock to soil, seismic waves slow down but get bigger. Hence a soft, loose soil may shake more intensely than hard rock at the same distance from the same earthquake. An extreme example for this type of amplification was in the Marina district of San Francisco during the 1989 Loma Prieta earthquake. That earthquake was 100 kilometers (60 miles) from San Francisco, and most of the Bay Area escaped serious damage. However, some sites in the Bay Area on landfill or soft soils experienced significant shaking. This amplified shaking was one of the reasons for the the collapse of the elevated Nimitz freeway. Ground motion at those sites was more that 10 times stronger than at neighboring sites on rock.



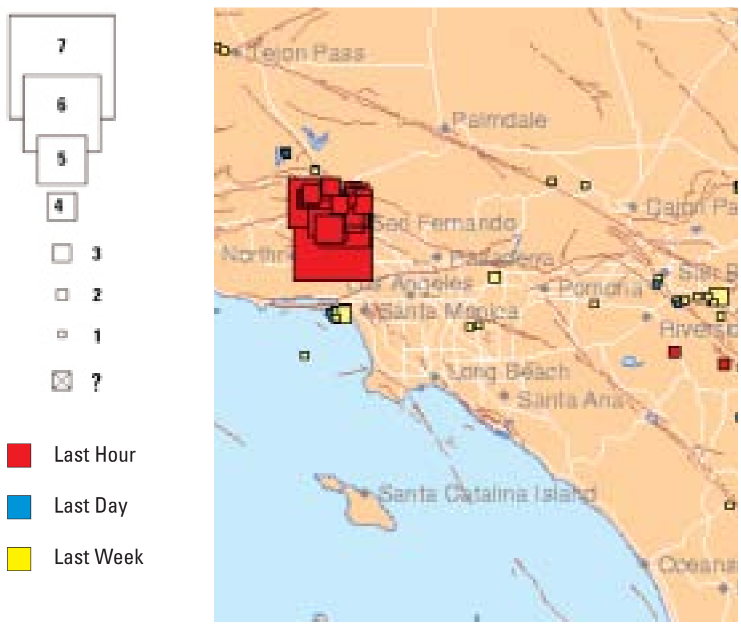
The same factors also apply to areas covered by thick sediment — such as the Los Angeles basin in Southern California where sediments can be as much as 10 kilometers (6 miles) thick. Shaking from an earthquake in the region can be 5 or more times greater at a site in the basin than the level of shaking in the nearby mountains.

P.S.

Several other factors can affect shaking. Earthquake waves do not travel evenly in all directions from the rupture surface; the orientation of the fault and the direction of movement can change the characteristics of the waves in different directions. This is called the radiation pattern. When the earthquake rupture moves along the fault, it focuses energy in the direction it is moving so that a location 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 directivity.

INFORMATION AVAILABLE AFTER EARTHQUAKES

Experiencing an earthquake can be frightening and confusing. Knowing what just happened can reduce our fear and help us understand what to expect next. This page describes information that will be available from various organizations after an earthquake, and how you can also provide valuable information.



Recent Earthquakes Map
5:30 am, January 17, 1994 (one hour after the Northridge earthquake).

Recent earthquake maps

Modern seismic networks can automatically calculate an earthquake's magnitude and location within a few minutes. Local networks of the Advanced National Seismic System (ANSS) have web sites with automatically generated maps and lists of recent earthquakes in their region.

For recent Southern California earthquakes, visit the Southern California Earthquake Data Center at www.data.scec.org

Because waves from large earthquakes travel throughout the world, networks both near and far will calculate the magnitude and location of an earthquake. These networks will sometimes report different magnitudes for the same earthquake, because of differences in seismometers and techniques. This has become less likely as moment magnitude becomes more commonly used (see *page 27*).

Mapping the intensity of shaking

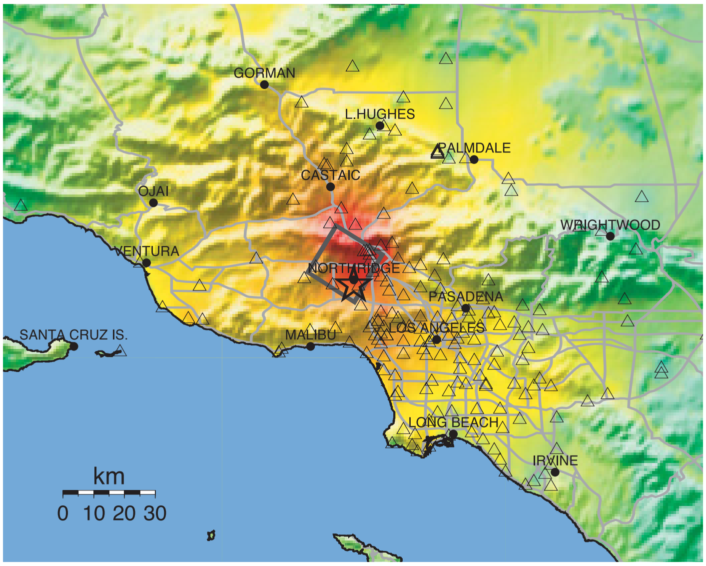
The ShakeMap and "Did You Feel It?" maps shown on the opposite page express the level of shaking experienced in terms of a range of intensities similar to the Modified Mercalli Intensity Scale. While magnitude describes the total energy released by the earthquake, intensity describes the level of shaking produced by the earthquake at a certain location. A single earthquake will have one magnitude value but will have many values for intensity, usually decreasing with distance from the epicenter. ShakeMap uses instruments to measure this shaking, while "Did You Feel It?" uses input from people about how strongly they were shaken and observations of how much damage was caused. Both systems map shaking according to increasing levels of intensity that range from imperceptible shaking to catastrophic destruction. The level of intensity is designated by Roman numerals.

ShakeMap

Modern seismic networks, with digital instruments and high-speed communications, have enabled seismic data to be used in new and innovative ways. A product of these new networks is ShakeMap, which shows the distribution of ground shaking in a region. This information is critical for emergency management. ShakeMaps are automatically generated and distributed on the Internet for most felt earthquakes (to view maps for Southern California earthquakes, visit www.cisn.org/shakemap). This information may save lives and speed recovery efforts.

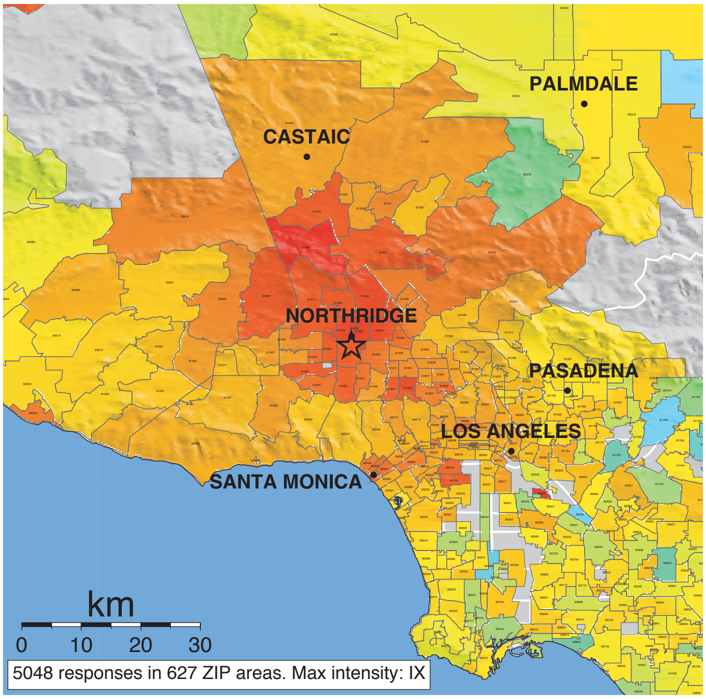
ShakeMap was first developed for Southern California as part of the TriNet Project, a joint effort by the U.S. Geological Survey (USGS), California Institute of Technology (Caltech), and the California Geological Survey (CGS).

Instrumental Intensity Map *(ShakeMap)*
1994 Northridge earthquake



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Community Internet Intensity Map *("Did You Feel It?")*
1994 Northridge earthquake



INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

"Did You Feel It?" community-made earthquake shaking maps

Not long ago, the first thing that most people did after feeling an earthquake was to turn on their radio for information. Now many people are getting this information via the Internet, and sharing their experience of the earthquake online. "Did You Feel It?" is a web site developed by the USGS (and regional seismic networks) that allows people to share information about the effects of an earthquake. Visitors to the site enter their ZIP code and answer a list of questions such as "Did the earthquake wake you up?" and "Did objects fall off shelves?" These responses are converted to intensities for each ZIP code and within minutes a map is created on the Internet that is comparable to ShakeMaps produced from seismic data. The map is updated frequently as people submit reports. Such "Community Internet Intensity Maps" contribute greatly in quickly assessing the scope of an earthquake emergency, especially in areas lacking seismic instruments. To report your experience of an earthquake, visit earthquake.usgs.gov/eqcenter/dyfi.php.

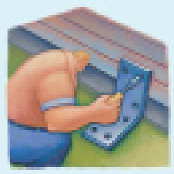
THE RESOURCE MINE

Earthquake Country **Alliance**
We're all in this together.

Answers for many of your questions, additional resources for the sections below, and online versions of the Southern California and San Francisco Bay Region editions of this handbook in multiple languages can be found at:

www.earthquakecountry.info

Why should I **care?**



Why should I care? (Page 4)

Historic Earthquakes in Southern California clickable map: www.data.scec.org/clickmap.html

Recent Earthquakes in Southern California: www.data.scec.org/recenteqs.html

Southern California clickable fault map: www.data.scec.org/faults/faultmap.html

California Geological Survey – Seismic Shaking Hazard Maps: www.consrv.ca.gov/CGS/rghm/psha/pga.htm

Landslide and Liquefaction Maps for Southern California: gmw.consrv.ca.gov/shmp

What should I **do?**

What should I do? (Page 12)

Earthquake Country Alliance: www.daretoprepare.org

American Red Cross: www.redcross.org

California Earthquake Authority: www.earthquakeauthority.com

California Seismic Safety Commission: www.seismic.ca.gov

Emergency Survival Program (ESP): www.espfocus.org

California Office of Emergency Services: www.oes.ca.gov

Federal Emergency Management Agency: www.fema.gov

"Step 1" in greater detail: www.quakeinfo.org

What should I **know?**

What should I know? (Page 24)

United States Geological Survey Earthquake Hazards Program: earthquake.usgs.gov

California Geological Survey: www.consrv.ca.gov/cgs

Southern California Earthquake Center: www.scec.org

Southern California Earthquake Data Center: www.data.scec.org

Recent Earthquakes in Southern California: www.data.scec.org/recenteqs.html

Southern California ShakeMaps: www.cisn.org/shakemap

Did You Feel It? - report it!: earthquake.usgs.gov/eqcenter/dyfi.php

Additional funding provided by:

National Science Foundation

USGS science for a changing world

U.S. Department of Homeland Security FEMA