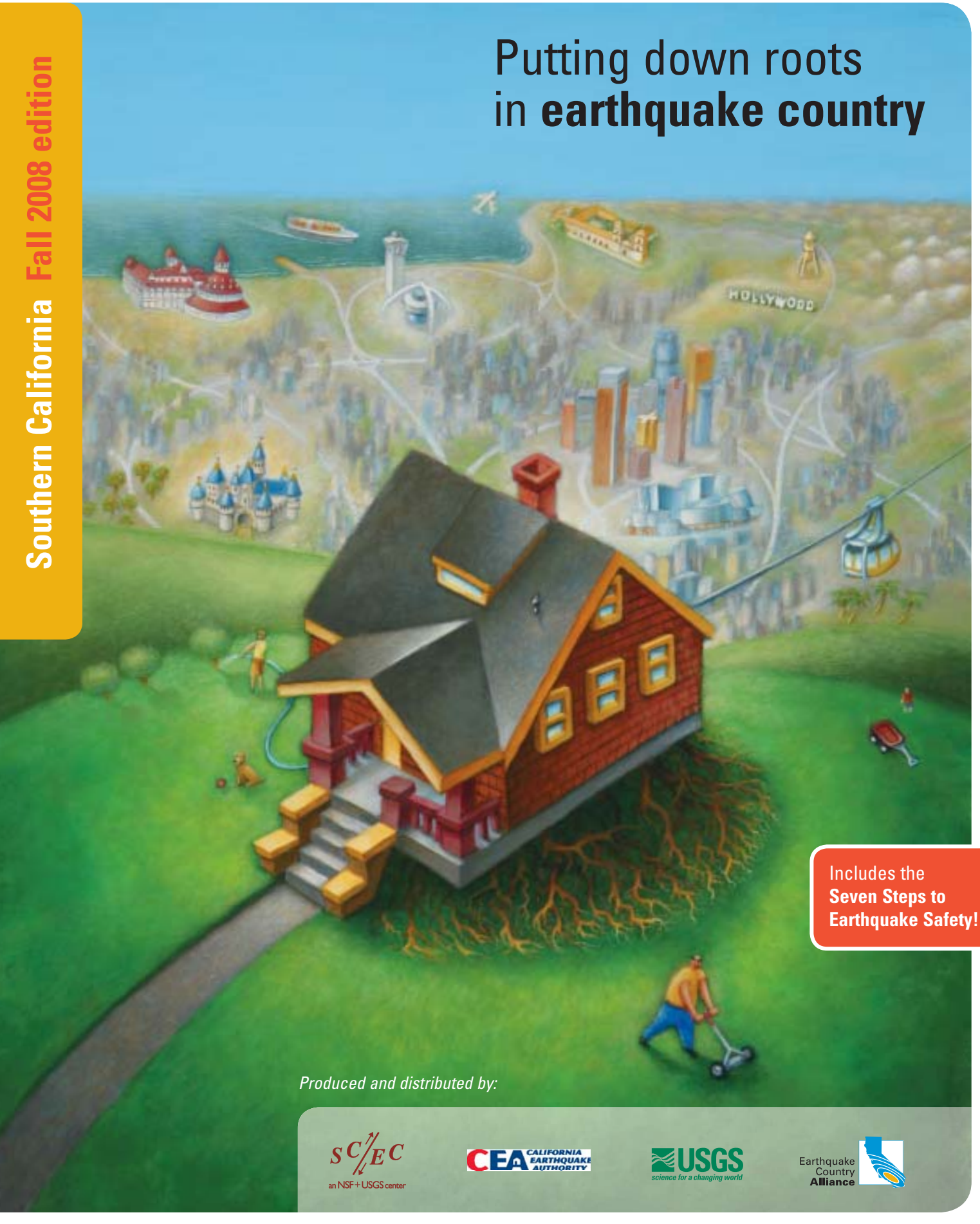
Southern California **Fall 2008 edition**

# Putting down roots in **earthquake country**




Includes the **Seven Steps to Earthquake Safety!**

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CEA California Earthquake Authority

USGS science for a changing world

Earthquake Country **Alliance**

# 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.**

*Disclaimer:* The suggestions and illustrations included in this document are intended to improve earthquake awareness and preparedness; however, they do not guarantee the safety of an individual or a structure. The writers, contributors, and sponsors of this handbook do not assume liability for any injury, death, property damage, or other effect of an earthquake.

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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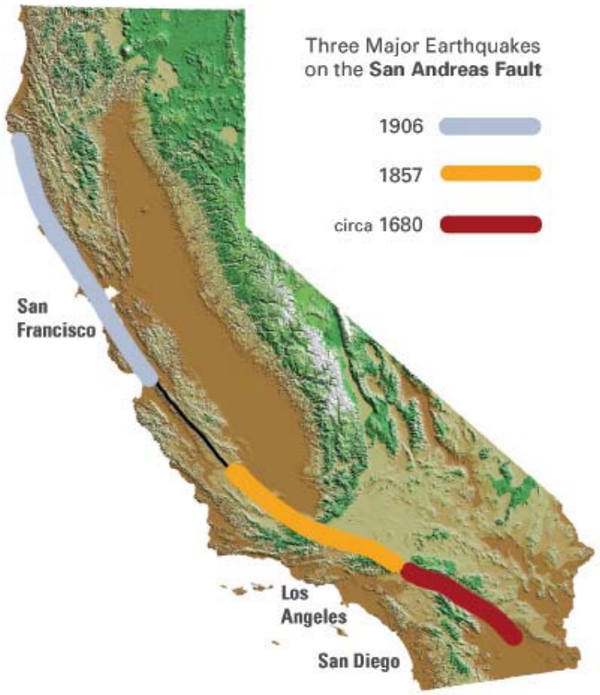



Generations of Californians have been "putting down roots" along one of the world's most famous faults—the San Andreas. However, few Californians have experienced a major San Andreas earthquake. In Northern California, the last major earthquake was 100 years ago in 1906. Over 3,000 people were killed 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 1680). Another major earthquake is likely to happen on this section of the fault within our lifetime, and will shake all of Southern California. A study led by the U.S. Geological Survey describes in great detail the extensive damage and casualties that result from such an earthquake, and recommends many ways that we can keep this natural disaster from becoming a catastrophe (see pages 8-11).

While the San Andreas is most likely to be the source of our largest earthquakes, there are hundreds of other faults throughout Southern California that could also cause damaging earthquakes. Some may happen before the next San Andreas earthquake and could be even more destructive if they occur directly beneath densely populated areas.

This handbook is a resource for living in earthquake country. It 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.

## Why should I **care**?

### Southern California *is* Earthquake Country



## What should I **do**?

### The Seven Steps to Earthquake Safety



## What should I **know**?

### Earthquake Basics



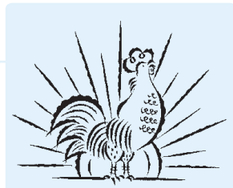
### The Resource Mine

Why should I **care?**

## 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 earthquakes have occurred in the past and where they may likely occur in the future, how the ground will shake when they do, and what may happen in a plausible "big one" on the San Andreas.

**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.

## SOUTHERN CALIFORNIA EARTHQUAKES AND FAULTS

The earthquakes of California are caused by the movement of huge blocks of the earth's crust – the Pacific and North American plates. 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 movement occurs on the San Andreas fault and some parallel faults—the San Jacinto, Elsinore, and Imperial faults (see map). Over time, these faults produce about half of the significant earthquakes of our region, as well as many minor earthquakes.

The last significant earthquake on the Southern California stretch of the San Andreas fault was in 1857, and there has not been a rupture of the fault along its southern end from San Bernardino to the Salton Sea since 1690. It is still storing energy for some future earthquake.

But we don't need to wait for a "big one" to experience earthquakes. Southern California has thousands of smaller earthquakes every year. A few may cause damage, but most are not even felt. And most of these are not on the major faults listed above. The earthquake map at top right shows that earthquakes can occur almost everywhere in the region, on more than 300 additional faults that can cause damaging earthquakes, and countless other small faults.

This is mostly due to the "big bend" of the San Andreas fault, from the southern end of the San Joaquin Valley to the eastern end of the San Bernardino mountains (see diagram at right). Where the fault bends, the Pacific and North American plates push into each other, compressing the earth's crust into the mountains of Southern California and creating hundreds of additional faults (many more than shown in the fault map). These faults produce thousands of small earthquakes each year, and the other half of our significant earthquakes. Examples include the 1994 Northridge and 1987 Whittier Narrows earthquakes.

**What does it mean?**

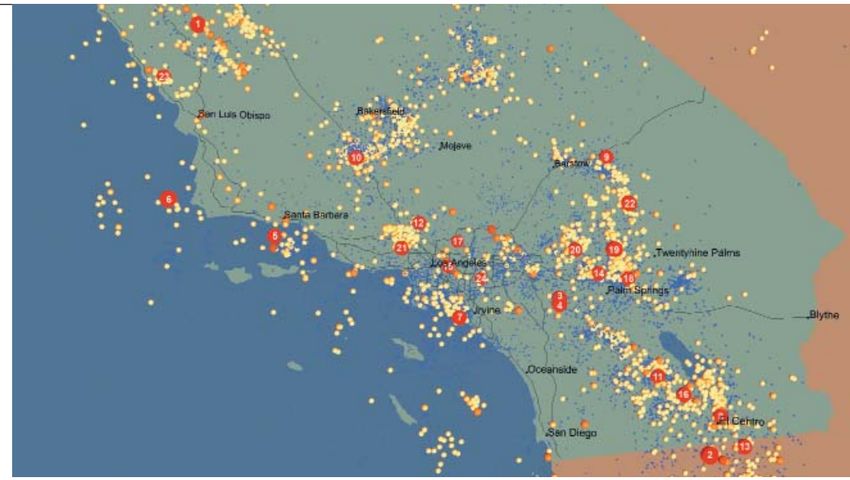
To become familiar with earthquake vocabulary, you may want to read the "What Should I Know" section first.

**Significant Southern California earthquakes since 1857**

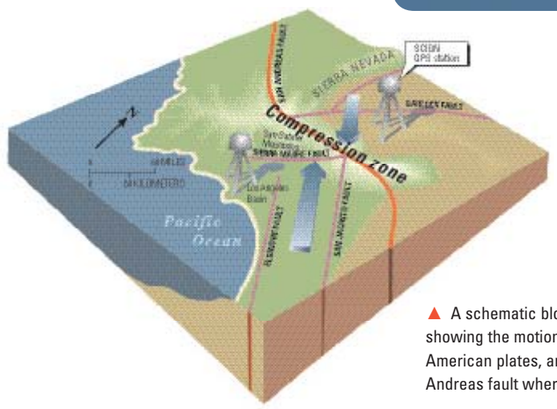
| | Date | Time | Location | Magnitude |
|---|---|---|---|---|
| 1. | 01.09.1857 | 8:24 am | Fort Tejon | 7.9 |
| 2. | 02.24.1892 | 11:20 pm | Laguna Salada | 7.3 |
| 3. | 12.25.1899 | 4:25 am | San Jacinto/Hemet | 6.7 |
| 4. | 04.21.1918 | 2:31 pm | San Jacinto | 6.8 |
| 5. | 06.29.1925 | 7:42 am | Santa Barbara | 6.8 |
| 6. | 11.04.1927 | 5:51 pm | Offshore Lompoc | 7.1 |
| 7. | 03.10.1933 | 5:54 pm | Long Beach | 6.4 |
| 8. | 05.18.1940 | 8:37 pm | Imperial Valley | 6.9 |
| 9. | 04.10.1947 | 7:58 am | Manix | 6.5 |
| 10. | 07.21.1952 | 3:52 am | Kern County | 7.5 |
| 11. | 04.09.1968 | 6:29 pm | Borrego Mountain | 6.6 |
| 12. | 02.09.1971 | 6:01 am | San Fernando | 6.6 |
| 13. | 10.15.1979 | 4:16 pm | Imperial Valley | 6.4 |
| 14. | 07.08.1986 | 2:21 am | North Palm Springs | 5.7 |
| 15. | 10.01.1987 | 7:42 am | Whittier Narrows | 5.9 |
| 16. | 11.24.1987 | 5:15 am | Superstition Hills | 6.6 |
| 17. | 06.28.1991 | 7:43 am | Sierra Madre | 5.8 |
| 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 |
| 24. | 07.29.2008 | 11:42 am | Chino Hills | 5.4 |

**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.




▲ Earthquakes plotted on this map (at their epicenters) include: significant earthquakes since 1850 as red numbered circles corresponding to the table at left; earthquakes larger than magnitude 5.5 (1850-1932) and magnitude 4 (1932-2008) as orange and red small circles; and earthquakes smaller than magnitude 4 (1933-2008) as blue dots. While there are thousands of earthquakes shown, this is only a very small window on the earthquake history of southern California! For recent earthquake information see page 30.


▲ 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.

▲ **SCEC Community Fault Model** This map shows the 3-dimensional structure of major faults beneath Southern California. Vertical faults such as the San Andreas (red 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 as they lie beneath broad areas (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.

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

**MYTH #2 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.

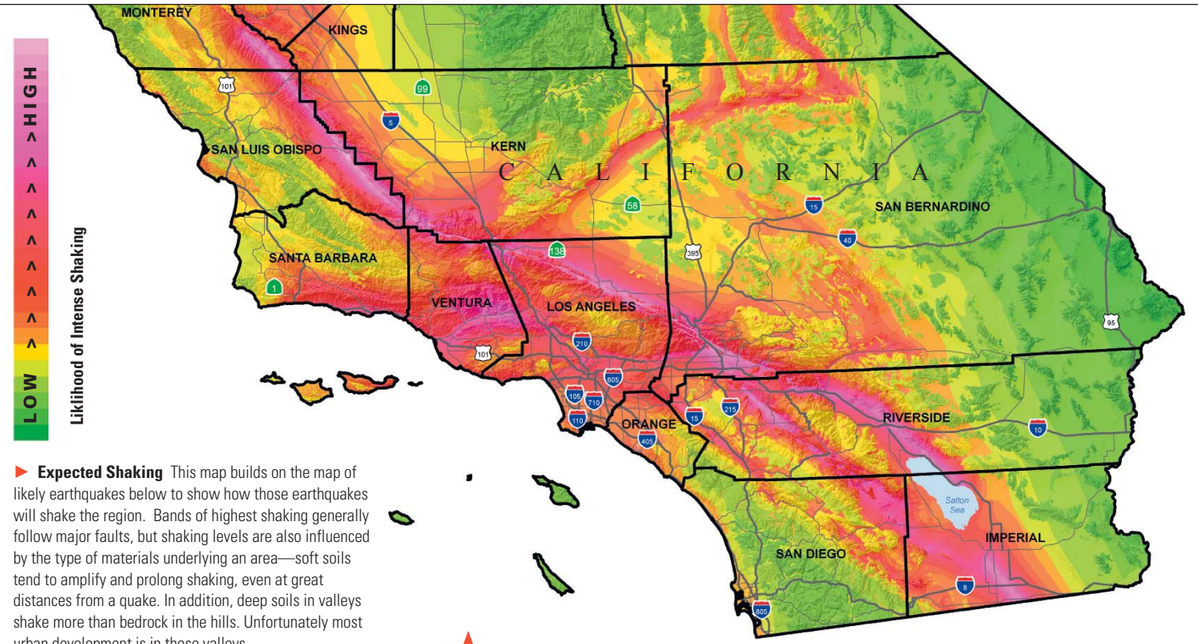
## FUTURE EARTHQUAKES

We know that southern California is subject to frequent—and sometimes very destructive—earthquakes. Forecasts of future quakes help us prepare for these inevitable events. But scientists cannot yet make precise predictions of their date, time, and place, so earthquake forecasts are in the form of probabilities that quakes of certain sizes will occur over longer periods of time.

The most comprehensive statewide analysis of earthquake probabilities (see below), determined that the chance of having one or more magnitude 6.7 or larger earthquakes in California over the next 30 years is 99.7% (see map at lower right). The fault with the highest probability of such earthquakes is the southern San Andreas– 59% in the next 30 years. For powerful quakes of magnitude 7.5 or greater, there is a 37% chance that one or more will occur in the next 30 years in southern California.

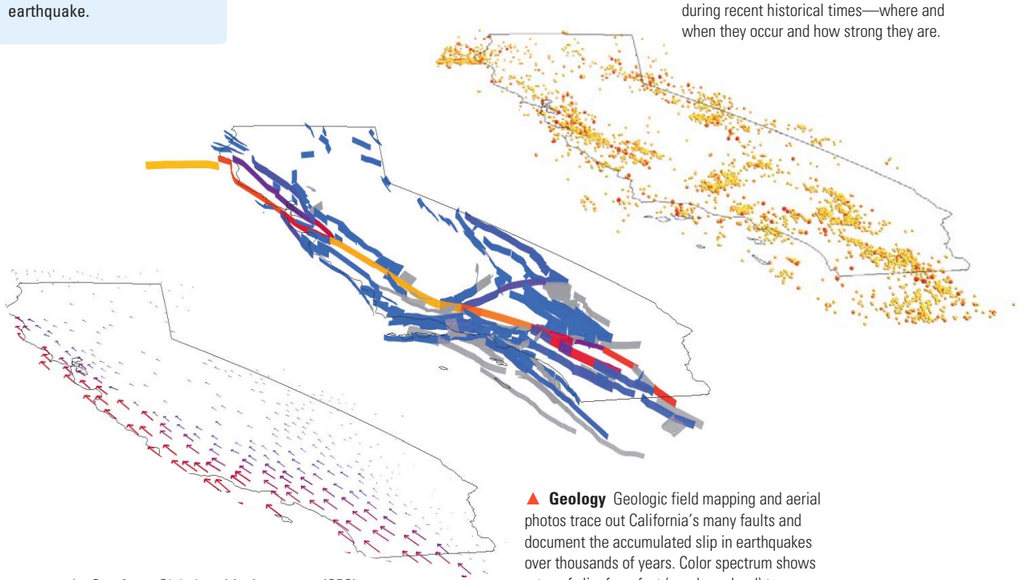
These results are incorporated into national seismic hazard maps, used for implementing building codes, setting earthquake insurance rates, and prioritizing emergency preparedness activities. These maps combine earthquake rupture forecasts with formulas for how shaking varies with distance and factors such as distance from the epicenter and local soil conditions (see pages 28 and 29).

A seismic hazard map produced by the California Geological Survey is shown at top right. Areas in red and pink are more likely to experience strong earthquake shaking. The map adds together shaking from all potential earthquakes. Smaller earthquakes will only cause shaking locally, while larger earthquakes may cause strong shaking throughout southern California.



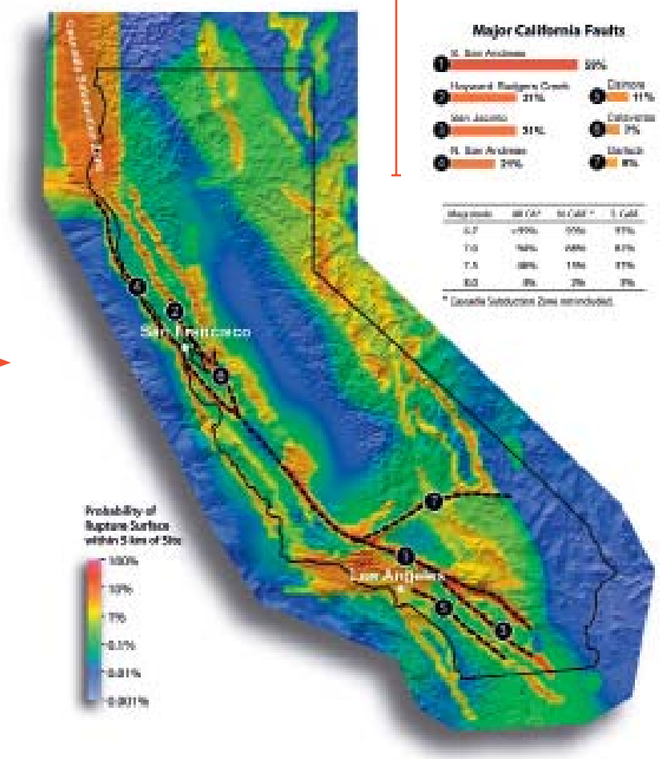

▶ **Expected Shaking** This map builds on the map of likely earthquakes below to show how those earthquakes will shake the region. Bands of highest shaking generally follow major faults, but shaking levels are also influenced by the type of materials underlying an area—soft soils tend to amplify and prolong shaking, even at great distances from a quake. In addition, deep soils in valleys shake more than bedrock in the hills. Unfortunately most urban development is in these valleys.

▼ **Seismology** Monitoring instruments provide a record of California earthquakes during recent historical times—where and when they occur and how strong they are.



▲ **Geodesy** Global positioning system (GPS) observations by satellite document how fast various points in California are moving (arrows) in response to the steady motion of the Pacific and North American tectonic plates.

▲ **Geology** Geologic field mapping and aerial photos trace out California's many faults and document the accumulated slip in earthquakes over thousands of years. Color spectrum shows rates of slip, from fast (purple and red) to very slow (dark blue).




## Earthquake Forecast

Multidisciplinary groups of scientists and engineers, each known as a "Working Group on California Earthquake Probabilities (WGCEP)" have developed earthquake forecasts since 1988. The 2007 WGCEP was commissioned to develop an updated, statewide forecast. The result is the *Uniform California Earthquake Rupture Forecast,* available for download at www.scec.org/ucerf. Organizations sponsoring WGCEP 2007 include the USGS, California Geological Survey, the Southern California Earthquake Center, and the California Earthquake Authority. The comprehensive new forecast builds on previous studies and also incorporates abundant new data and improved scientific understanding of earthquakes.

◀ **The Composite Forecast—UCERF** The final forecast results from evaluating and integrating several types of scientific data. This map shows the likelihood of having a nearby earthquake rupture (within 3 or 4 miles) for all areas of California. Areas along major faults (numbered) stand out as having the highest probabilities for earthquake rupture.

## ONE PLAUSIBLE BIG ONE

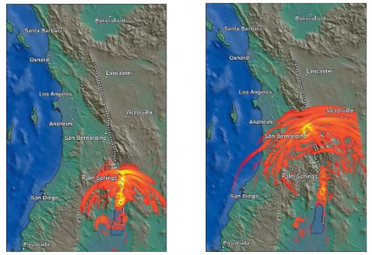
As shown on the previous page, it is only a matter of time before an earthquake strikes southern California that is large enough to cause damage throughout the entire region. What will that earthquake be like, and what will its impacts be? Could this be southern California's version of Hurricane Katrina? What could be done now to reduce these impacts? These are the kinds of questions that motivated the development of the *ShakeOut Earthquake Scenario,* a comprehensive study of a magnitude 7.8 earthquake, led by the U.S. Geological Survey with the Southern California Earthquake Center, California Geological Survey, and hundreds of experts. The study was the basis of The Great Southern California ShakeOut, the largest earthquake readiness campaign in U.S. history.

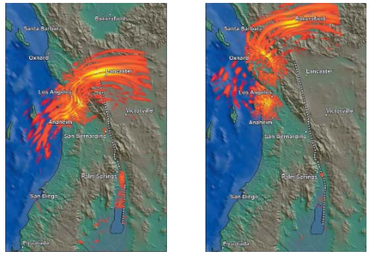
The "what if?" earthquake modeled in this study ruptures the southern San Andreas Fault for more than 200 miles (black line on map below). The epicenter is on the northeast side of the Salton Sea in Imperial County, though strong shaking will be produced all along the fault as it ruptures through the Coachella Valley, into San Bernardino, across the Cajon Pass and further to the northwest until ending near Lake Hughes west of Lancaster.

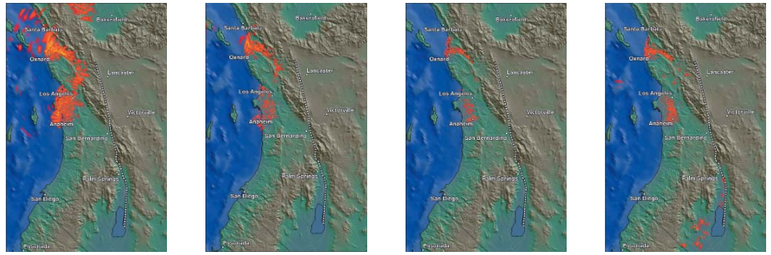
As the rupture progresses it will offset the ground along the fault by more than 20 feet in places, and bend or break any road, railroad, pipeline, aqueduct, or other lifeline that crosses the fault. Overall the rupture will produce more than 100 seconds of shaking throughout southern California. As shown in the large ShakeMap at left, shaking will be strong along the fault but also further away where soil type, thickness of sediments, and other factors amplify earthquake shaking. In some areas, the ground will shift violently back and forth, moving nearly 2 meters (6 feet) in each second—shoving houses off foundations, sending unsecured furniture and objects flying.

The overall shaking in this earthquake will be more than 50 times the shaking produced by the Northridge earthquake (see inset at left). In addition, large earthquakes create earthquake waves that are never created by smaller earthquakes like Northridge. These *long period* waves can cause damage very far from the fault, and are especially damaging to tall buildings or certain infrastructure.

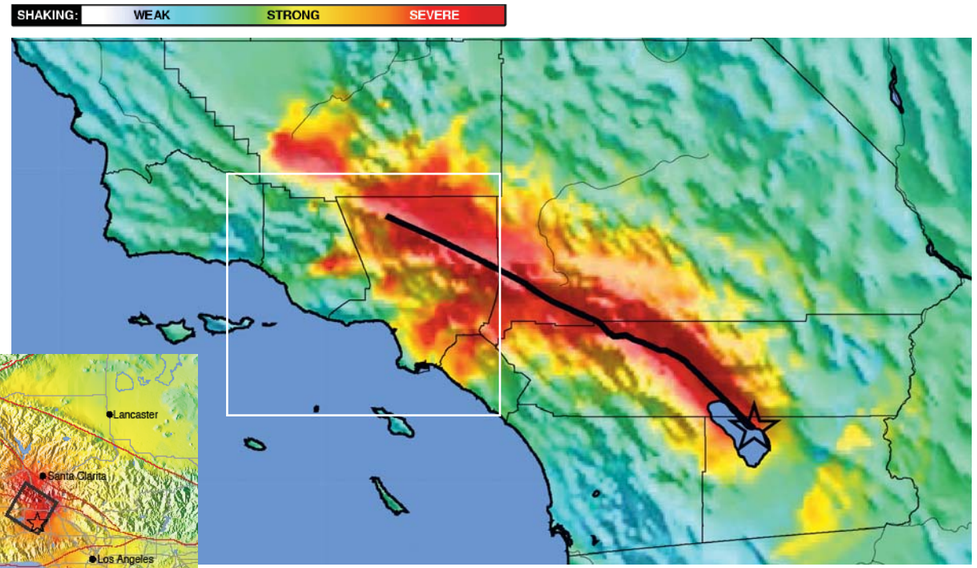
Finally, damage may also result when strong shaking occurs in areas prone to landslides and in materials that are susceptible to liquefaction whenever the groundwater is close enough to the surface. Maps of areas where landslides and liquefaction are possible in future earthquakes are available at www.consrv.ca.gov/cgs.




▲ **Earthquake Shaking Animation** These computer-generated snapshots show maximum velocity of ground motion as the earthquake waves move out from the fault and travel through southern California. Snapshots are taken at 30, 60, 90, 120, 150, 180, 210, and 240 seconds after the fault starts rupturing. Yellow indicates the most damaging level, with orange and red also likely to cause damage. Note the persistent shaking in sedimentary basins where waves have gotten trapped and reverberate. To view the complete movie, visit urbanearth.usgs.gov/shakeout. *[Images credit: Simulation by Rob Graves, URS Corporation, for the Southern California Earthquake Center on high-performance computers at the University of Southern California; images courtesy of Geoff Ely, University of California San Diego/San Diego Supercomputer Center]*




▲ **Shaking Intensities in the *ShakeOut Scenario* Earthquake** An earthquake has only one magnitude and epicenter but a pattern of shaking intensity that depends on several factors. The strongest shaking (red on map) occurs very near the fault and dies off as seismic waves travel away. Away from the fault, in natural basins filled with sediments, some waves get trapped and reverberate, causing pockets of strong shaking (red and orange that in this earthquake persist for as long as a minute. Ground shaking continues as the waves travel away, and in this earthquake, total shaking lasts for more than 3 minutes. *[Map credit: USGS]*

▲ **Shaking Intensities in the Northridge Earthquake** During the 1994 magnitude 6.7 Northridge earthquake, intense shaking affected a much smaller area and millions fewer people. Northridge was not a major earthquake and very few people have experienced one. Even for Scenario experts it is hard to imagine what one would be like. Even for Scenario experts, it proved challenging to think outside the "Northridge box" while studying a much larger earthquake. *[Map credit: USGS]*

## How to Use the *ShakeOut Scenario*

The Scenario describes a *what if* earthquake, not a prediction. More than 300 experts from research, government, and private industry, led by the U.S. Geological Survey, collaborated to identify the physical, social and economic consequences of one plausible earthquake on the San Andreas fault. The full report is available at urbanearth.usgs.gov/scenario08. While this particular earthquake may never occur, that doesn't limit the value of the study.

Looking in detail at one major earthquake provides insight into how to prepare for the other earthquakes that may occur instead. Thus, **appropriate uses of the *ShakeOut Scenario*** include:

- ☐ Urban planning;
- ☐ Emergency response training;
- ☐ School, business, and public earthquake drills;
- ☐ Prioritization of preparedness efforts;
- ☐ Understanding potential impacts on financial and social systems; and
- ☐ Identifying possible vulnerabilities of infrastructure, especially due to interactions among systems that are usually considered separately.

When a major earthquake does occur, it may be on a different fault, or create a different pattern of ground shaking and damage. Thus, **inappropriate uses of the *ShakeOut Scenario*** include:

- ☐ Deciding where to live or work;
- ☐ Concluding you don't have an earthquake problem;
- ☐ Changing building codes; or
- ☐ Evaluating cost-effectiveness of mitigation.

## RECOVERING FROM A BIG ONE

The *Shakeout Scenario* evaluated all aspects of the major earthquake described on the previous page to estimate damages to buildings and infrastructure. From these estimates all other aspects of the study emerged, including emergency response in the critical first week after the earthquake, casualties, mental health and sheltering needs, and the impacts on different sectors of the region's diverse economy.

The study estimates that should it occur, this earthquake will cause some 1,800 deaths and 53,000 injuries. Yet this terrible tragedy could be considerably worse. By comparison, the similarly sized, 2008 Sichuan, China earthquake may have caused 100,000 fatalities

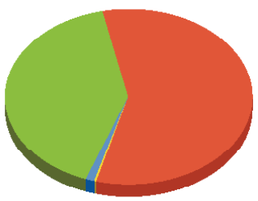
The *ShakeOut Scenario*'s casualty numbers are a testament to decades of life safety improvements in California's building codes, which have evolved as understanding has grown regarding building performance in earthquakes. The intent of the building codes is to protect people during an earthquake, not to keep buildings functional after the quake. Nor do the building codes fix existing buildings that are now recognized to do poorly in earthquakes—it takes retrofitting to do that.

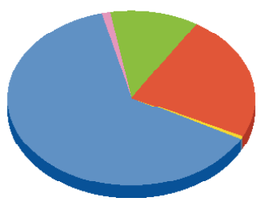
Thousands of older buildings will collapse in the ShakeOut earthquake, and another 45,000 will be complete economic losses.

Earthquakes start fires in numerous ways, and earthquake damages to phones, roads, and buildings enable fires to spread before help can arrive. In areas where there is strong shaking to start fires, and tightly spaced wood buildings that allow fire to spread, the fires will grow into conflagrations, burning tens to hundreds of blocks. Without fires, the ShakeOut earthquake's casualty and loss numbers would be halved.

This earthquake's economic losses total $213 billion, due to shaking damage and several other factors. Because fire damage is so complete, the fires have the worst impact on the costs of replacing buildings and contents. However, disruption of utilities is the main reason that it will take a long time for business to get back to normal.

One important result of the *ShakeOut Scenario* study is that the key to recovery lies with infrastructure: the essential facilities like roads, hospitals and dams; and the lifelines that supply water, power, gas, and communication. The more damage there is to infrastructure, the slower the recovery.




▲ The ShakeOut earthquake will cause many shocks to southern California's regional economy. Understanding and comparing the impact of these shocks is important to recovery planning. When considering the cost of replacing lost buildings, building contents, and infrastructure, fire creates the biggest shock to the economic system, bigger than shaking, fault rupture, landslides, and liquefaction combined. This makes sense, because fire can destroy so completely. However, when considering the length of time that normal business will be interrupted, disruption of utility service creates the biggest shock. This makes sense, because few businesses can function without water or power.

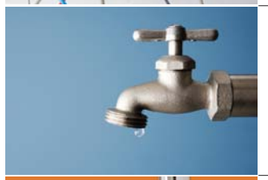
MYTH #3 Don't be fooled!

**"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.

## Lifelines and Facilities — The Key to Recovery

**Power** will go out immediately, everywhere, and restoration times vary. In the most heavily damaged areas, **electricity** will remain out for weeks or longer. Some residences will suffer broken **gas** lines when their houses slip from unbolted foundations.



**Water** will stop flowing in many taps for weeks or months. In many communities, strong ground shaking will break old, brittle water pipes and connectors, and there will be so many breaks that it will prove cheaper and faster to replace the entire conveyance system, rather than hunt and repair every break. The process will be neither cheap nor fast, and communities will compete for repair priority.

Many **wastewater** pipes are also old and brittle, and run alongside water pipes under the streets. Broken sewer pipes will contaminate broken water pipes, and in some places, tap water will be unsafe to drink for as long as a year.

**Telecommunications** will be out for at least a day, because of some damage and much overuse. Phone systems will be oversaturated because millions are trying to make calls at once. How cell phone towers are affixed to buildings is not regulated, so towers will be damaged by shaking. Two thirds of the region's internet lines will be ruptured by the fault.

**Transportation** by road and rail will be disrupted by fault rupture and landslides, and take months to repair. Retrofitting of state highway bridges prevents their collapse, but not those under most local jurisdictions. For months, getting around the southland will take longer, and travel time delays add more than $4 billion to economic losses.


**Hospitals** in the hardest hit counties of Riverside, San Bernardino, and Los Angeles will be operating at reduced functionality. At a time when thousands of disaster victims need hospital care, some hospital buildings will be closed by structural damage; many others will be unusable because of non-structural damage such as broken water pipes and unsecured equipment.

**Public schools**—grades K-12 and community colleges—are protected by the Field Act, legislation that sets special construction and inspection standards. Structurally, public schools will hold up well, although non-structural and contents damage will pose problems. Private schools and universities are not protected by the Field Act and some will suffer both structural and non-structural damage.

The **Ports** of Los Angeles and Long Beach are important contributors to the region's economy. They will not suffer much damage from this far-away earthquake, but their flow of goods will be disrupted for months, as many principal train routes and truck routes are damaged by fault rupture.


▲ To bounce back quickly from a disaster, communities need to become resilient. Community resilience depends on how many individuals, businesses, schools, agencies, and organizations are prepared. It is a lot like voting, where personal decisions and actions can affect everyone: an individual learns about the issues (learns about the earthquake impacts and mitigation strategies), decides how to vote (decides which mitigation efforts will best protect loved ones and financial security), then casts a ballot (takes action to increase preparedness). If enough people vote the same way (get prepared), they will have a winning platform (they will have a resilient community)!

## THE SEVEN STEPS TO EARTHQUAKE SAFETY

Earthquakes are inevitable, but the damage from earthquakes is not–even in a large earthquake on the San Andreas fault such as the one described on previous pages. 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. Actually, almost all earthquake damages and losses can be reduced by steps you take before, during, and after. Many also think that all the damage and injuries from earthquakes comes from collapsing buildings. Again, this isn't the case. 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 that follow include a range of actions to do before, during, and after earthquakes in order to be safe and reduce potential damage. 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 and prevent countless casualties in the next large earthquake.

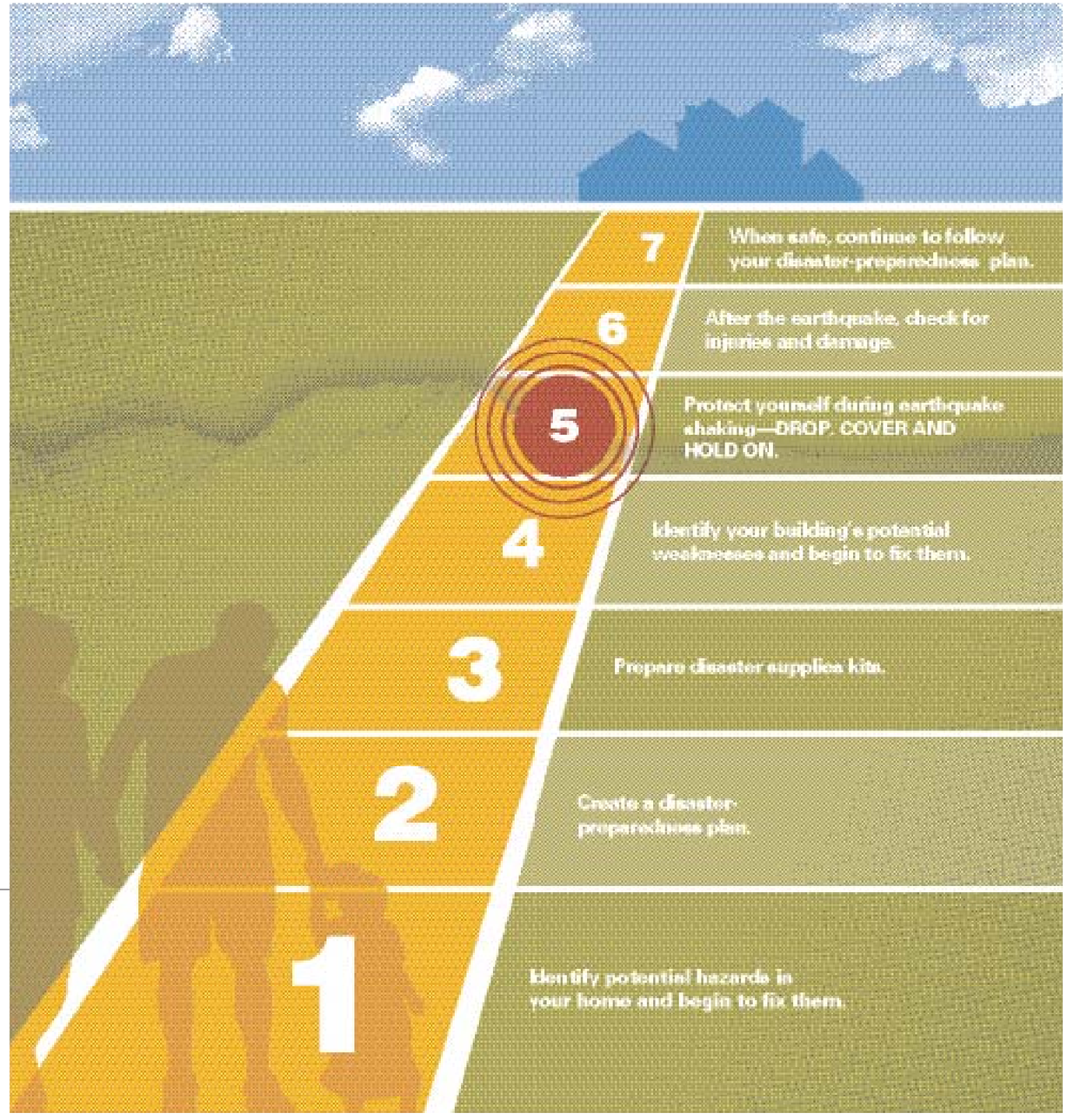
We're all in this together, so talk to your family, friends, neighbors, and co-workers about what you've learned in this handbook about earthquakes in southern California. Then discuss what everyone has done to prepare and plan together what else can be done. Visit www.daretoprepare.org for instructions and resources to help you act now.

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...




Be prepared at home **and** work!

The ***Seven Steps to an Earthquake Resilient Business*** and other supplemental documents are online at www.earthquakecountry.info/roots

**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.

### Objects on open shelves and tabletops

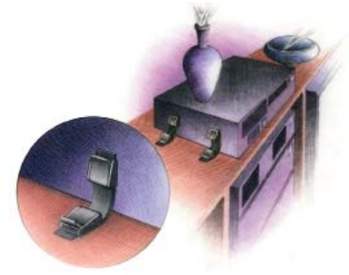
Collectibles, pottery objects, and lamps can become deadly projectiles. Use either hook and loop fasteners on the table and object, or non-damaging adhesives such as earthquake putty, clear quake gel, or microcrystalline wax to secure breakables in place. Move heavy items and breakables to lower shelves.

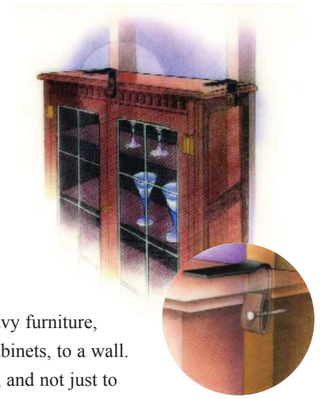
### Hanging objects

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.

### 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.





### Furniture

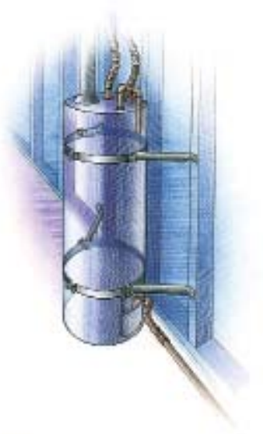
Secure the tops of all top-heavy furniture, such as bookcases and file cabinets, to a wall. Be sure to anchor to the stud, and not just to the drywall. Flexible fasteners such as nylon straps allow tall objects to sway without falling over, reducing the strain on the studs. Loose shelving can also be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

### 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.

### 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.



Additional information, including how-to instructions, is available at

**www.daretoprepare.org**

## #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.
- ☐ Get a fire extinguisher for your home. Your local fire department can train you and your family to use it properly.
- ☐ Teach everyone in your household to use emergency whistles and/or to knock three times repeatedly if trapped. Rescuers searching
- ☐ 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.
- ☐ Install smoke alarms and test them monthly. Change the battery once a year, or when the alarm emits a "chirping" sound (low-battery signal).
- ☐ Work with your neighbors to identify who has skills and resources that will be useful in an emergency, and who may need special attention (children, elderly, disabled, etc.)
- ☐ 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). Financial recovery planning resources are listed at www.daretoprepare.org.

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


www.dropcoverholdon.org





## #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 (ATMs might not work)
- ☐ 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 or much longer in some places 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 supply of the following items to last at least 3 days and ideally for 2 weeks:

- ☐ Water (minimum one gallon a day for each person and pet, for drinking, cooking, and sanitation)
- ☐ 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 (or hand crank for charging)
- ☐ Additional flashlights or light sticks
- ☐ 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.

## 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.

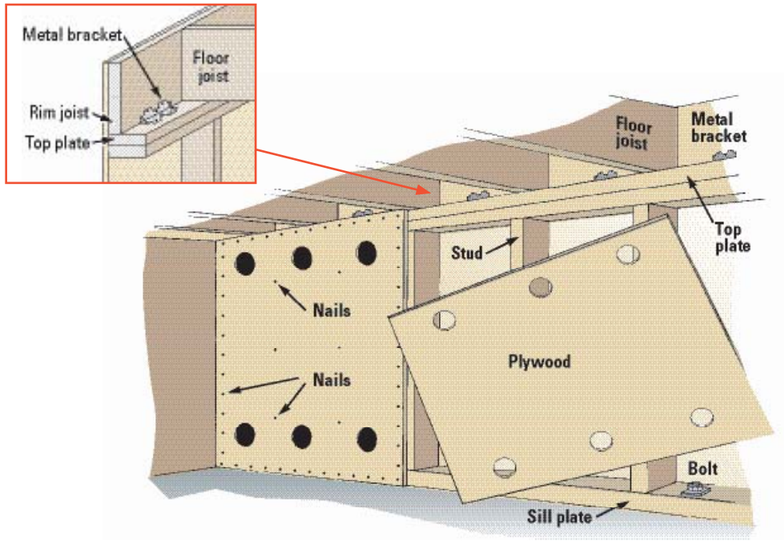
After the earthquake, remember that children will be under great stress. They may be frightened, their routine will probably be disrupted, and the aftershocks won't let them forget the experience. Adults tend to leave their children in order to deal with the many demands of the emergency, but this can 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**




▲ This cutaway diagram shows how weak cripple walls can be strengthened by properly attached plywood sheets. *[Illustration credit: San Leandro EQ Retrofit Program]*

### 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.

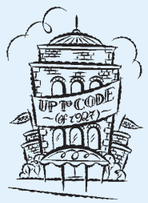
*Inadequate foundations.* Look under your house at your foundation. If the foundation is damaged or built in the "pier and post" style, consult a contractor or engineer about replacing it with a continuous perimeter foundation. Look for bolts in the mudsills. They should be no more than 1.8 meters (6 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.

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.

## Structural-Safety Quiz for Single-Family Home or Duplex

If you live in a single-family home or duplex, the strength of your home depends on when it was built, its style of construction, and its location.

*My score*

**1. When was your home built?**
- ☐ Before 1960 = 5 points
- ☐ 1961–1978 = 3 points
- ☐ After 1978 = 1 point

**2. How tall is your home?**
- ☐ 2 or more stories with living area above a garage = 5 points
- ☐ Split level, on a hillside or gentle slope = 6 points
- ☐ 1 story, 3 or more steps up to the front door = 4 points
- ☐ 1 story, less than 3 steps up to the front door = 1 point

**3. How hard is the ground likely to shake under your home?**
- ☐ Portions of southern California shown as yellow or green in color on the shaking hazard map (page 7) = 5 points
- ☐ Elsewhere in southern California = 7 points

**TOTAL POINTS**

*If your home scores 13 or more points on the quiz, you probably should have an engineer, architect, or contractor evaluate it unless it has been strengthened in the past few years.*

### 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?

### 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."

### 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.

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.

#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?

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.

Learn more about what to do (and what not to do) to protect yourself during earthquakes at www.dropcoverholdon.org.

### If you are…

*Indoors:* **Drop, cover, and hold on.** 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. 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.

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.





#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!

## #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 by visiting www.fema.gov/about/process/.

▲ Sleeping bags and flashlights may be quite handy in the days or weeks after a major earthquake.

### 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 (www.fema.gov/about/process/). 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


**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 and recover more quickly next time.

## 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.

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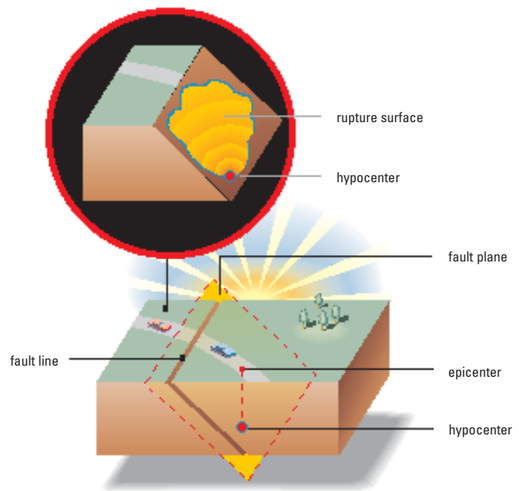



## EARTHQUAKES AND FAULTS

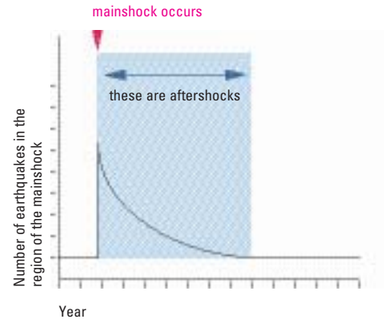
### What is an earthquake?

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).

**How do we know it's an aftershock?**




*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.

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.

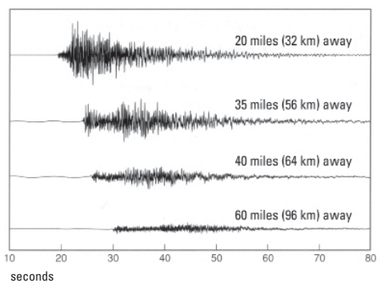
## LOCATING AND MEASURING EARTHQUAKES

### 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.

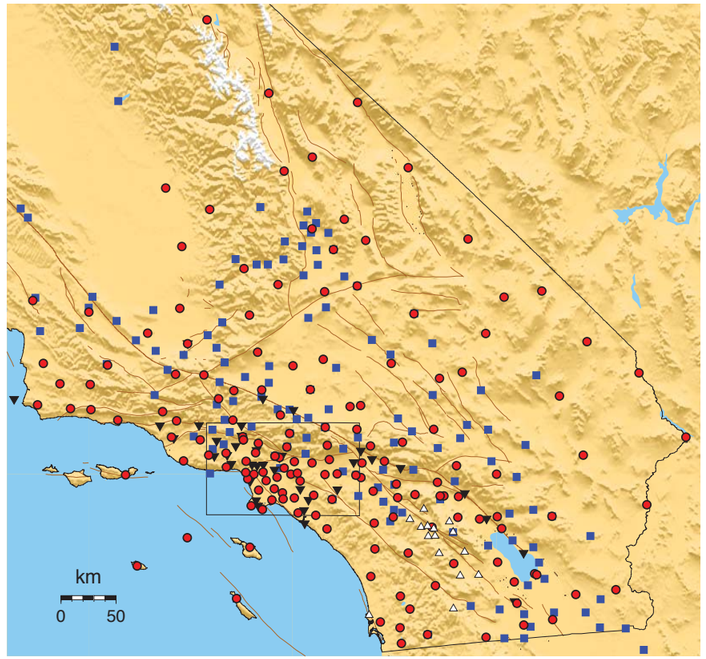
A magnitude 6.0 earthquake has about 32 times more energy than a magnitude 5.0 and about 1,000 times more energy than a magnitude 4.0 earthquake. This does not mean there will be 1,000 times more shaking at your home. A bigger earthquake will last longer and release its energy over a much larger area.

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.**

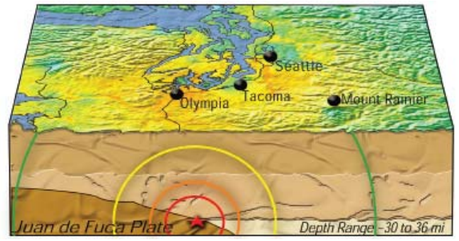
| Magnitude | Date | Location | Rupture Length (kilometers) | Duration (seconds) |
|---|---|---|---|---|
| 9.1 | December 26, 2004 | Sumatra, Indonesia | 1200 | 500 |
| 7.9 | January 9, 1857 | Fort Tejon, CA | 360 | 130 |
| 7.9 | May 12, 2008 | Sichuan, China | 300 | 120 |
| 7.8 | April 18, 1906 | San Francisco, CA | 400 | 110 |
| 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 |
| 5.4 | July 29, 2008 | Chino Hills, CA | 5 | 1 |



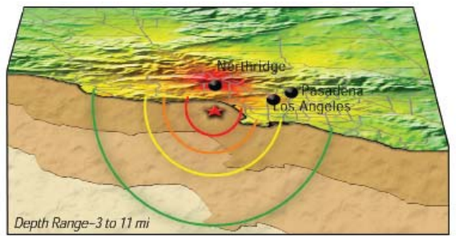

▲ The Southern California Seismic Network (SCSN) records data from more than 370 seismic stations. Each station records seismic waves from both near and distant earthquakes. All the data are transmitted automatically to Caltech/USGS in Pasadena for processing and distribution of information such as epicenters, magnitudes, and ShakeMaps. The SCSN is also part of the California Integrated Seismic Network (CISN) that coordinates earthquake monitoring statewide. The symbols indicate different types of seismic stations.

## 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.

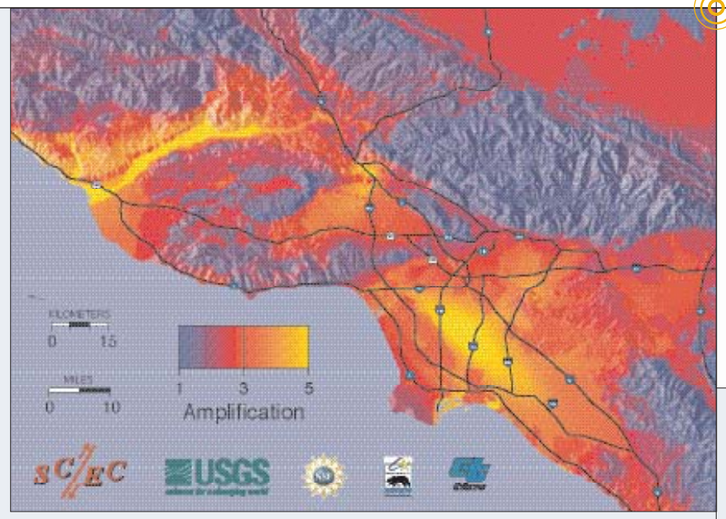
An earthquake begins at a hypocenter, and from there the rupture front travels along the fault, producing waves all the time it is moving. Every point crossed by the rupture front gives off shaking, so longer faults produce bigger earthquakes that have longer durations. The actual durations of 15 earthquakes 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.

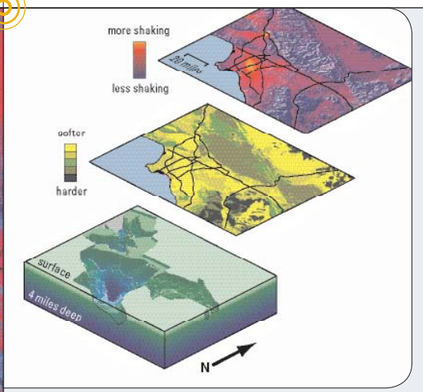
### Distance

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 collapse of the elevated Nimitz freeway. Ground motion at those sites was more that 10 times stronger than at neighboring sites on rock.

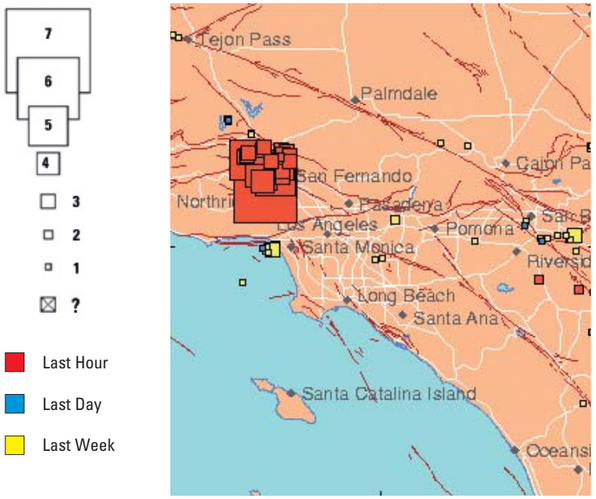
The same factors also apply to areas covered by thick sediment — such as the Los Angeles basin in Southern California where sediments can be as much as 10 kilometers (6 miles) thick. Shaking from an earthquake in the region can be 5 or more times greater at a site in the basin than the level of shaking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

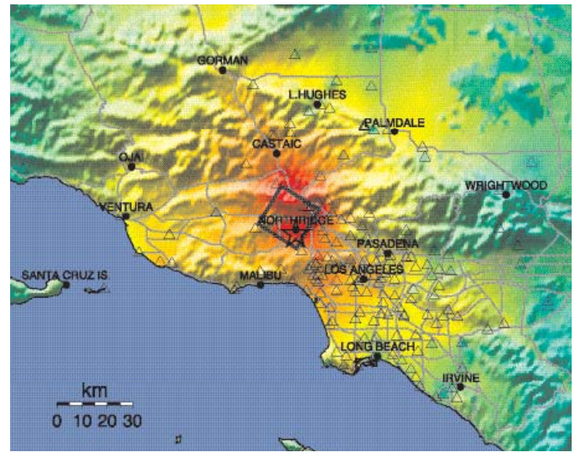
The ShakeMap and "Did You Feel It?" maps shown on the opposite page express the level of shaking experienced in terms of a range of intensities similar to the Modified Mercalli Intensity Scale. While magnitude describes the total energy released by the earthquake, intensity describes the level of shaking 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.

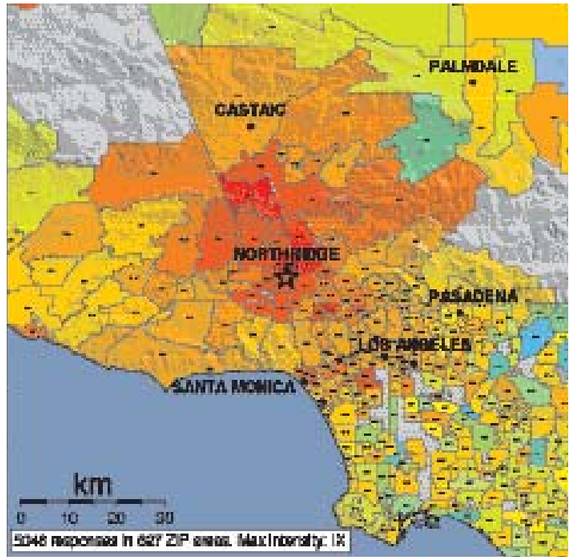
ShakeMap was first developed for Southern California as part of the TriNet Project, a joint effort by the U.S. Geological Survey (USGS), California Institute of Technology (Caltech), and the California Geological Survey (CGS).

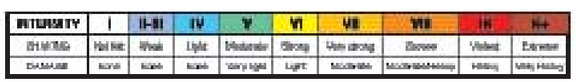
**Instrumental Intensity Map** *(ShakeMap)*
1994 Northridge earthquake





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




### "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, online versions of this handbook in multiple languages, the ***Seven Steps to an Earthquake Resilient Business*** and other supplemental documents, are all available 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

The ShakeOut Earthquake Scenario: urbanearth.usgs.gov/scenario08

### What should I do?

**What should I do?** (Page 12)

Earthquake Country Alliance:
www.daretoprepare.org www.ShakeOut.org www.dropcoverholdon.org www.terremotos.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 support provided by:

National Science Foundation · U.S. Department of Homeland Security · FEMA · The Home Depot "You can do it. We can help." · Quake Hold! quakehold.com · State Farm Insurance