

FAULTS AND EARTHQUAKES IN CALIFORNIA

California straddles the juncture of two great crustal plates: the Pacific plate and the North American plate. Monterey, Santa Barbara, Los Angeles and San Diego are on the Pacific plate, which is constantly moving northwestward past the North American plate. The North American plate includes the rest of California east of the San Andreas Fault. The relative rate of movement is about 2 inches (50 mm) per year. Although the San Andreas Fault is considered the boundary of the two great crustal plates, some of the motion is taken up on faults as far away as central Utah. In California, about 40 mm/year of the slip occurs on the faults of the San Andreas system, and about 10 mm/year of slip occurs on faults in the Mojave Desert and Basin and Range area, east of the Sierra Nevada (a system known as the eastern California shear zone).

FAULTS

The constant motion of the crustal plates causes stress in the brittle upper crust of the earth. These tectonic stresses build up as the rocks are gradually deformed. This rock deformation, or strain, is stored in the rocks as elastic strain energy. When the strength of the rock is exceeded, rupture occurs along a fault. The rocks on opposite sides of the fault slide past each other as the rocks spring back to a relaxed position. The strain energy is released partly as heat and partly as elastic waves called seismic waves. The passage of these seismic waves produces the ground shaking of an earthquake.

Fractures in the earth's crust along which the rocks on one side have shifted relative to those on the other side are called faults. The total amount of displacement along a fault may be a few inches or many miles if it has accumulated over millions of years. Faults are more likely to have future earthquakes if they have had more recent

earthquakes along them, have had greater total displacement, and are aligned so that movement can relieve the accumulating tectonic stresses.

There are thousands of recognized faults in California, hundreds of which have been given formal names, but only a very small number of these pose significant hazards. The motion between the Pacific and North American plates occurs primarily on the faults of the San Andreas Fault system and the eastern California shear zone. Other faults have much lower rates of movement, and correspondingly longer times between significant earthquakes.

In order to classify faults by their relative hazards, geologists have found they can recognize faults that have been active since the last ice age (during the "Holocene," about the last 11,000 years). These include the most active faults, and represent most of the earthquake hazard. Faults that have ruptured to the ground surface in Holocene time are "active" and are included in Alquist-Priolo earthquake fault zones (see <http://www.consrv.ca.gov/cgs/rghm/ap/index.htm>). There are several other definitions of activity, used for other purposes, such as the siting and design of large dams, power plants and other facilities. Another commonly used designation is for faults that have offset geologic units from the Quaternary period (the last 1,800,000 years). Faults that offset Quaternary units are sometimes called "potentially active." Determining if a fault is "active" or "potentially active" depends on geologic evidence, which may not be available for every fault. Although there are probably still some unrecognized active faults, nearly all the movement between the two crustal plates, and therefore the majority of the seismic hazards, are on the well-known active faults.



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Ground shaking from large earthquakes is responsible for most of the damage caused by earthquakes. Damage to structures is related to the type and quality of construction, and foundation materials. Building codes have been periodically revised to account for our current understanding of how earthquake shaking can damage buildings. Other earthquake hazards, including the surface rupture of a fault, and liquefaction and landslides that can be caused by the shaking, are significant hazards. California state law gives the State Geologist the responsibility of establishing zones where detailed geologic studies must be done before development projects can begin. (<http://www.consrv.ca.gov/cgs/rghm/ap/index.htm> and <http://gmw.consrv.ca.gov/shmp/index.htm>).

HOW OFTEN DO EARTHQUAKES OCCUR?

Every day earthquakes are detected in California by sensitive seismographs that record the minute vibrations of the earth. Each year 100 to 150 earthquakes occur in the state that are big enough to be felt, but few of these cause any damage. Earthquakes large enough to cause moderate damage to structures in the vicinity of the epicenter—those of M5 or larger—occur 3 or 4 times a year. The M6 Whittier Narrows earthquakes, caused by a buried thrust fault, resulted in hundreds of millions of dollars worth of property damage.

On the average of once every 2 or 3 years, a moderate earthquake (M6 to 6.9) strikes somewhere in the state. An earthquake of this size, such as the Northridge earthquake of 17 January 1994 (M6.7, buried thrust fault) or the Coalinga earthquake of 2 May 1983 (M6.5, buried thrust fault) is capable of causing major damage if the epicenter is near a densely populated area.

Major earthquakes (M7 to 7.9) occur in California about every 10 years on average. Two recent major earthquakes, the Landers earthquake of June 1992 (M7.3) and the Hector Mine earthquake of October 1999 (M7.1) caused extensive surface fault rupture, but relatively little damage because they occurred in lightly populated areas of the Mojave Desert. Earthquakes of similar size, such as the M6.9 Loma Prieta earthquake of October 17, 1989, cause extensive damage over large areas when they occur in densely populated regions. The two largest earthquakes in California, the Fort Tejon earthquake of 1857 and the famous San Francisco earthquake of 1906 were similar in magnitude (M7.9 and M7.8) and resulted from movement along the San Andreas Fault. Earthquakes of this size (M7.7- 7.9) can cause more extensive damage over a larger area than the M7.1 - 7.4 earthquakes that have stricken California in recent decades.

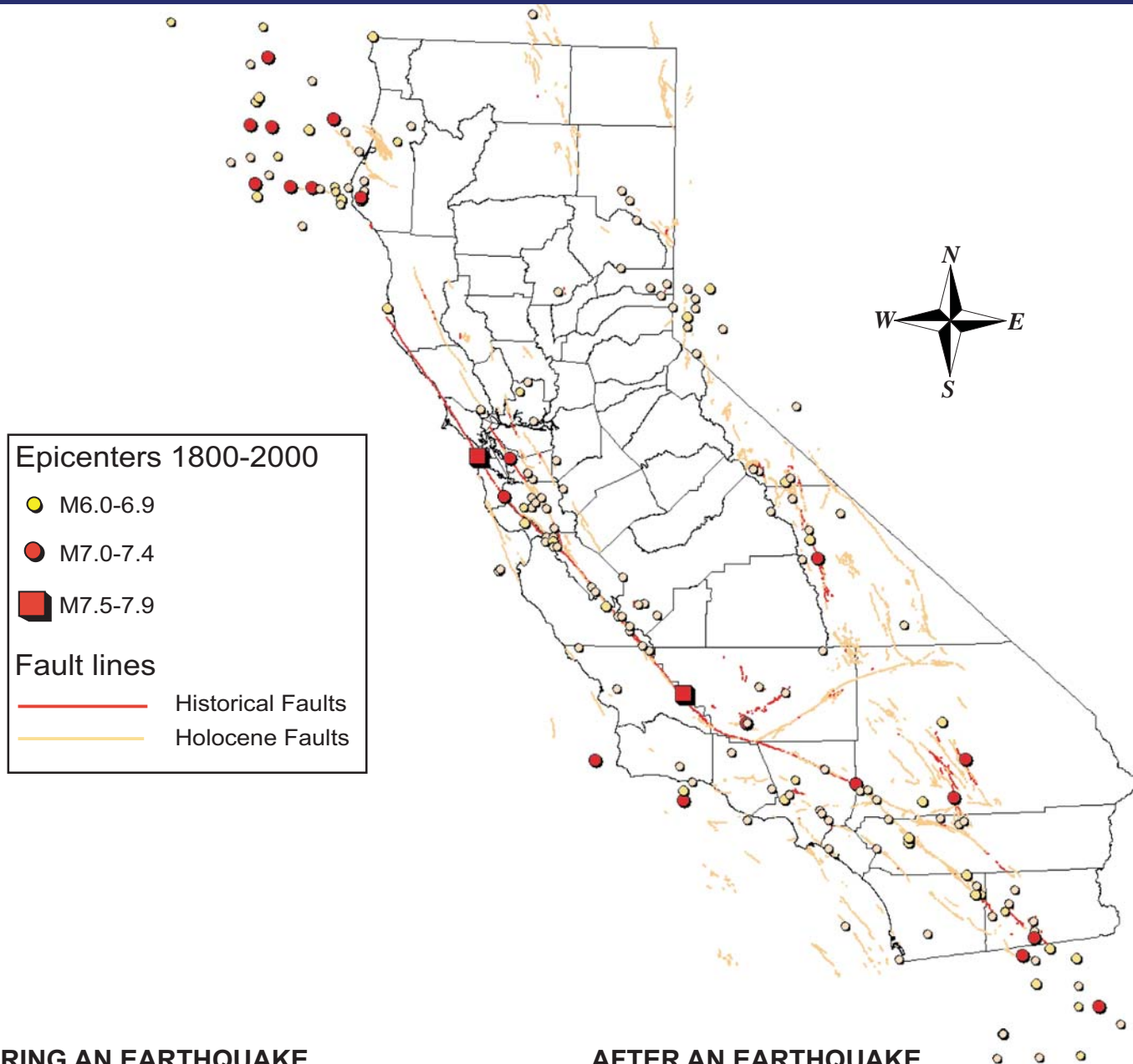
Great earthquakes (M greater than 8) have not occurred in California in historic time, but one earthquake in January 1700 may have been this large. Based on Native American oral histories, tree-ring studies, geological studies that show the uplift or subsidence of large areas of coastal land, and records of a tsunami that struck Japan and cannot be correlated with an earthquake anywhere else around the Pacific, a great (M9) earthquake occurred January 26, 1700 on the Cascadia subduction zone extending north from Cape Mendocino to British Columbia. An earthquake of this size is similar to the one that struck Alaska in 1964 and is capable of extensive damage over a very broad region.

EARTHQUAKE SAFETY

Although there is no way to eliminate earthquake dangers, injury and damage can be reduced substantially if the following steps are taken before, during, and after the quake.

BEFORE AN EARTHQUAKE

- 1) Store emergency supplies: food, water, first-aid kit, flashlight, and batter-powered radio.
- 2) Take a first-aid course.
- 3) Locate your house's main switches and valves for water, gas, and electricity. Know how to turn them off.
- 4) Have a plan for each family member to follow after the earthquake.
- 5) Have tall, heavy furniture bolted to the walls.
- 6) Have water heater strapped to wall.
- 7) Support community programs that inform the public and emergency personnel about earthquake preparedness.
- 8) Strengthen or eliminate structures that are not earthquake-resistant.
- 9) Support "parapet ordinances" that would remove dangerous, unreinforced overhangs and cornices from buildings.
- 10) Support building codes that require earthquake-resistant construction and careful foundation preparation and grading.
- 11) Support land-use policies that recognize and allow for active fault zones and other earthquake hazards.
- 12) Support basic research into the cause and mechanism of earthquakes and fault movement.



DURING AN EARTHQUAKE

- 1) Don't panic.
- 2) If you are indoors, stay there. Duck or drop to the floor, take cover under a sturdy desk or table, and hold onto it so that it doesn't move away from you. Wait there until the shaking stops. Stay away from windows.
- 3) Do not rush outside. Falling debris has caused many deaths and injuries.
- 4) Watch for falling plaster, bricks, and other objects.
- 5) If you are outside, move away from buildings and power lines. Stay in the open.
- 6) If you are in a moving car, stop as soon as it is safe. Remain in the car.

AFTER AN EARTHQUAKE

- 1) Check the people near you for injuries.
- 2) Inspect the utilities for damage to water, gas, and electrical lines. If damage is detected, turn off the utility.
- 3) Extinguish open flames.
- 4) Do not use the telephone except to report an emergency.
- 5) Turn on battery-powered radio for emergency information.
- 6) Do not go sightseeing.
- 7) Stay away from damaged structures; aftershocks can cause their collapse.
- 8) Stay away from beaches and waterfront areas subject to seismic sea waves (tsunamis).

More Information of California's Faults and Earthquakes

- **Fault Activity Map of California and Adjacent Areas**, By Jennings, C.W., 1994: California Geological Survey, Geological Data Map GDM 006, Scale 1:750,000
- **Seismic Shaking Hazard Maps of California**, By Petersen, M., Beeby, D., Bryant, W., Cao, T., Cramer, C., Davis, J., Reichle, M., Saucedo, G., Tan, S., Taylor, G., Topozada, T., Treiman, J., Wills, C., 1999: California Geological Survey, Map Sheet MS 48.
- **Epicenters and Areas Damaged by $M \geq 5$ California Earthquakes, 1800-1999**. By Topozada, T., Branum, D., Petersen, M., Hallstrom, C., Cramer, C., and Reichle, M., 2000: California Geological Survey, Map Sheet MS 49, Scale 1:1,000,000.
- **Living with Earthquakes in California--A Survivor's Guide, Yeats, R.S., 2001**: Oregon State University Press, Corvallis, Oregon.

To order these or other California Geological Survey publications, call 916-445-6199, or visit the CGS publication Web page at <http://www.conservation.ca.gov/cgs/information/publications/index.htm>.

- **Web sites:** California Governors Office of Emergency Services:
<http://www.oes.ca.gov/Operational/OESHome.nsf/1?OpenForm>
- California Seismic Safety Commission:
<http://www.seismic.ca.gov>
- Association of Bay Area Governments *Living on Shakey Ground*:
<http://quake.abag.ca.gov/>
- Southern California Earthquake Center:
<http://www.scec.org>
- USGS Recent Earthquakes in California and Nevada:
<http://quake.wr.usgs.gov/recenteqs/latest.htm>
- USGS National Seismic Hazards Mapping Project:
<http://geohazards.cr.usgs.gov/eq/>

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