The Tangshan earthquake of July 27, 1976, leveled the city and killed at least 250,000 people.

A gap in the historic earthquake pattern along the San Andreas Fault south of San Francisco was filled in 1989 by the Loma Prieta earthquake.

This map of the Pacific coast of Mexico shows faulted segments of the subduction zone and recent seismic gaps between faulted segments (ovals).

Groups of migrating earthquakes on the North Anatolian Fault in Turkey from 967 to 1050, 1254 to 1784, and 1939 to 1999.
A magnitude 8.2 earthquake in 1923 destroyed Tokyo from an epicenter 90 kilometers away. 105,000 died.

Recurrence ~70-year intervals for 500 yrs

schematic diagram to show relative offsets of layers

Colluvial sediment

north wall of a trench across the Wasatch Fault zone at Brigham City, Utah

Before faulting

F3 F2 F1

NW SE

(a)

(b)

(c)
Global positioning system (GPS) stations placed in a straight line across a fault curve as the Earth’s crust on one side bends elastically with respect to the crust on the other side.

Point Reyes ~2.6 m offset

earthquakes near Denver, Colorado, in the early 1960s timing of fluid waste injection
earthquake epicenters in the United States from 1899 to 1990, larger circles represent larger earthquakes.

Fig. 4-12, p.72

Fig. 4-13, p.72

areas with a 2 percent probability of exceeding the indicated percentage of the acceleration of gravity over the next fifty years.

Fig. 4-14, p.73

(a) earthquake epicenters and (b) seismic zones with the probability of exceeding the indicated fraction of the acceleration of gravity.

Fig. 4-15, p.73

Athens, Greece, in a magnitude 5.9 earthquake in September 1999.

Table 4-1: Some of the Most Catastrophic Earthquakes in Terms of Casualties

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Date</th>
<th>Magnitude</th>
<th>Casualties</th>
<th>Probable Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumatra</td>
<td>Dec. 26, 1994</td>
<td>9.0</td>
<td>130,000</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Kobe, Japan</td>
<td>Jan. 17, 1995</td>
<td>7.2</td>
<td>6400</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Gujarat, India</td>
<td>Apr. 26, 1991</td>
<td>7.5</td>
<td>35,000</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Iquique, Chile</td>
<td>Apr. 1, 1960</td>
<td>8.5</td>
<td>3600</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Kobe, Japan</td>
<td>July 17, 1995</td>
<td>7.2</td>
<td>6400</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Kobe, Japan</td>
<td>Jan. 17, 1995</td>
<td>7.2</td>
<td>6400</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Java, Indonesia</td>
<td>Sept. 20, 1975</td>
<td>8.5</td>
<td>12,000</td>
<td>Subduction zone</td>
</tr>
</tbody>
</table>

Table 4-1b, p.74
dashed part of the San Andreas fault, south from Hollister, creeps continuously without significant earthquakes.

### Table 4-2 The Largest World Earthquakes Since 1900

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Date</th>
<th>Magnitude</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>May 22, 1960</td>
<td>9.5</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Anchorage, Alaska</td>
<td>Mar. 28, 1964</td>
<td>9.2</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Andreanof Is., Alaska</td>
<td>Mar. 9, 1957</td>
<td>9.1</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Northern Sumatra</td>
<td>Dec. 26, 2004</td>
<td>9.0</td>
<td>Subduction zone</td>
</tr>
<tr>
<td>Kamchatka</td>
<td>Nov. 4, 1952</td>
<td>9.0</td>
<td>Subduction zone</td>
</tr>
</tbody>
</table>

San Andreas and proportional to the rates of ground movement relative to the stable continental interior based on GPS measurements

Note differential movement as can be seen across each of the major faults shown in orange

San Andreas Fault shows as a series of straight valleys slicing through the coast ranges

The San Andreas makes a long, straight furrow through hills of the Carrizo Plain north of Los Angeles

1965 aerial view south along the San Andreas Fault in Daly City and Pacifica
The Cascadia oceanic trench to the north and the San Andreas transform fault to the south dominate the Pacific continental margin of the United States.

The 1857 Fort Tejon earthquake caused 9.5 meters of this movement.

Hollister, California creep along the San Andreas Fault.

The Hibernia Bank building in San Francisco was destroyed by the 1906 earthquake.

1906 earthquake in San Francisco: Slumping toppled many buildings during the 1906 earthquake in San Francisco.

Market Street
horses were killed by falling debris during the San Francisco 1906 earthquake.

1906 break extended from near Santa Cruz to Cape Mendocino

probability of a magnitude 6.7 or larger earthquake on the main faults. The Loma Prieta epicenter is shown as a star.

LA eq magnitudes greater than 4.8 since 1920

schematic diagrams of the big bend in the San Andreas Fault near Los Angeles

1994 Northridge earthquake

Older structural brick buildings were heavily damaged
Many first-floor garages in timber apartment buildings were not well braced; the buildings then collapsed on the cars below.

Northridge stadium parking structure collapsed during the 1994 earthquake in spite of being built from flexible materials. Blind thrust fault movement that caused the 1994 Northridge earthquake.
North Anatolian Fault in Turkey shows sequential westward migration of major earthquakes with time. The August 1999 earthquake continued the migration. The upper plot shows that the longer the lateral break on the fault (horizontal axis), the greater the amount of slip (vertical).

This modern, multistory apartment building in Izmit pancaked over to the right.

Older apartment buildings in Izmit lie in ruins after the poorly braced lower floors of most of them collapsed. Poor-quality construction contributed.

Buildings sank or tilted because of liquefaction.

April 6, 2010 Mg. 7.2 Baja quake; Borrego fault; ~28 km.
Fig. 4-44, p. 88

Locations of subfossil trees (dots) with respect to faults (lavender), volcanic hazard zones (brown), and landslides (green)

Graphic by Pat Pringle
Dating of the Tacoma Fault at Catfish Lake

Photo and 14 C age by Josh Logan, WADNR

~1200 yr BP?

Support beam on the Alaska Way viaduct in Seattle was damaged in the 2001 Nisqually earthquake

2003 Bam earthquake.
Poor construction materials and quality led to widespread collapse of buildings and the tragic death toll in Bam.

Near complete destruction in Bam

Adobe collapsed during the Bhuj earthquake.
prominent fault scarp crosses the East Bench, out from the base of the Wasatch Front.

AWasatch Front fault scarp cuts a 19,000-year-old glacial moraine from Cottonwood Canyon near Salt Lake City.

Broad low mounds in a nearly flat area below the Wasatch Front west of Farmington, near Ogden, Utah, mark an area of liquefaction of soft clays.

Recent microearthquake epicenters in the New Madrid region appear to outline three fault zones responsible for the earthquakes of 1811 and 1812. Two lateral-slip faults are offset by a short fault that pushed the southwestern side up over the northeastern side.
Charleston, South Carolina, was heavily damaged by the 1886 earthquake.

This map of the East Coast fault system between South Carolina and Virginia shows how the fault zone lies close to the buried boundary between the continental crust of the Piedmont and the Atlantic oceanic crust. The Piedmont is rising.

Sidebar 4-1

Some large earthquakes in the Los Angeles area in the last 150 years:

- 1994, $M_w = 6.7$
- 1991, $M_I = 5.8$
- 1990, $M_I = 5.3$
- 1989, $M_I = 5.0$
- 1988, $M_I = 5.0$
- 1987, $M_I = 5.9$
- 1979, $M_I = 5.2$
- 1978, $M_I = 5.9$
- 1971, $M_w = 6.7$
- 1970, $M_I = 5.2$
- 1967, $M_I = 5.9$
- 1933, $M_I = 6.4$
- 1930, $M_I = 5.2$
- 1857, $M_w = 7.9$ (Fort Tejon)

Note that following the big earthquake in 1857, there have been many much smaller earthquakes. Recall also that we need 32 or 33 magnitude 7 quakes to expend as much energy as a magnitude 8 quake—and more than 1,000 magnitude 6 quakes for the same energy as the magnitude 8 quake. Smaller quakes do not release much of the pent-up strain on the fault.