CHAPTER 3
PRIMER ON EARTHQUAKES AND TSUNAMIS

Those of you that live on the Pacific Coast are more knowledgeable, on average, about earthquakes and tsunamis than those of you that live in the Mississippi Valley and on up to Lake Superior. Many on the west coast have experienced earthquakes of various magnitudes, from ones that you barely felt, to perhaps really significant ones such as the 1994 Northridge Earthquake in Los Angeles, or the 1989 Loma Prieta Earthquake in the San Francisco area.

I'm going to use these two earthquakes as examples of the destructive power of earthquakes in urban areas, and keep in mind that these will be considered baby quakes compared to the monsters that will take place in October and November of 2008.

The Loma Prieta Earthquake occurred October 17, 1989, was a magnitude of 6.9 on the Richter Scale (more on this later) and lasted 15 seconds. It was situated 10 miles (16 km) north of Santa Cruz and 60 miles (95 km) from the San Francisco Marina District. Sixty-three people died directly or indirectly from the earthquake. The most people died when the upper level of the Nimitz Freeway collapsed onto the level below, killing 40 people. One section of the San Francisco Bridge also collapsed on the level below, killing one person. Over 3,700 people were also injured.

Liquefaction of the soil (more on that later) caused extensive damage in San Francisco, and there were fires, although not as bad as the 1906 earthquake where firestorms raged and almost wiped out the city. Other effects included sand volcanoes, landslides, and ground ruptures. There would have been several hundred more people killed, as this happened during rush hour, but many people had left work early to watch a World Series baseball game between the Oakland Athletics and the San Francisco Giants. People across the United States saw the earthquake take place shortly before the start of the game. The earthquake caused over $6 billion in damages, which was the most in U.S. history at that time.

The Northridge earthquake transpired on January 17, 1994 with its epicenter located near the community of Northridge, California, which is 20 miles (31 km) northwest of downtown Los Angeles. The earthquake measure 6.7 on the Richter Scale but had the highest "ground acceleration" measurement ever recorded in an urban area of North America. That means the shaking of the ground was very intensive. The earthquake took place 11.3 miles (18.2 km) below the surface of the

earth and lasted for thirty seconds. Seventy-two people died in this earthquake and over 11,000 were injured. The earthquake caused an estimated $12.5 billion in damage, the most in U.S. history.

This earthquake did not even occur on the San Andreas Fault line, but on a previously undiscovered fault. Damage occurred up to 85 miles (125 km) away including Santa Monica and Simi Valley. Over 250 gas lines erupted, igniting numerous intense fires, and 9 highway overpasses crumbled, totally disrupting the freeway traffic. Portions of Interstate 10, Interstate 5, and California Highway 14 collapsed and had to be rebuilt. Many of the fires were caused by broken gas pipes in houses that shifted or by water heaters that were unsecured. Another result of the earthquake was an outbreak of Valley Fever, a respiratory disease caused by inhaling airborne spores carried aloft in the large clouds of dust from the earthquake. There were over 200 cases and three deaths. Can you even imagine how much dust will be thrown up by a series of earthquakes over 2,000 miles long?

Eleven hospitals were damaged and could not accept patients, nor could they take care of the patients on hand. They had to transfer them to other hospitals that were not damaged, putting a great strain on those hospitals.

So what do all these 6.9 and 6.7 magnitudes actually mean? Charles Richter developed the Richter Scale in 1935 in collaboration with Beno Gutenberg. I am not going to give you all the scientific basis of this scale. You can do an internet search should you desire to read more about the scale. We are only interested here in what the scale means. Here is the scale:

Description	Richter Magnitudes	Earthquake Effects	Frequency of Occurrence
Micro	Less than 2.0	Micro earthquakes, not felt.	About 8,000 per day
Minor	2.0-2.9	Generally not felt, but recorded.	About 1,000 per day
Minor	3.0-3.9	Often felt, but rarely causes damage.	49,000 per year (est.)
Light	4.0-4.9	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	6,200 per year (est.)
Moderate	5.0-5.9	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	800 per year
Strong	6.0-6.9	Can be destructive in areas up to about 100 miles across in populated areas.	120 per year

Major	7.0-7.9	Can cause serious damage over larger areas.	18 per year
Great	8.0-8.9	Can cause serious damage in areas several hundred miles across.	1 per year
Great	9.0-9.9	Devastating in areas several thousand miles across.	1 per 20 years
Great	10.0+	Never recorded; see below for equivalent seismic energy yield.	Extremely rare (Unknown)

(*Based on U.S. Geological Survey documents.*)[1]

As you can see from the above scale, even 9.0 to 9.9 earthquakes are not unheard of. The Indonesian earthquake on December 26, 2004 that produced the large tsunamis was between 9.1 and 9.3. The New Madrid earthquake will be close to a 9.0 in magnitude. The others will be in the 8.0 to 8.9 range.

There is another scale used to measure earthquakes. It is the ABRIDGED MODIFIED MERCALLI INTENSITY SCALE. It was developed in 1931 before the Richter Scale and is less reliable, as it relies on human assessment, and the person assessing damage may not be close to the actual epicenter. I also found it much more technical, and therefore I will only list here the Intensity Value and Descriptions for VI to XII (I don't know why they used Roman Numerals) and not the Average Peak Velocity or Average Peak Acceleration. Again, do an internet search if you wish to read more about this scale.

ABRIDGED MODIFIED MERCALLI INTENSITY SCALE

VI. **Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.**

VII. **Everyone runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.**

VIII. **Damage slight in specially designed structures; considerable in ordinary substantial building with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed.**

IX. **Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.**

X. **Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.**

XI. **Few, if any, masonry structures remain standing. Bridges are destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails are greatly bent.**

XII. **Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.**

From "Earthquakes" by Bruce A. Bolt

The earthquakes that will take place in the Mississippi Valley and on the Pacific Coast will have intensities at the top of the Mercalli Scale. Reread XI and XII. If I were doing the scale I would have a XIII—"Changes in the course of rivers, with resulting river tidal waves and flooding, and collapse of hundreds of square miles of land into the ocean."

There are several different kinds of earthquakes—Volcanic earthquakes caused by the eruption of a volcano; Explosion earthquakes caused by the detonation of dynamite or a nuclear test; Collapse earthquakes such as the one in the Utah mine disaster in August, 2007, and Tectonic earthquakes, which are the most common. These earthquakes occur when rocks suddenly break in response to geological movements. They naturally pose the greatest hazard and these are the earthquakes that will strike the Mississippi Valley and the Pacific Coast.

Let's look at some other commonly used terms in describing earthquakes:
The EPICENTER of an earthquake is the point on the surface of the earth directly above the focus of the earthquake. The epicenter of the New Madrid earthquake will be close to Memphis, Tennessee and the epicenter of the Pacific Coast earthquake will be between San Diego and Los Angeles, California.

The CRUST of the earth is the outermost rocky shell. This will be what the Mississippi Valley earthquakes move to the east and west as the crust sits on top of the tectonic plates.

Three different types of shock waves cause earthquake shaking and damage. Two of these go through or within the rocks. The faster one is called the PRIMARY or P WAVE. It's like a sound wave that spreads out and it is the first one you feel as it pushes and pulls the rock below the surface. It's like a sonic boom.

The second wave you feel is a nasty one. It's called the SECONDARY or S WAVE. As it goes out, it shears the rock sideways at right angles to the direction it's headed. So when these arrive you feel up-and-down and side-to-side motions. These motions are extremely damaging to structures.

The third wave is called a SURFACE WAVE and is like a ripple of water going out from the epicenter on the surface. These Surface waves travel slower than the P and S waves, so it can seem that you are experiencing more than one earthquake, or it seems to go on FOREVER. You can learn more about these waves, if you wish, by searching on the internet.

AFTERSHOCKS are typically smaller earthquakes in the same general area as the first larger one. After the Alaska earthquake in 1964 at a magnitude of 8.4, there were over 12,000-recorded aftershocks with nineteen of a magnitude 6.0 or above!

SOIL LIQUEFACTION is an extremely important term to understand, as liquefaction will occur both during the Mississippi Valley earthquakes and the Pacific Coast earthquakes. The easiest way to explain it is that the soil turns to mud with the violent shaking of an earthquake. The land most susceptible to liquefaction are beach sands, silt from riverbeds, and lands where wind-blown silt and sands exist. Basically it means that the land sitting under buildings and houses cannot hold the structures and they collapse, or sink in an irregular fashion, breaking utility pipes below. As noted above, liquefaction was a major factor in the destruction of the San Francisco Marina District during the 1989 Loma Prieta earthquake. Apartment buildings and other structures just sank into the ground. Liquefaction was a huge problem during the famous 1906 San Francisco earthquake causing huge fires that swept across the city. Cities and towns built on silt along the Mississippi River will also experience this soil liquefaction, and many homes and buildings will collapse.

An INTERPLATE earthquake is one whose focus is on a plate boundary. As an example the North American plate rests against the Pacific plate. A MEGATHRUST earthquake occurs where one tectonic plate slips under the other. Due to the size of these plates and the shallow boundary between them, these earthquakes are among the world's largest, with magnitudes that can exceed 9.0, especially along the "Ring of Fire," which includes the Pacific Coast. Since these earthquakes deform the ocean floor, they almost always generate a significant tsunami. That's what's going to happen on the west coast.

A TSUNAMI is a SERIES of waves (keep that in mind) when the ocean is rapidly displaced by either an earthquake or landslide. I'm sure you remember the devastating scenes of the tsunamis that struck Indonesia, Thailand and Sri Lanka on December 26, 2004. For a reminder of the destruction, go to www.youtube.com and enter "tsunami" in the search box. There are a large number of videos, but be sure to watch the one of Banda Acheh, Indonesia when the tsunami barreled through the streets sweeping cars, trucks, all sorts of refuse, and of course humans along in its wake. As you watch the other videos, notice how there seems to be one smaller wave and then the big ones come after that and come and come. Keep in mind that these tsunamis were caused by earthquakes offshore, not on land, so the people you see in the resorts recording the tsunamis were fairly safe up on the upper

floors. The lower floor or floors washed out, but the structure stood. But what would happen if a great amount of land collapses into the ocean during a great land earthquake? The structures would be greatly weakened or not standing when the tsunamis strike the shoreline. Many will crash into the ocean.

I was given a new term for this book—BACK-LASH TSUNAMI. This will occur when a large amount of land on the Pacific Coast collapses into the ocean. It will cause a tsunami to go out across the ocean, but the DISPLACEMENT of the water will first be pushed out, and then it will come rushing back in with great energy and will flood the land that did not drop into the ocean. This is described in more detail later in the chapter on the west coast.

I have kept this chapter as simple as possible, as most of us do not have scientific backgrounds. If you wish to learn more about the studies of earthquakes and tsunamis, please go online and search these two words and you'll find a wealth of information. A good place to start would be http://earthquake.usgs.gov.

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