

Exercise 3 Earthquake Hazards

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Student Name _____

Section _____

In this lab you will:

examine various earthquake hazards and some of the techniques that can help minimize the loss of life and property damage.

Background Reading and Needed Supplies

Prior to doing this exercise you should read Chapter 4 in the textbook.
 With respect to supplies, you will need a calculator, ruler, and colored pencils.

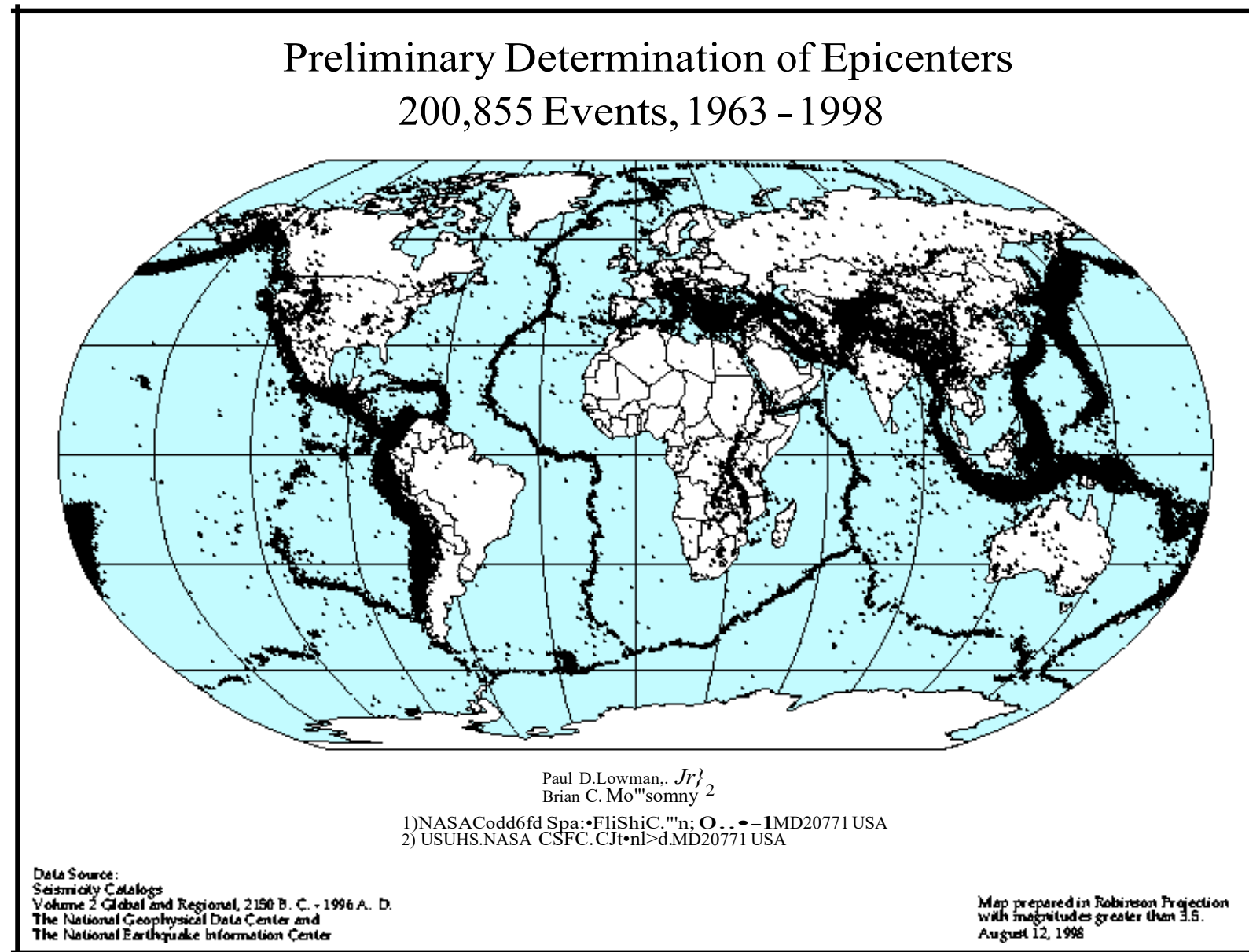
Part I – Earthquakes and Plate Tectonics

Each year, the vibrational (seismic) waves from earthquakes cause buildings to fail somewhere in the world, resulting in the death of large numbers of people. In addition to buildings, earthquakes cause considerable damage to human infrastructure, such as utility lines and transportation systems. Seismic waves also can trigger highly destructive tsunamis and landslides. Although humans cannot prevent earthquakes, we can use science and engineering to help minimize the hazards. In this exercise we will explore some of the earthquake hazards and ways we can reduce the loss of life and property damage.

- 1) The map in Figure 3.1 shows the location of earthquake epicenters that occurred over a 35-year period. Note how the epicenters clearly define the edge of Earth's tectonic plates.
 - a) Using a red colored pencil, place a set of arrows at the plate boundaries listed below so as to indicate whether the boundary is dominated by compressional, tensional, or shearing forces (i.e., indicate whether the boundaries are convergent, divergent, or transform.

mid-ocean ridge in the Atlantic	Aleutian Islands of Alaska
western coast of South America	Japan
western coast of North America	Islands of Indonesia
 - b) What is the name of the geologic process that takes place along the plate boundary running through the Atlantic basin?
 - c) What geologic process occurs along the convergent boundaries you identified on the map?
 - d) What is the name of the earthquake hazard that can develop along convergent boundaries which is capable of bringing death and destruction to distant shorelines?
 - e) Explain why large magnitude earthquakes are relatively rare along divergent boundaries, but quite common along convergent boundaries.

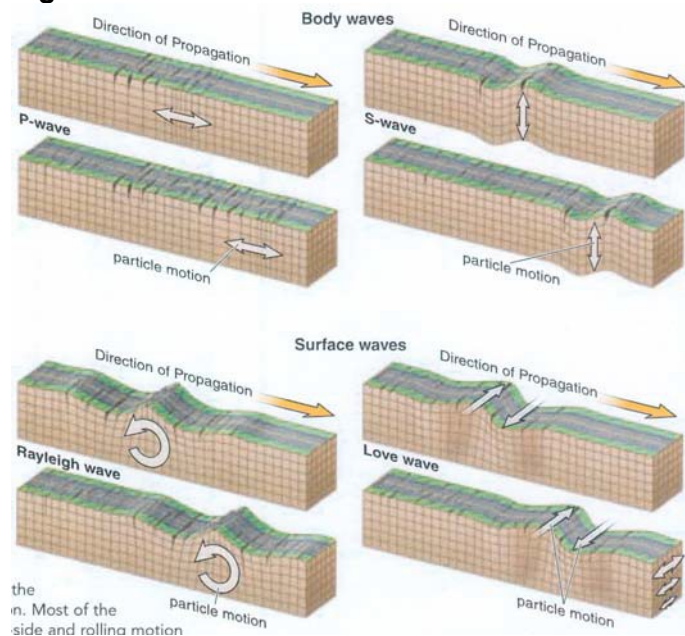
Figure 3.1



Part II – Seismic Waves and Buildings

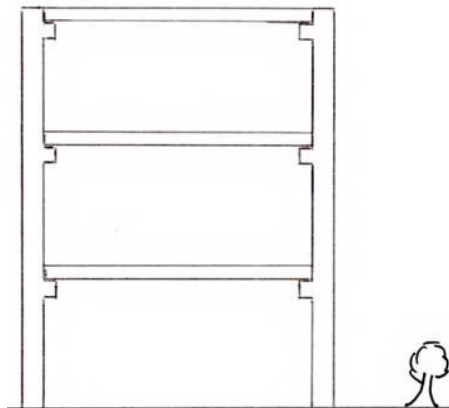
- 2) Figure 3.2 illustrates how earth materials vibrate differently in response to the passing of different types of seismic waves. Based on this illustration, explain why surface waves generally cause the most damage to human structures.

Figure 3.2



- 3) Figure 3.3 is a simplified sketch showing the structural skeleton of a typical multi-story building. A supporting structure usually consists of steel or steel-reinforced concrete. Based on what you learned in the textbook about seismic waves and buildings, indicate on the sketch the three types of engineering features that could be added to help prevent this building from collapsing in the event of an earthquake.

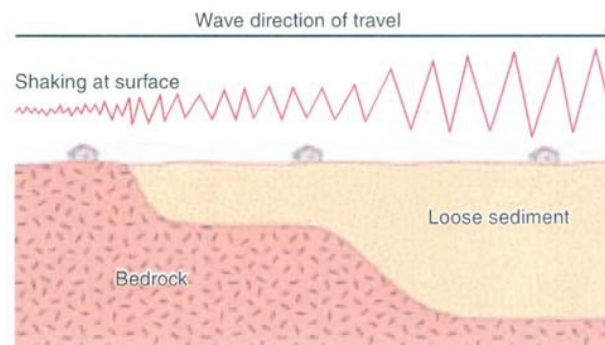
Figure 3.3



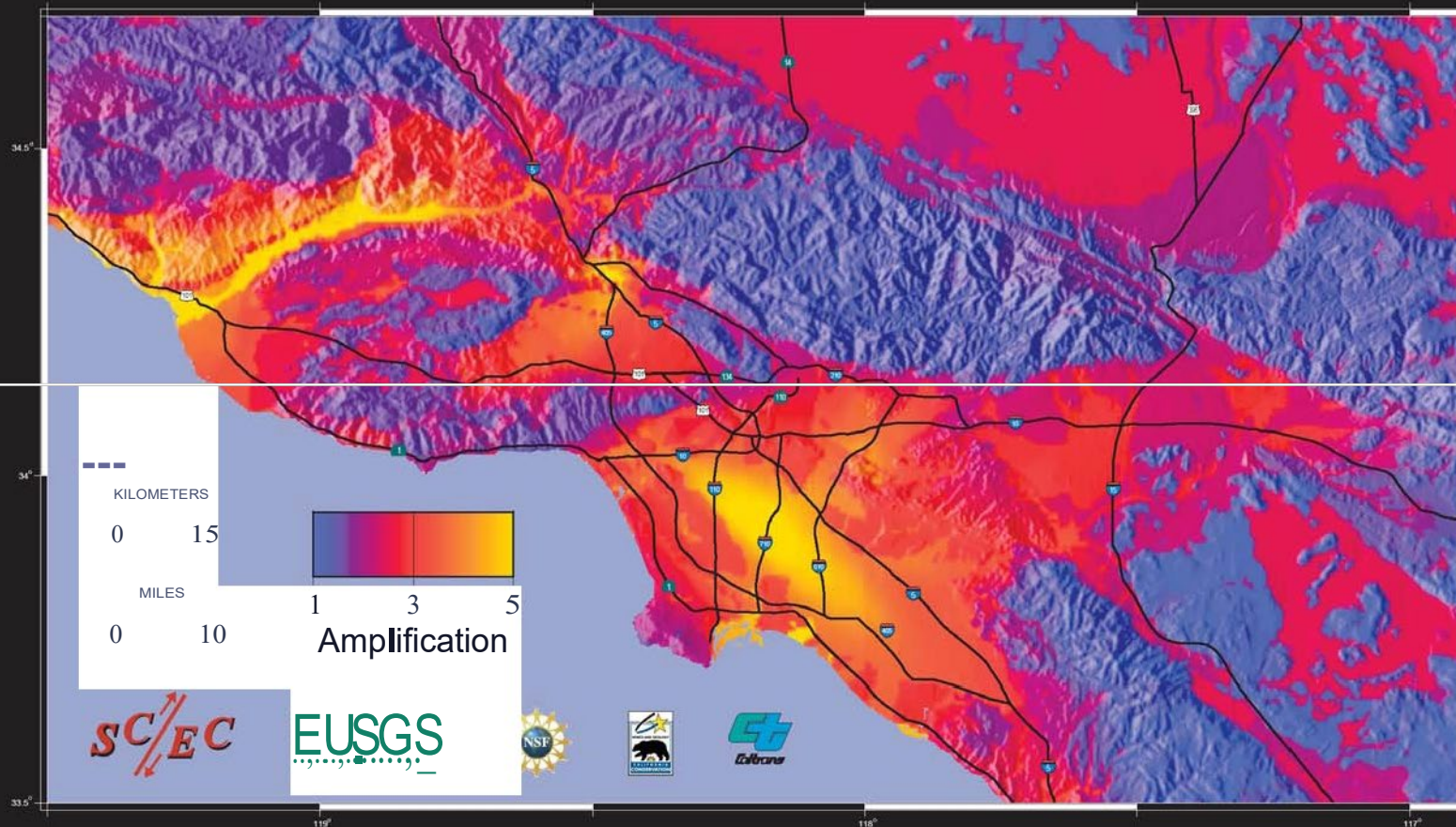
4) Seismic engineering controls in multi-story buildings are especially important should the building experience the phenomenon known as *resonance*, which causes it to shake more violently during an earthquake. Describe how resonance works and explain why it may occur in some multi-story buildings within a city and not others.

5) As seismic waves travel outward from the focus through solid bedrock they naturally lose energy and become weaker. However, if the waves encounter unconsolidated sediment, such as in a sedimentary basin, they will begin to slow down and lose energy at a faster rate. As illustrated in Figure 3.4, this more rapid transfer of energy can lead to *ground amplification* where the ground itself shook more violently, thereby increasing the threat to buildings and infrastructure.

Figure 3.4



- The relief map on the following page shows the amount of ground amplification that can be expected to occur in the Los Angeles area. Using a black colored pencil, outline those areas where ground amplification is expected to occur (i.e., non-purplish areas where amplification is > 1).
- Add labels to your map indicating what areas are underlain by bedrock and those underlain by sediment.
- Provide an explanation as to why some parts of the sedimentary deposit are expected to experience as much as a five-fold increase in ground shaking (yellow color), whereas in other areas the increase may be by a factor of three or less (reddish colors).
- Notice that the yellow area in the northwest portion of the map has a distinct shape. Describe what this feature represents and explain why the ground amplification is expected to be so high there.



Earthquake Ground-Motion Amplification in Southern California

by
Edward H. Field
2001

Technical Details

This map is based on information in the Southern California Earthquake Center (SCEC) Phase-III Report, a collection of 14 papers published in a special issue of the *Bulletin of the Seismological Society of America* (2000, Volume 90, Number 6B). All of the papers cited below are in this special issue. The amplification is based on the attenuation relationship of Field (2000) for 1.0-second response spectral acceleration. This relationship characterizes each site with two parameters. The first is the average shear-wave velocity in the upper 30 meters (V_{s0}), as given in the map by the California Division of Mines and Geology (Wills and others, 2000). The second is the basin depth (B_{depth}) as defined by the 2.5 km/sec shear-wave velocity isosurface in the SCEC 3D velocity model for southern California (Maggiore and others, 2000). The degree of amplification is given by:

$$\text{Amplification} = (V_{s0}/1000)^{-0.794} \cdot (0.12 \cdot B_{\text{depth}})$$

where V_{s0} has units of m/sec and B_{depth} is positive and in km. Here, B_{depth} was capped at 6 km for sites where the actual value is greater; this prevents extrapolation beyond the basin depths in data used to constrain the attenuation relationship. Note that of all the ground motion parameters examined by Field (2000), the 1.0-second spectral acceleration shown here exhibited the maximum degree of amplification.

The two most important factors influencing the level of earthquake ground motion at a site are the magnitude and distance of the earthquake. This map shows the influence of a third important factor, the site effect: conditions at a particular location can increase (amplify) or decrease the level of shaking that is otherwise expected for a given magnitude and distance. Site effects at the areas shown in yellow will amplify ground motion by a factor of five, on average, relative to those shown in blue. Combining this information with where and how often earthquakes of various magnitudes are likely to occur should provide improved assessments of seismic hazard.

Caveats

Although this amplification map represents a significant step in our evolving scientific understanding of earthquake phenomena, it is also based on certain assumptions and on data that have inherent uncertainties. Therefore, any use of this map should be made with a clear understanding of these limitations. The map constitutes a working hypothesis that will be tested with additional data in the future. It is possible that future site-amplification maps will look significantly different from this one. Finally, in addition to the average amplification patterns shown here, each individual earthquake will exhibit unique areas of anomalous ground motion. See Field and others (2000) for further discussion of this and other topics (such as seismic hazard implications). Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Acknowledgments

Research that contributed to this poster was conducted by SCEC, the United States Geological Survey (USGS), and the California Division of Mines and Geology (CDMG). Funding was provided by the National Science Foundation, USGS, California Department of Transportation, and CDMG. The image was made using the Generic Mapping Tools (<http://www.seis.hawaii.edu/gmt/>). This is SCEC Publication Number 584 and USGS Open File Report 01-164.

- 6) Explain why the areas in metro Los Angeles with an increased risk of ground amplification also happen to be places where the population density is the highest. In other words, why did most of the development occur where the risk of earthquake damage is the greatest?

- 7) Imagine that you are an executive with a large insurance company. Explain how a map of potential ground amplification might affect your company's rates for earthquake insurance.

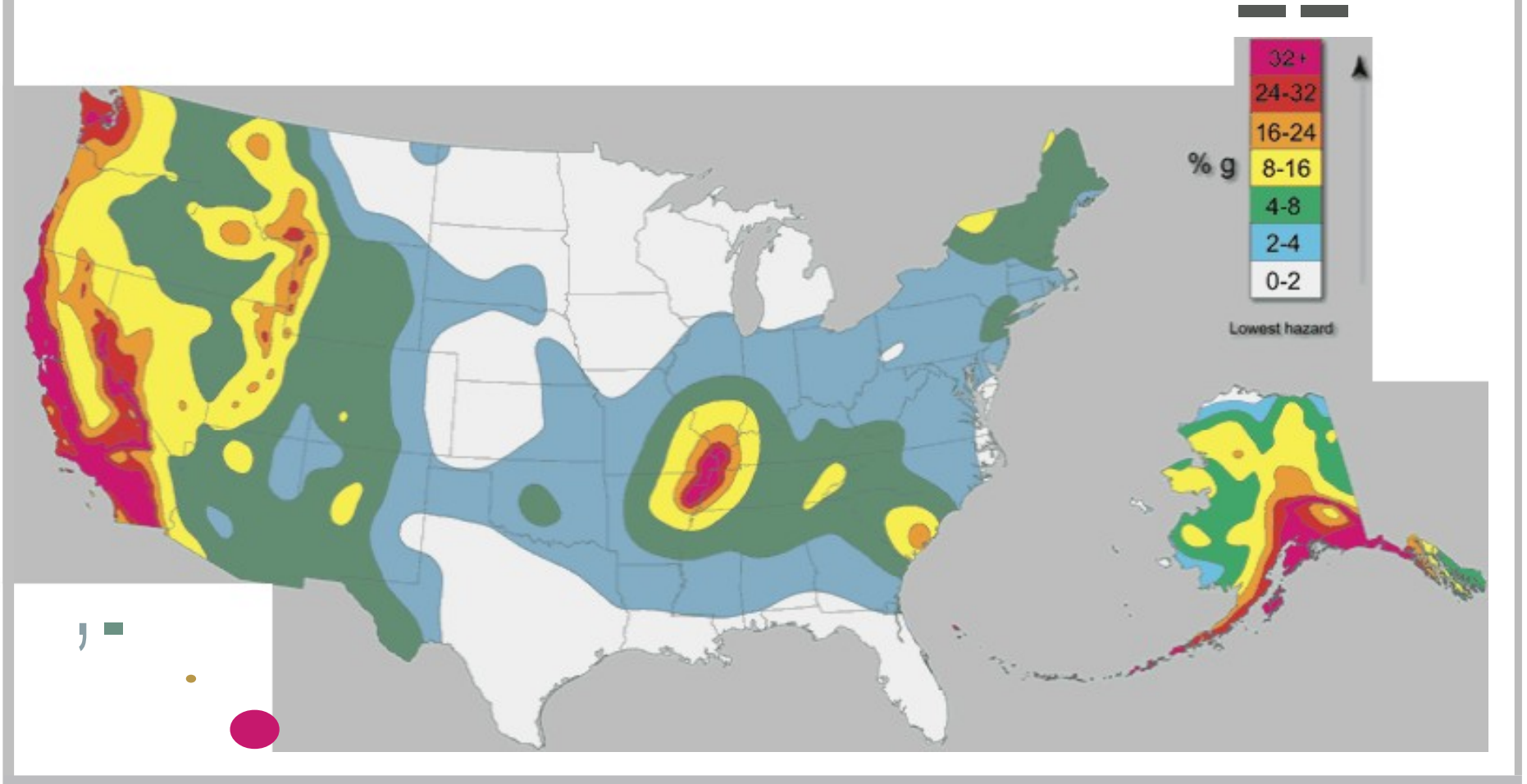
- 8) Suppose you were to move to a city where the risk of a major earthquake is relatively high, but ground amplification maps are not available. Describe the types of geologic information that you could use instead which might help you avoid moving into a high-risk area.

Part III – Intraplate Earthquakes

Large earthquakes are most common along convergent and transform plate boundaries, but they can also take place along old, buried faults in the middle of tectonic plates. These so-called *intraplate* earthquakes are of great concern because they occur rather infrequently, which means people are generally less prepared. We can get an idea of the risk of intraplate quakes in the U.S. by examining the USGS seismic hazard map shown in Figure 3.5. This map shows the strength of the horizontal ground motion (relative to gravity) that has a 10% chance of occurring over a 50-year period. For example, we can see that in the Los Angeles area, there is a 10% probability in next 50 years of an earthquake with a lateral ground motion of more than 0.32 times the force of gravity.

Although the seismic hazard map in Figure 3.5 provides information as to the probability of different levels of ground shaking in a given area, it says nothing about the level of earthquake preparedness. Along the transform plate boundary in California, for example, major earthquakes are relatively common. Consequently, state and local building codes in this region generally require seismic engineering controls that are designed to help structures withstand lateral ground shaking. With the exception of California, most of the high-risk areas in the United States have not experienced a major earthquake in modern times, thus are far less prepared in terms of seismic engineering and emergency management planning.

Figure 3.5



9) Notice in Figure 3.5 how the area along the Mississippi River valley has a seismic-risk level similar to what is found along the plate boundary in California. In the winter of 1810-11, a series of magnitude 8 quakes occurred in the Mississippi valley region, but caused little structural damage because the area was largely undeveloped at the time.

a) Using a U.S. map or atlas, list two major U.S. cities in the Mississippi valley seismic zone that lie within the 8 to 32% gravity shake zones (yellow-orange-red).

b) Explain why the Mississippi valley region, despite experiencing large magnitude earthquakes in the early 1800s, has so few buildings with the types of seismic engineering designs that are so common in California and Japan.

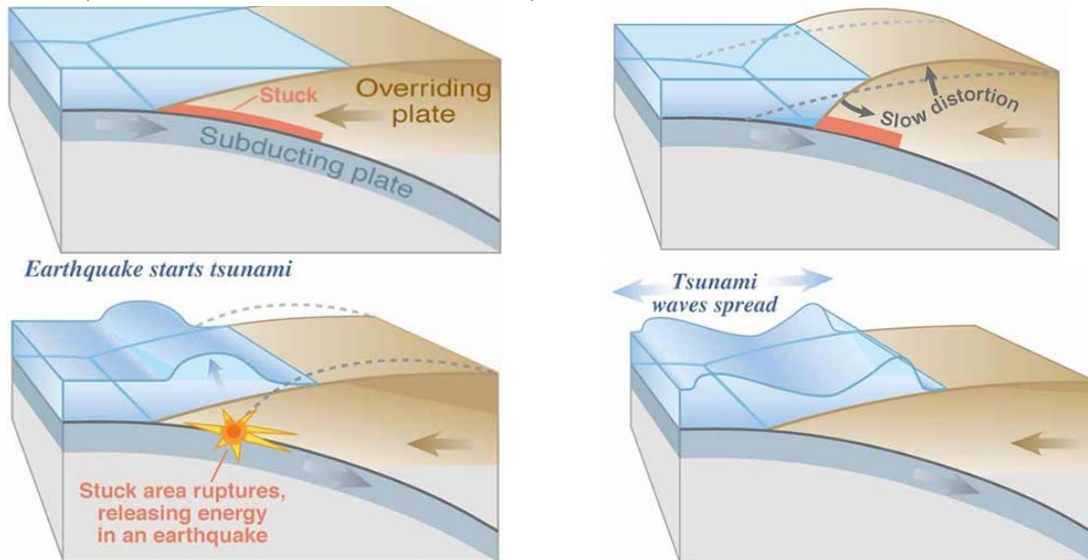
10) The area around Charleston, South Carolina, is another active intraplate seismic zone in the eastern United States. In 1886, a large magnitude quake occurred near Charleston, causing considerable damage.

a) Using an atlas and Figure 3.5, list the major U.S. cities that lie within the 4 to 24% gravity shake zones (green-yellow-orange) surrounding Charleston.

b) How well prepared do you think these cities are for a future earthquake? Explain your answer.

11) Notice in Figure 3.6 how western Washington state lies in a high-risk zone. Here the earthquake risk is related to a convergent plate boundary and associated subduction zone. Figure 3.6 illustrates how earthquakes are generated along subduction zones.

Figure 3.6 (Source: USGS Fact Sheet 150-00)



a) Explain why the largest earthquakes on record, around magnitude 9, are found associated with subduction zones. In other words, what it is about the subduction process itself that generates such large earthquakes?

b) Although the Puget Sound and Seattle area in Washington state lies in a high-risk zone, relatively few building have incorporated seismic engineering controls similar to those required in California. Explain how this reduced level of preparedness is related to the subduction zone process itself.

12) Communities along the Washington, Oregon, and northern California coast all face the prospect of a major subduction zone earthquake that generates a series of large tsunami waves. Describe why it is difficult for emergency management officials to develop effective evacuation procedures for coastal communities should a subduction zone earthquake occur in this area. Hint: examine how tsunamis travel in Figure 3.6.