EENS 3050	Natural Disasters
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Earthquake Hazards and Risks

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Earthquake Risk

- Many seismologists have said that "earthquakes don't kill people, buildings do". This is because most deaths from earthquakes are caused by buildings or other human construction falling down during an earthquake.
- Earthquakes located in isolated areas far from human population rarely cause any deaths.
- Thus, earthquake hazard risk depends on

1. Population density
2. Construction standards (building codes)
3. Emergency preparedness

Examples:

- Worst earthquake in recorded history occurred in 1556 in Shaaxi, China. Killed 830,000 people, most living in caves excavated in poorly consolidated loess (wind deposited silt and clay).
- Worst earthquake in the 20th century also occurred in China (T'ang Shan Province), killed 240,000 in 1976. Occurred at 3:42 AM, Magnitude 7.8 Earthquake and magnitude 7.1 aftershock. Deaths were due to collapse of masonry (brick) buildings.
- Worst earthquake so far in the 21st Century was a magnitude 7.0 earthquake that occurred in Haiti on January 12, 2010 with an estimated death toll of 230,000! (The death toll in this earthquake is still debated.The Hatian government claims 316, 000 deaths, while U.S. estimates suggest something between 46,000 and 86,000).
- Contrast - In earthquake prone areas like California, in order to reduce earthquake risk, there are strict building codes requiring the design and construction of buildings and other structures that will withstand a large earthquake. While this program is not always completely successful, one fact stands out to prove its effectiveness. In 1989 an earthquake near San Francisco, California (The Loma Prieta, or World Series Earthquake) with a Moment Magnitude of 6.9 killed about 62 people. Most were killed when a double decked freeway in Oakland collapsed. About 10 months earlier, an earthquake with moment magnitude 6.8 occurred in Armenia, where no earthquake-proof

building codes existed. The death toll in the latter earthquake was about 25,000!

Similarly the Moment Magnitude 7.0 2010 earthquake in Haiti had a huge death toll mainly because of the lack of earthquake-resistent structures. Most buildings were made of poorly reinforced concrete.

- Computer simulations for large cities, like San Francisco or Los Angeles, California, indicate that a magnitude >8.0 earthquake would cause between 3,000 and 13,000 deaths.
  - 3,000 if at night, when populace is asleep in wood frame houses
  - 13,000 if during day when populace is in masonry buildings and on freeways.

Architecture and Building Codes

While architecture and building codes can reduce risk, it should be noted that not all kinds of behavior can be predicted.

- Although codes are refined each year, not all possible effects can be anticipated. For example different earthquakes show different frequencies of ground shaking, different durations of ground shaking, and different vertical and horizontal ground accelerations.
- Old buildings cannot cost-effectively be brought up to code, especially with yearly refinements to code.
- Even with construction to earthquake code, buildings fail for other reasons, like poor quality materials, poor workmanship, etc. that are not discovered until after an earthquake.

Hazards Associated with Earthquakes

Possible hazards from earthquakes can be classified as follows:

Ground Motion - Shaking of the ground caused by the passage of seismic waves, especially surface waves, near the epicenter of the earthquake are responsible for the most damage during an earthquake and is thus a primary effect of an earthquake. The intensity of ground shaking depends on:

- Local geologic conditions in the area. In general, loose unconsolidated sediment is subject to more intense shaking than solid bedrock.
- Size of the Earthquake. In general, the larger the earthquake, the more intense is the shaking and the duration of the shaking.
- Distance from the Epicenter. Shaking is most severe near the epicenter and drops off away from the epicenter. The distance factor depends on the type of material underlying the area. There are, however, strange exceptions. For example, the 1985 Mexico City Earthquake (magnitude 8.1) had an epicenter on the coast of Mexico, more than 350 km

to the south, yet damage in Mexico City was substantial because Mexico City is built on soft unconsolidated sediments that fill a former lake (see Liquefaction, below).

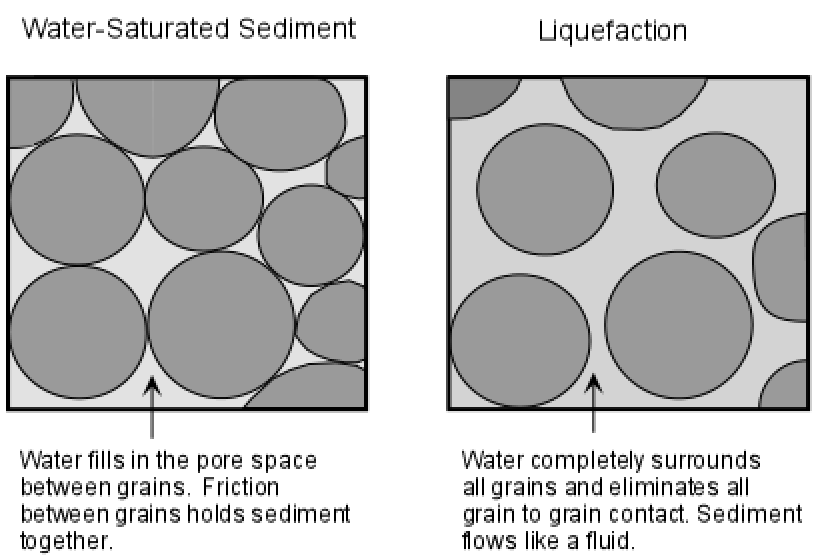
- Damage to structures from shaking depends on the type of construction.
  - Concrete and masonry structures are brittle and thus more susceptible to damage
  - wood and steel structures are more flexible and thus less susceptible to damage.

Faulting and Ground Rupture - Ground rupture generally occurs only along the fault zone that moves during the earthquake, and are thus a primary effect. Thus structures that are built across fault zones may collapse, whereas structures built adjacent to, but not crossing the fault may survive.
Aftershocks - These are smaller earthquakes that occur after a main earthquake, and in most cases there are many of these (1260 were measured after the 1964 Alaskan Earthquake). Aftershocks occur because the main earthquake changes the stress pattern in areas around the epicenter, and the crust must adjust to these changes. Aftershocks are very dangerous because they cause further collapse of structures damaged by the main shock. Aftershocks are a secondary effect of earthquakes

Fire - Fire is a secondary effect of earthquakes. Because power lines may be knocked down and because natural gas lines may rupture due to an earthquake, fires are often started closely following an earthquake. The problem is compounded if water lines are also broken during the earthquake since there will not be a supply of water to extinguish the fires once they have started. In the 1906 earthquake in San Francisco more than 90% of the damage to buildings was caused by fire.

Landslides - In mountainous regions subjected to earthquakes ground shaking may trigger landslides, rock and debris falls, rock and debris slides, slumps, and debris avalanches. These are secondary effects.

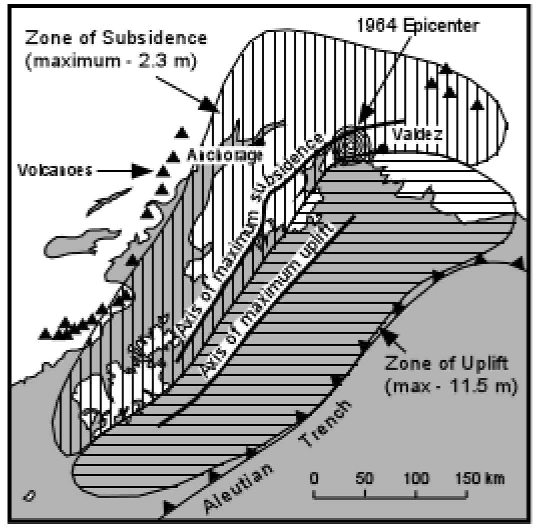
Liquefaction - *Liquefaction* is a processes that occurs in water-saturated unconsolidated sediment due to shaking. In areas underlain by such material, the ground shaking causes the grains to lose grain to grain contact, and thus the material tends to flow.



Liquefaction, because it is a direct result of ground shaking, is a primary effect.

You can demonstrate this process to yourself next time your go the beach. Stand on the sand just after an incoming wave has passed. The sand will easily support your weight and you will not sink very deeply into the sand if you stand still. But, if you start to shake your body while standing on this wet sand, you will notice that the sand begins to flow as a result of liquefaction, and your feet will sink deeper into the sand.

Changes in Ground Level - A secondary or tertiary effect that is caused by faulting. Earthquakes may cause both uplift and subsidence of the land surface. During the 1964 Alaskan Earthquake, some areas were uplifted up to 11.5 meters, while other areas subsided up to 2.3 meters.

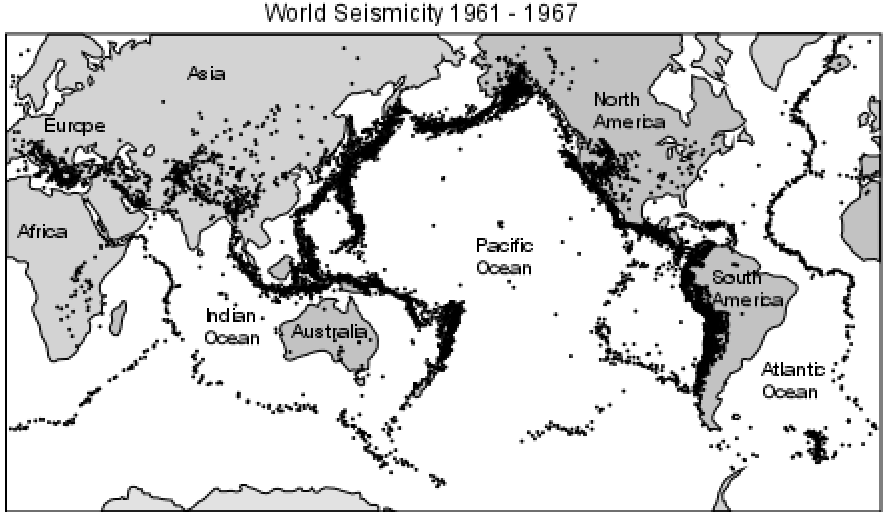


Tsunami - Tsunami a secondary effect that are giant ocean waves that can rapidly travel across oceans, as will be discussed in more detail later. Earthquakes that occur beneath sea level and along coastal areas can generate tsunami, which can cause damage thousands of kilometers away on the other side of the ocean.

Flooding - Flooding is a secondary effect that may occur due to rupture of human made dams and levees, due to tsunami, and as a result of ground subsidence after an earthquake.

World Distribution of Earthquakes

World Seismicity 1961 - 1967



The distribution of earthquakes is called ***seismicity.*** Seismicity is highest along relatively narrow belts that coincide with plate boundaries. This makes sense, since plate boundaries are zones along which lithospheric plates move relative to one another.

Earthquakes along these zones can be divided into shallow focus earthquakes that have focal depths less than about 100 km and deep focus earthquakes that have focal depths between 100 and 700 km.

Earthquakes at Diverging Plate Boundaries. Diverging plate boundaries are zones where two plates move away from each other, such as at oceanic ridges. In such areas the lithosphere is in a state of tensional stress and thus normal faults and rift valleys occur. Earthquakes that occur along such boundaries show normal fault motion, have low Richter magnitudes, and tend to be shallow focus earthquakes with focal depths less than about 20 km. Such shallow focal depths indicate that the brittle lithosphere must be relatively thin along these diverging plate boundaries.

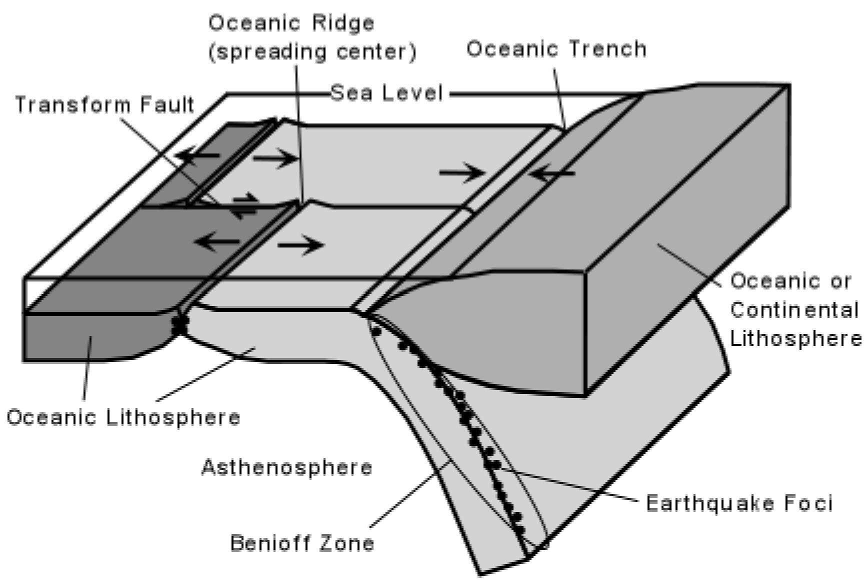
- Examples - all oceanic ridges, Mid-Atlantic Ridge, East Pacific rise, and continental rift valleys such as the basin and range province of the western U.S. & the East African Rift Valley.

Earthquakes at Transform Fault Boundaries. Transform fault boundaries are plate boundaries where lithospheric plates slide past one another in a horizontal fashion. The San Andreas Fault of California is one of the longer transform fault boundaries known. Earthquakes along these boundaries show strike-slip motion on the faults and tend to be shallow focus earthquakes with depths usually less than about 100 km. Richter magnitudes can be large.

- Examples - San Andreas Fault, California, South Island of New Zealand, through Port Au Prince, Haiti.

Earthquakes at Convergent Plate Boundaries. Convergent plate boundaries are boundaries where two plates run into each other. Thus, they tend to be zones where compressional stresses are active and thus reverse faults or thrust faults are common. There are two types of converging plate boundaries. (1) subduction boundaries, where oceanic lithosphere is pushed beneath either oceanic or continental lithosphere; and (2) collision boundaries where two plates with continental lithosphere collide.

- Subduction boundaries -At subduction boundaries cold oceanic lithosphere is pushed back down into the mantle where two plates converge at an oceanic trench. Because the subducted lithosphere is cold it remains brittle as it descends and thus can fracture under the compressional stress.



When it fractures, it generates earthquakes that define a zone of earthquakes with increasing focal depths beneath the overriding plate. This zone of earthquakes is called the ***Benioff Zone***. Focal depths of earthquakes in the Benioff Zone can reach down to 700 km.

- Examples - Along coasts of South American, Central America, Mexico, Northwestern U.S., Alaska, Japan, Philippines, Caribbean Islands.

Collision boundaries - At collisional boundaries two plates of continental lithosphere collide resulting in fold-thrust mountain belts. Earthquakes occur due to the thrust faulting and range in depth from shallow to about 200 km.

- Examples - Along the Himalayan Belt into China, along the Northern edge of the Mediterranean Sea through Black Sea and Caspian Sea into Iraq and Iran.

Intraplate Earthquakes - These are earthquakes that occur in the stable portions of continents that are not near plate boundaries. Many of them occur as a result of re-activation of ancient faults, although the causes of some intraplate earthquakes are not well understood.

- Examples - New Madrid Region, Central U.S., Charleston South Carolina, Along St. Lawrence River - U.S. - Canada Border.

Seismic Hazard and Risk Mapping

The risk that an earthquake will occur close to where you live depends on whether or not tectonic activity that causes deformation is occurring within the crust of that area.

- For the U.S., the risk is greatest in the most tectonically active areas, that is near the plate margin in the Western U.S. Here, the San Andreas Fault which forms the margin between the Pacific Plate and the North American Plate, is responsible for about 1 magnitude 8 or greater earthquake per century.

- Also in the western U.S. is the Basin and Range Province, where extensional stresses in the crust have created many normal faults that are still active.

- Historically, large earthquakes have also occurred in the area of New Madrid, Missouri; Charleston, South Carolina; Boston, Massachusetts; and along the St. Lawrence River near the New York - Canada Border. Why earthquakes occur in these areas is not well understood, However, **if earthquakes have occurred before, they are expected to occur again.**

Another way of looking a seismic risk that is more useful to construction designers and engineers, and therefore to the development of building codes, is based on expected horizontal ground acceleration. Acceleration is measured relative to the acceleration due to gravity (g = 980 cm/sec^2). Ground accelerations of 0.1g are considered able to cause damage.

An Earthquake hazard risk map is shown for the World, U.S. and Canada on page 79 of your text.

Examples of questions on this material that could be asked on an exam

1. In earthquake prone areas, what factors contribute the most to earthquake risk?
2. At any given locality, what factors determine the intensity of ground shaking and

subsequent damage from an earthquake.

3. Considering geologic time scales, where are earthquakes most likely to occur?

4. What are the main primary and secondary effects of earthquakes?

5. What kinds of faults that cause earthquakes occur at each of the various types of plate boundaries. Is it possible for an earthquake to occur in locations other than plate boundaries? If so, give an example of an earthquake that has occurred in such a location.

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