Lecture 3:

Earthquakes

Ch. 3: p. 32-36; 44-53; 56-58

“A bad earthquake at once destroys our oldest associations: the earth, the very emblem of solidity, has moved beneath our feet like a thin crust over a fluid.” Charles Darwin, “The Voyage of the Beagle.”

Earthquake Damage in the United States:

Pre-1989: about $230 million per year
Post-1989: about $4.4 billion per year (estimated).

Awareness of Earthquake Hazards: Commonly, people either don’t know or don’t want to know that they live in a region with significant earthquake risk (e.g., Borah Peak earthquake, near Challis, Idaho (1983), M6.9).

Where are the earthquake-prone regions in the United States?

So we need to know more about what creates the hazards associated with earthquakes and how to deal with them.

What are the earthquake hazards and risks?:

• Ground shaking (failure of buildings and other structures)
• Ground fissures (deep cracks in the ground)
• Liquefaction (when solid turns to goo)
• Landslides and avalanches (compounded during rainy season)
• Tsunamis (inundation of low-lying areas) and Seiches (sloshing water)
• Fire (sparked by broken gas mains and downed power lines)
• Loss of infrastructure (roads, electricity, water, sewage lines, medicines)
• Disease (contaminated water, decomposing bodies)
• Exposure to the elements (winter earthquakes can be devastating)
• Breakdown of governments (no leadership for relief efforts)

Ground Shaking is due to Seismic Waves: Vibrations that move through the Earth (i.e., ENERGY). This energy travels in the form of waves. What is a wave?

The vibrational frequency refers to the number of waves per second (measured in Hertz, Hz). 1 Hz = 1 wave per second.

Seismic Waves have variable types, speeds, and frequencies:

• P-waves: primary waves or compressional waves (~5-6 km/s). They are the fastest waves and so are the first to be felt.
• S-waves: secondary waves or shear waves (~3.5 km/s). S-waves are the second-fastest and so are felt next.
Taken together, P-waves and S-waves are referred to as BODY WAVES. This is because they travel through the body of the Earth away from some depth below the surface. They have a vibrational frequency in the range 1-30 Hz.

- **Love waves**: back and forth motion along the surface (~2-4.5 km/s).
- **Rayleigh waves**: up and down motion along the surface (also ~2-4.5 km/s, but slower than Love waves).

Taken together, Love waves and Rayleigh waves are referred to as SURFACE WAVES. This is because they travel along the surface of the Earth. They have a vibrational frequency of <1 Hz.

**How do we measure seismic waves?**: Seismic waves are recorded using a seismograph (also called a seismometer). The record of the earthquake produced by the instrument is called a seismogram. Different wave types (P, S, Love, Rayleigh) can be distinguished from each other on the seismogram.

**What causes an earthquake?**: What actually HAPPENED at Borah Peak in 1983? Motion occurred along a ________

Faults can be thought of as planar fractures or breaks within the Earth’s lithosphere. This surface is inclined, or dipping. The “block” of rocks that sits beneath this inclined surface is called the ____________________. The “block” of rock that sits above the inclined fault surface is called the ____________________.

We can identify three distinct styles of faults that have different types of motions. If the HW moves up and the FW moves down, the fault is called a ____________________. TYPE OF FORCES: [ ____________________ ]

If the FW moves up and the HW moves down, the fault is called a ____________________.

TYPE OF FORCES: [ ____________________ ]

If there is lateral (sideways) motion along an almost vertical break, the fault is called a ____________________.

There are two possibilities: ____________________ and ____________________.

TYPE OF FORCES: [ ____________________ ] or [ ____________________ ].

The types of environments in which the faults form has to do with the forces generated by plate tectonics. What types of plate tectonic environments do the faults form in? Think back to the types of plate boundaries (transform/divergent/convergent). **Now match each of the three fault types with the type of plate boundary in which they are most likely to be found.**

**But what makes the faults move?**: The behavior of rocks that allows faults to build up energy and eventually produce earthquakes is called ____________________.

**Elastic Rebound Theory**: The stress from plate motions causes rocks to warp alongside faults. When the FRICTION of the fault is overcome, an earthquake occurs.

**How deep into the earth do faults go?**: Earthquakes represent BRITTLE behavior in the lithosphere. In the asthenosphere, the rocks are ductile and cannot produce earthquakes. Also, because the thickness of the lithosphere is variable, earthquakes in oceanic lithosphere are shallow but in continental lithosphere, they can be much deeper.

**The first point of rupture along the fault is deep underground**: The rupture spreads along the fault while the seismic waves radiate out into the surrounding rocks. The earthquake starts along a fault at the FOCUS or HYPOCENTER, which can be many kilometers underground. The point on the Earth’s surface directly above the focus is called the EPICENTER. This is where body waves first reach the surface and produce surface waves.
**We can always find the epicenter using seismograms:** First, we look at the time lag between the arrival of the P and S-waves, which depends on the distance from the earthquake and the relative speeds of the 2 waves. Then, we calculate the distance to the epicenter. At least 3 separate seismograph stations are needed to triangulate the exact epicenter location.

*Why do we care where the epicenter is?*

**Earthquake magnitude:** To calculate the RICHTER MAGNITUDE of the earthquake, we need to know 2 things: (1) Distance from the event. (2) Amplitude of the S-wave. These are plotted on a NOMOGRAPH to find the magnitude. The scale uses numbers in the 0 to 10 range (e.g., M5.0). The scale is logarithmic so an increase of 1 in magnitude represents 10 times more wave amplitude and 32 times more energy.

For very large earthquakes, the MOMENT MAGNITUDE is typically used.

*Is magnitude the most useful scale to measure an earthquake?*

Think of the most expensive earthquake in US history: ________________________________

*What does the magnitude of this event tell us about the distribution of damage?* __________________________

The extent of damage varies with location and is described using the earthquake INTENSITY.