LECTURE #6: Plate Tectonics: Boundaries & Earthquake Science

Date: 29 January 2025

I. Review from Last Class

- brief history of Plate Tectonics and how it came to be *(using the steps of the Scientific Method)*
- the two hypotheses that combined to become the *Theory of Plate Tectonics* what were these?
 - 1. _____ 2.
 - _____
- can you recall the 5 steps of the *Scientific Method* without looking back at the notes?

II. Today: Expand Upon *Plate Tectonics*

- three types of plate boundaries:
 transform, divergent, convergent
- major <u>compositional</u> zones of the Earth
 crust, mantle, outer core, inner core
- major <u>mechanical</u> zones of the upper Earth
 o lithosphere, asthenosphere
- how do we know the interior structure of the Earth?
 by examining seismic waves as they move through the interior
- three types of plate boundaries:
 - o divergent
 - plates spreading apart
 - generally produce <u>small</u> earthquakes
 - > example: ocean floors
 - convergent
 - plates come together
 - called: subduction zones
 - increased volcanic activity
 - mostly produce <u>large</u> earthquakes
 - > example: South America





- \circ transform
 - plates slide past one another
 - generally produce <u>moderate</u> earthquakes
 - > example: San Andreas fault



- how do we know the structure of the Earth?
 - by using seismology
 - study of seismic waves as they move through the Earth
 - created by EQ's
 - can be VERY destructive
 - > but also used to "image" the structure of the Earth
 - > will look at this more when we examine earthquake (EQ) disasters

III. Seismology

- *definition:* the branch of geophysics concerned with the study and analysis of EQs and the science of the energy they produce
- seismic waves:
 - energy travels in the form of waves (causing particle motion) radiating out from a fault rupture (*break*)
 - \circ two main types:
 - body waves
 - surface waves
 - *type 1:* Body Waves:
 - move through the <u>volume</u> of the Earth
 - two sub-types: P-waves, S-waves
 - P (primary) waves:
 - compressional particle motion
 - fastest average speeds in the crust (~ 6 km/s)
 - behave similar to sound waves in air
 - can pass through solid, liquid and gas
 - S (secondary/shear) waves:
 - second fastest wave (~ 3.5 km/s)
 - shearing (side to side movement) particle motion
 - > more damaging to structures because of the shearing ground motion
 - can only passes through solids

• *type 2:* Surface Waves:

- confined to the very upper surface of the crust
- are slower than both P & S waves
- can be very damaging to structures
- two main sub-types: Love-waves, Rayleigh-waves

- Love waves:
 - similar to the motion of S-waves
- Rayleigh waves
 - Retrograde (reverse) rotating particle motion
- we will discuss how we can use these waves along with a seismogram (below) to estimate the distance to an EQ epicenter
 - this will help us to understand earthquake locations and disasters in the coming weeks!
 - notes:



Seismic record of an EQ

- location of EQ epicenters (at subduction zones)
 - o related to the dip angle of the ocean crust being subducted
 - this location is further from the subduction zone (more inland) for shallow dipping ocean crust
 - conversely, they are closer to the subduction zone (and to the shore line) for steeper dipping ocean crust



important to understand that the dip of the subducting ocean plate determines the location of the volcanoes and EQs on the ground above (known as the epicenter)

- generalized structure of the Earth
 - o how do we know what is below our feet?
 - we have only drilled down several kilometers
 - never through the crust:
 - > 5 km thick (ocean crust) and 35 km thick (continental crust)
 - > by comparison, the Earth has a radius of 6,370 km!
 - o examining the seismic waves as they pass through the Earth
 - waves change speeds when they travel through different rock compositions, densities, and solid/liquid
 - seismologists can model these changes and estimate:
 - ➤ the rock types
 - rock layer thicknesses
 - their state (a solid or liquid)



<u>yellow arrow:</u> "low-velocity" zone (small amount of liquid) – both P and S waves slow <u>red ellipse:</u> outer core (all liquid) – P waves slow dramatically & S waves stop

- structure of the Earth's interior:
 - o major *compositional* zones of the Earth
 - crust
 - ➤ two types: oceanic and continental
 - 1. continental crust
 - ➤ thicker (30-50 km)
 - less dense (granitic rocks)
 - older (some regions up to ~3 billion years old)
 - 2. oceanic crust
 - ➤ thinner (~ 5km)
 - more dense (gabbroic rocks)
 - much younger (only up to ~200 million years old)

- mantle
 - > extends from the crust boundary down to the outer core
 - ≻ ~ 2900 km
 - some indirect sampling when material (called kimberlites) is brought to the surface from very deep rooted, explosive volcanoes
 - > most information comes from seismic profiles
 - relatively uniform composition of rock
 - pressure/temperature increases with depth
 - low-velocity zone (upper 80-300 km) in upper mantle
 - has a few percent of molten material
 - <u>critical:</u> this zone allows Plate Tectonics to happen
- <u>core</u>
 - ➢ two zones that are VERY different
 - > enriched in metal compared to the crust/mantle
 - ➢ much more dense
 - mostly iron (plus ~ 5% nickel and 1-2% sulfur)
 - 1. outer core
 - liquid (caused by the very high temperatures)
 - rotation of this metallic liquid (convection) creates the Earth's magnetic field
 - 2. inner core
 - solid (even higher pressures overcome the very high temperatures)
- o major *mechanical* zones of the upper Earth
 - upper layer (lithosphere)
 - defines a tectonic plate
 - brittle behavior
 - does not flow and therefore fractures when stress is applied (such as an EQ)
 - all of the crust and part of the upper mantle (both compositional zones) define the lithosphere (a mechanical zone)
 - asthenosphere below this
 - > all mantle material
 - plastic behavior flows when stress is applied
 - small amount of partial melting
 - the "low velocity" zone because seismic waves slow down through this partial melt zone



Cross section A-B (in figure below)

