Oceanography Notes Week Two
Week of September 17, 2018
Note Taker: Julia Winberg

Plate Tectonics I

Theory and Early Evidence

- The crust of our planet is constantly moving, about the rate that our fingernails grow
- The theory that the Earth's crust is moving is a pretty old theory, and humans have been thinking about this for a long time, since the late 1500s.
    - Abraham Ortelius, 1596, theorizes the continents were once together and then ripped apart
    - Francis Bacon (1561-1626)
    - Antonio Snider-Pellegrini
    - Benjamin Franklin (1706-1790)
- Alfred Wegener- 1912
    - Champion of Continental Drift
    - Theorizes that the continents are moving across the globe
    - Thinks continents were once connected and then drifted
    - ridiculed by science community for this
- Evidence for Continental Drift
    - **Fit**
        - 200 mya
        - Pangaea supercontinent surrounded by Panthalasa and Tethys Sea
        - Continents today look like they "fit" together
        - If you were to match up the continents, the best fit would be around 2000 meters form the coast because of variation in continental shelves (Eastern side of North America has very long continental shelf) - this was discussed starting around the early 1960s
    - **Mountains**
        - Mountains in some continents (ex: Appalachian Mountains) have rock type that match mountain ranges in continents halfway across the world (Caledonian Mountains in UK)

        - **Glaciers**
            - scarring and deposits in unlikely places: South America, South Africa, India, Australia (really warm climates today)
            - Theory: Once fit together, placed more southern on the globe, closer to Antarctica
            - 300 million years ago
            - Glacier deposits not everywhere on the globe, which debunks ice age counterargument
        - **Fossils**
            - Glossopteris: large fern plant fossil present in India, Australia, South Africa, South America
            - 1885, Edward Seuss
            - Continental Drift possible explanation
            - Animal fossils present in different continents as well
            - Supercontinent theory most parsimonious theory
        - In review: Wegener's evidence for continental drift:
            - Fit
            - Mountains
            - Glaciers
            - Fossils
- Wegener's doubt: Where he went **wrong**
    - **Wrong:** He theorizes that continents "plow" through ocean basins using incorrect calculations
    - **Wrong:** He theorizes the continents move because of gravitational attraction of sun and moon on the equator. **In reality** the gravitational forces are too small to move Earth
- Structure of the Earth is centered around density
    - Density stratification
        - Distinct layers
        - Each layer heavier than the last: Inner core solid, Outer core molten,
    - **Hydrosphere**: Area in which all of life exists, ocean, land as we know it, etc. is 4km thick.

    - **Crust** makes up 0.4% of the Earth, 35-40km thick, low density. Made of Lighter elements like Aluminum, Silicon, Oxygen
    - **Mantle** makes up 68% of the Earth, approx. 2900km thick. Dense, hot rocks, Magnesium, Iron, Silicon, Oxygen
    - **Core** makes up 31.5%, about 3500 km thick. Outer core is liquid, Inner core is solid, made of Iron and Nickel, Inner core is solid temperature and pressure
- The inner core is solid because of high temperature and pressure. The higher the pressure, the higher the melting point! For example, if something's melting point is 9,900 degrees F, if you add pressure, it would take a substantial increase in temperature to melt it. It might melt around 22,000 degrees F.
- If pressure is too high, it won't melt. Think: Solid Inner core.
- Our outer core melts because the temperature is high enough even with the sustained pressure from the Earth above it.
- The Mantle:
    - Also called **Mesosphere**
    - Outer mantle called the **Asthenosphere**
- Crust:
    - The **Lithosphere**
- The crust of our planet is incredibly thin. Most of our planet is crazy inner earth. We, and all of the biology of our planet, exist upon this thin crust.
- **Land Crust vs. Ocean Crust**
    - **Continental Crust (Land)**
        - Thick, light (think styrofoam)
        - about 2.7 grams per cubic centimeter
        - Granite (or other light minerals/ rock)
        - OLD
        - Coarse, Light
        - Approx. 30-40 km thick
    - **Oceanic Crust (Underneath the Sea)**
        - Thin, Dense
        - 3 grams per cubic centimenter
        - Basalt
        - Young!

        - Fine, Coarse
        - Approx. 4-10km thick
        - Dark
- Upper Mantle
    - Called the “**Moho**,” named for Andrija Mohorovicic, who discovered it
    - It is a boundary between the crust in the Ocean or Land and the Mantle.
    - As a boundary, it is about 3.3 grams per cubic centimeter, and it is denser than wither continental or oceanic crust.
    - Moho is closest to the center of the Earth when it is underneath the thin and dense crust of the ocean.
- ****If it helps, think of the Continental Crust as Styrofoam and the Oceanic Crust as Aluminum Foil!*****
- Buoyancy and Isostatic Pressure
    - **Isostatic Pressure** is what happens when you add weight to something that causes it to think. Think about what happens when you load up a cargo ship or when you stand on a boogie board in water.
    - **Isostatic Rebound** is what happens when you release that pressure and it comes back up as it gets lighter. Think of what might happen as you unload a cargo ship, or you jump off a boogie board or a dock you are standing on.
    - When weight is added or removed, an equilibrium is disturbed.
    - Isostatic Pressure is a driving force in our sea levels today.
    - **Isostatic Adjustment** is adding and removing pressure to an object
    - Earth’s continents are floating on the Earth’s mantle. The Oceanic crust floats lower, and the Continental crust floats higher.
- Affecting Isostatic Pressure and Rebound
    - Icebergs, Ice, and Glaciers
        - Canada is actually *lower* and depressed deeper in the **asthenosphere** than other countries because of the sheer weight of ice on the country.
        - New England is *still* experiencing Isostatic Rebound from the disappearance of a large glacier that was present thousands of years ago. It is still rising.

- Louisiana is experiencing Isostatic Pressure as the weight of water from the Mississippi and the Gulf Coast press heavier and heavier into the land.

Wednesday, September 19, 2018

Plate Tectonics II

- Review at the beginning of class:
    - What is Isostatic Rebound?
    - Compare the Continental vs. Oceanic Crust
    - Who is Alfred Wegener?
- Harry Hess
    - US Navy Captain in World War II
    - He leaves his depth recorder on all the time as he travels and discovers something extraordinary.
    - Aside: a depth sounder fives a much better picture of depth vs. a less advanced method, like the *Challenger* expedition.
    - Hess gives us a picture of the sea floor which is a new visual, a new map.
    - Hess notices:
        - Underwater mountain ranges lining the centers of ocean basins all around the world
        - Extremely deep trenches at the edges of ocean basins, along coasts
    - Now we can see that our oceans are bisected by “stitches” of mid-ocean ridges, like on a baseball. We weren't able to see this until the 1950’s, thanks to Hess.
    - Underwater mid-ocean ridges are the **world’s longest mountain chain.**
- Deep Trenches at Continental Margins
    - Peru-Chili Trench (S. America)
    - Japan Trench
    - Kurile Trench (Japan)
- Hess **also** notices:
    - undersea volcanoes have flat tops
    - There is **less** sediment at the peaks of mid-ocean ridges

- Flat-top volcanoes

    - Flat top due to erosion. They are in a different spot on the surface of the Earth than they were years prior, and as they move, they erode.
    - How did Hess tell the difference between volcanoes and mountains underwater? This has to do with their distribution. Volcanoes are off-center to the chain of mountains.
- Thus, Hess coins idea **Geopoetry.** Championed by Wegener, refined by Hess.
    - **Geopoetry** or **Sea Floor Spreading** is the theory of Plate Tectonics in its infancy.
    - New ocean crust is formed at ridges
    - Undersea volcanoes, once close to surface, eventually erode away
    - Undersea trenches are where the seafloor descends back into the mantle
    - Sediment is thinner at mid-ocean ridges because the seafloor is far younger there
    - Older, cooler, denser rock is sinking, and spreading to the trenches.
- Fun Fact: Harry Hess failed his first course in mineralogy at Yale. Lesson: don't let people tell you you can't be anything.
- To accomodate for the movement of the Earth's crust, the Earth is:
    - **RECYCLING BY SUBDUCTION**
- Map shows there is thin sediment in open oceans, and thick sediment (affected by river runoff) on coasts, like Louisiana (Mississippi), India (Ganges), N. Brazil (Amazon)
- The longer you are around, the easier it is for more stuff to get piled on top of you. Think old rock here.
- The youngest rock in the ocean is at the seam of the ocean basins, on the mid-ocean ridges.
- The oldest **continental** rock is about 4 billion years old, around the age of the Earth itself.
- However, the oldest **oceanic** rock is about 200 million years old, due to subduction and constant recycling of rock back into the mantle.
- The less dense continental crust does not subduct like the ocean floor because it is floating on top of all this.
- **Drummond Matthews and Fred Vine**
    - measured the first magnetic anomalies in the Indian Ocean.
    - Why does this matter? Who cares about magnets?

    - Well, all the sediment on the seafloor has a **magnetic signature.** This means that when the crust was young and full of hope, and was new, hot and light magma, the magnetic bits and pieces in the rock, like iron oxide, matched the magnetic signature of the Earth. As the rock cooled and became old, the rock retained that imprint of the Earth's magnetic orientation.
    - Because of the magnetic signature of ocean sediment, we can see that young, new crust have very different signatures than old crust.
- **Magnetometer**
    - Used by Matthews and Vine, measures Earth's magnetic field and the magnetic signature in oceanic crust as you drag it through the ocean.
- Thus, the rocks are recording the Earth's magnetic field and polarity as the magnetic pieces of new rock match the magnetic signature of Earth and "freeze" like that. For years and years and years. Think of the oldest oceanic rock present today.
- **Paleomagnetism**, or deciphering the messages in these rocks (Paleo= old)
    - What was the Earth's magnetic field at the time this rock was formed?
    - Makes it way easier to tell age of the Earth and rocks
    - Where rocks first formed
    - Earth's ancient magnetic fields (they change!)
- **Magnetic Dip**
    - Particles *will* align with Earth's magnetic signature.
- **Magnetite**
    - Cooled magma with iron oxide
- Drummonds and Vine use the insights they find to give us insight into how old oceanic crust is.
- There is a **historical record** in the sea floor.
- BIG TAKEAWAY: The seafloor is constantly spreading, being subducted, then recycling. We can tell this by looking at:
    - Sediments
    - Magnetic signature
    - Trenches
    - Age of rocks

- **Marie Tharp**

    - Makes a map of the sea floor by combining data and measurements from the depth soundings of Harry Hess, among other things
    - Ignored by textbooks for years
- **Magnetic Polarity Reversals**
    - Every so often, the Earth's magnetic polarity will switch. Every 25k to 30 million years.
    - The Earth is overdue for a reversal in polarity. When will this happen? What will it be like? We don't know (you will be fine). We know the Earth has been gradually reversing, but we don't know if the entire process is going to be gradual or if one day we will just wake up and South will be North.
- **The Magnetic Field**
    - Protects from the Sun and Solar Storms
    - Useful to Animals: cow, deer, whales, and even bacteria.
    - What might a change in polarity mean for migrations?

Friday, September 21, 2018

Plate Tectonics 3

- Hess (review): Discovers ridges, trenches, seafloor volcanoes with flat tops
    - Convection cells in mantle drive seafloor spreading
- Plate tectonic system is driven by **heat**
- Think of the mantle as a viscous substance underneath us: rock so hot it is molten
- Seafloor spreads at the mid-ocean ridge
- Subduction zones: ocean trench site of crust destruction. Subduction generates deep sea trenches
- The Earth isn't getting bigger, so it must be recycling crust
- Heat Flow
    - Heat from the Earth's interior (mantle and core) is released to the surface. Temperature very high at mid-ocean ridge, very low at subduction zones.
- At this point in class we watched a youtube video: https://www.youtube.com/watch?v=MmMX83diwl0

    - This video points out the CO_2 cycle that phytoplankton are a part of: they absorb CO_2 in the atmosphere, sink to the bottom of the ocean, die, and are subducted underneath the continent. As the rock melts, the CO_2 rises and is released into the atmosphere via volcanoes.
- **Ridge Push**
    - **Buoyant magma breaks through Earth's crust at mid-ocean ridges, and the heat and force of the magma pushes ridges out of the way and drives plates apart.**
- **Slab Pull**
    - **Old, dense, cold plates that sink underneath plates in subduction pull whatever is behind it with it, like a conveyor belt.**
    - Aka slab suction
    - **SLAB PULL IS STRONGER THAN RIDGE PUSH**
- How fast do plates move?
    - 2-12cm or 1-5 inches per year, the rate at which your fingernails grow.
- Most large earthquakes occur at subduction zones, because **earthquake activity mirrors tectonic plate boundaries.** On a map, plate boundaries match up almost perfectly with earthquake occurrences.
- **Lithospheric plates: Convergent and Divergent boundaries and Transform faults**
    - At **Divergent Boundaries,** crust is formed.
    - At **Convergent Boundaries,** crust is recycled into the Earth
    - At **Transform Faults,** crust is neither formed nor recycled. The plates slide past one another.
- Divergent Boundaries
    - A continental example is the Rift Valley in Africa, where the land spreads apart and cracks open, Eventually, if this rift becomes wide enough, it could become a new ocean basin. It's called continental rifting.
    - Mid-ocean Ridges
    - Spreading Centers:
        - Oceanic Rise: Fast-spreading, gentle slopes like in the Eastern pacific

        - Oceanic ridge: slow-spreading, like at mid-ocean ridges, steep peaks
        - Ultra-Slow: Deep rift valley, widely scattered volcanoes
- Convergent Boundaries
    - Plates are moving into one another
    - Crust is destroyed
    - The denser plate will subduct: hence, oceanic plate subducting underneath continental plate
    - You can have ocean-ocean, ocean-continent, or continent to continent convergent boundaries. On continent- continent convergent boundaries, there is no destruction of crust and the collision forms mountains. Example: Himalayas
- Transform Faults
    - Also called a strike-slip
    - The reason why California isn't going to fall into the sea, the North American Plate is rubbing up against the plate adjacent and they are sliding past each other. No crust formed or destroyed
    - San Andreas fault: California, you can see the plates side-by-side