LECTURE #5: The Scientific Method: Introduction to Plate Tectonics

Date: 27 January 2025

I. Reminder:

- exam 1 is two weeks from today
  - come talk to me during office hours if something is not making sense
  - study from the notes
  - I will show a few example questions next week

II. Review from Last Class

- moved from mineral to rocks
  - definition of a rock
  - minerals as they relate to rock type
    - especially for some of the hazards we will discuss in the coming weeks
  - three major rock types
    - igneous
      - forms from molten rock
      - crystal size depends on how fast the rock cooled
    - metamorphic
      - forms from *solid-state* transformation
      - *high pressure/temperature but not enough to melt the rock*
    - sedimentary
      - forms either from mechanical (from pieces of other rocks, sediments, living matter) or chemical (precipitates out of water) processes
  - rock cycle
    - describes pathways of the rock-formation process

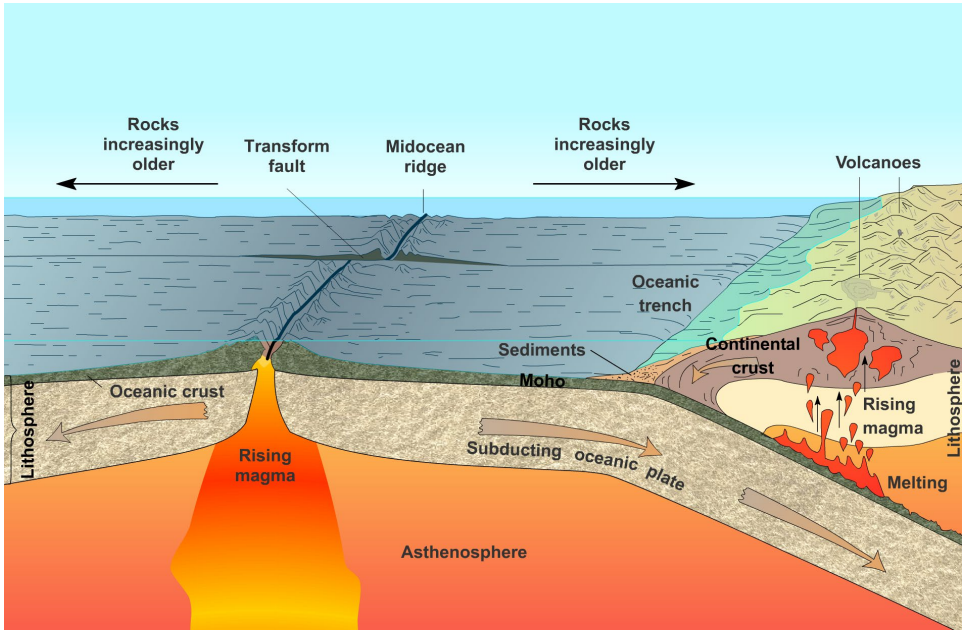
III. Plate Tectonics

- today we will examine the basic concepts of Plate Tectonics in light of the **Scientific Method**
  - what is the Scientific Method?
  - how do scientists use it to form hypotheses and theories from observable data?
  - how was it used specifically for the Theory of Plate Tectonics?

- Solid Earth Circulation
  - *yes, the solid Earth circulates*
  - Earth's crust moves horizontally and vertically
  - together with erosion, weathering and lithification *(process of forming a rock)*
    - these all produce a large amount chemical recycling
    - also, VERY important for chemical recycling of the oceans and atmosphere

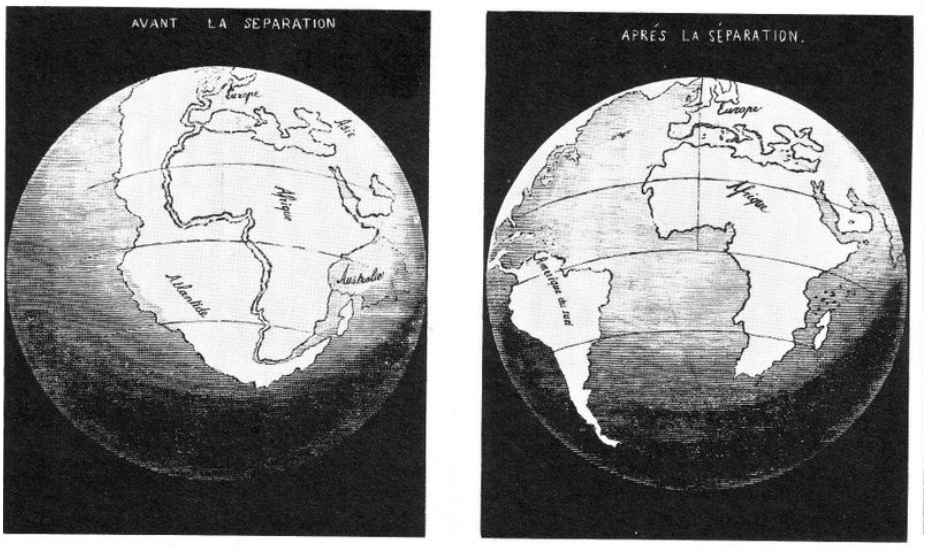
- for example, *the carbon cycle cycles CO_2 from the air into living material, into the ocean, eventually into the rocks (limestone), and then back again*

- need to understand how the Earth moves
  - what is the energy source for this? *(described in lecture #2)*
  - what is the rock cycle? *(described in last lecture)*



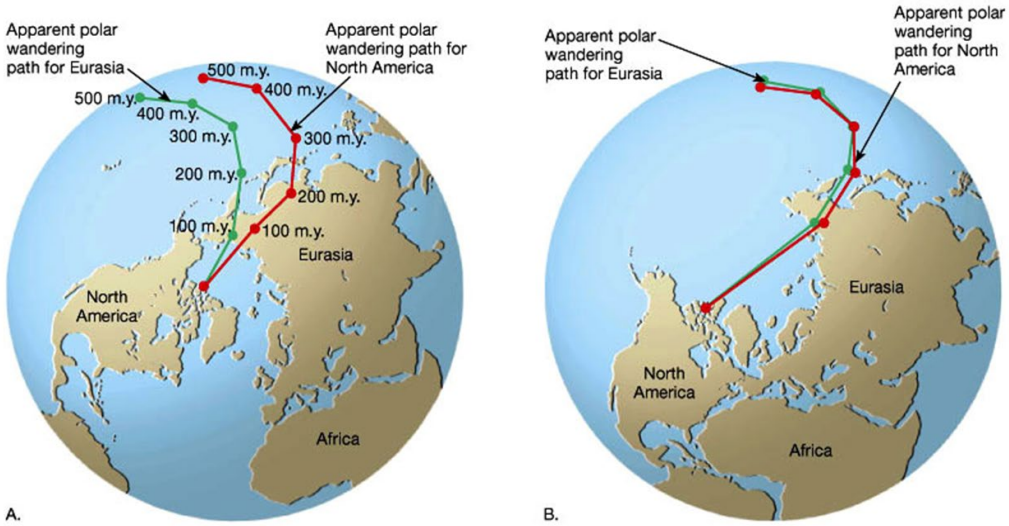
Modern concept of Plate Tectonics

- early observations of what was then called *Continental Drift*
  - Alfred Wegener proposed a hypothesis called Continental Drift in 1924
    - observed that the continents seemed to fit together if the oceans were removed from maps
    - was the first to describe it in detail scientifically, but not the first to note this:
      - Abraham Ortelius (1596), Francis Bacon (1625), Benjamin Franklin (1858), Antonio Snider-Pellegrini (1858)



first known illustration of the Opening of the Atlantic Ocean by Antonio Snider-Pellegrini, 1858

- Wegner had more information/data than those earlier scientists
  - he noted similar geology on these continents as if they were formed at the same location
  - he observed data of similar fossils and species on both continents
  - other evidence:
    - ancient climate zones (coral reefs and deserts)
    - glaciations (location and direction of glaciers impossible in current climate)
    - "polar wandering" *(shown below)*



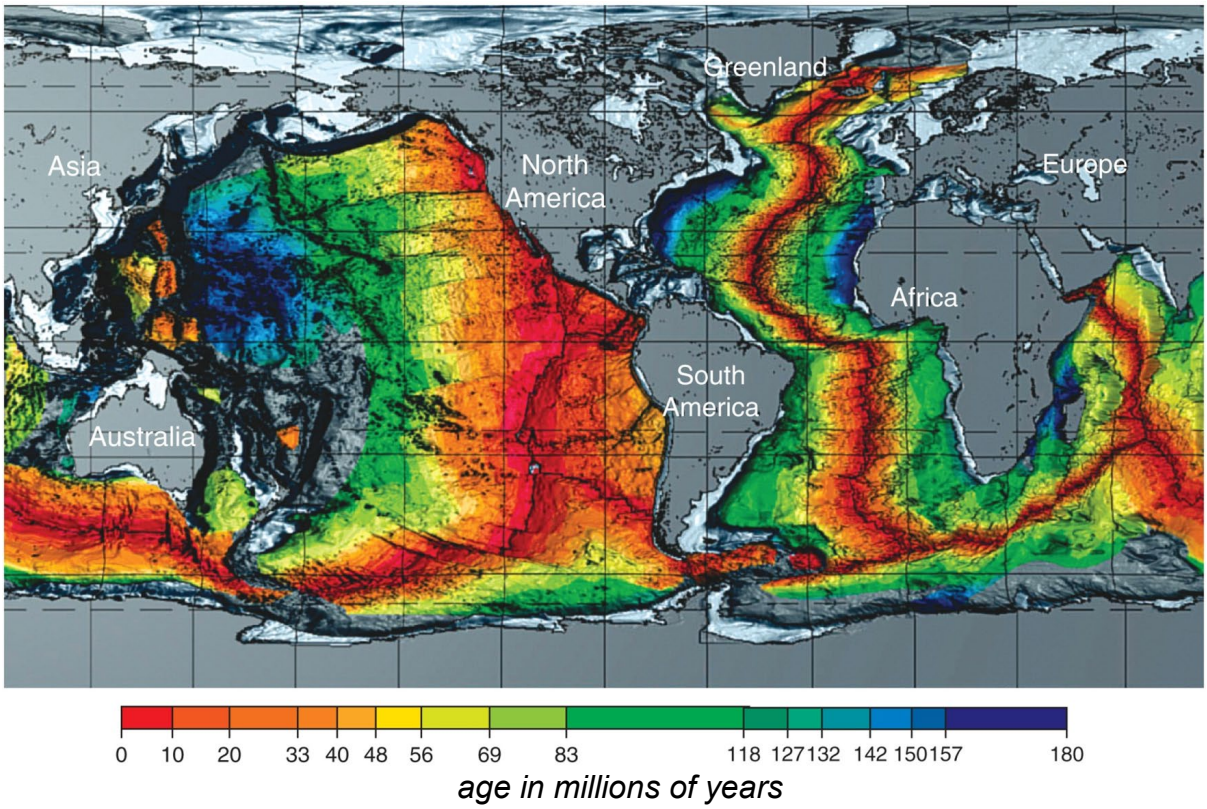
- **skeptics** of Continental Drift said:
  - there was no explanation of the energy source
  - there was no ability to refute a claim that plants and animals may have just migrated
  - there was no data/information included about the sea floor
    - how does something as large as a continent just plow its way through the ocean floor!?
    - after all, could the continental fit just be a coincidence?
    - much debate and the hypothesis eventually died
    - *that is all part of the scientific process!*

IV. Scientific Method

- allows hypotheses to be tested and debated
- the good ones hold up and the weak ones die out
- does **not** imply that scientists are unsure
- **does** imply that scientists are constantly testing new and better ideas
  - it is NOT a closed-door or closed-minded approach

- so, how did the Continental Drift *Hypothesis* eventually lead to the *Theory* of Plate Tectonics??
  - more data were collected decades after Continental Drift died away
    - in the early 1960's it was noted that the sea floor appeared to be spreading from its center *(data from submarines and satellites)*

- younger rocks at the center ridge and older rocks near the continents
- known as the *Sea Floor Spreading Hypothesis*
- could that be linked to the movement of the continents?



- lead to the proposal that the mantle of the Earth was convecting much like water boiling on the stove top
  - driven by the Earth's internal heat
  - this was the driving force (energy) that Wegner lacked for his hypothesis
  - the movement of the mantle created new ocean floor crust, which spread out and pushed the passive continents along

- *this then became the unifying theory for the geosciences: Theory of Plate Tectonics (but only in the late 1960s!)*

- General Stages of the Scientific Method
  1. observation & data collection
     - example:
       - Wegner's original observations
       - geophysical data from the sea floor in the 1960's

  2. hypothesis
     - example:
       - ocean floor created at the center, destroyed at the edges
       - continental crust therefore must move as part of this process

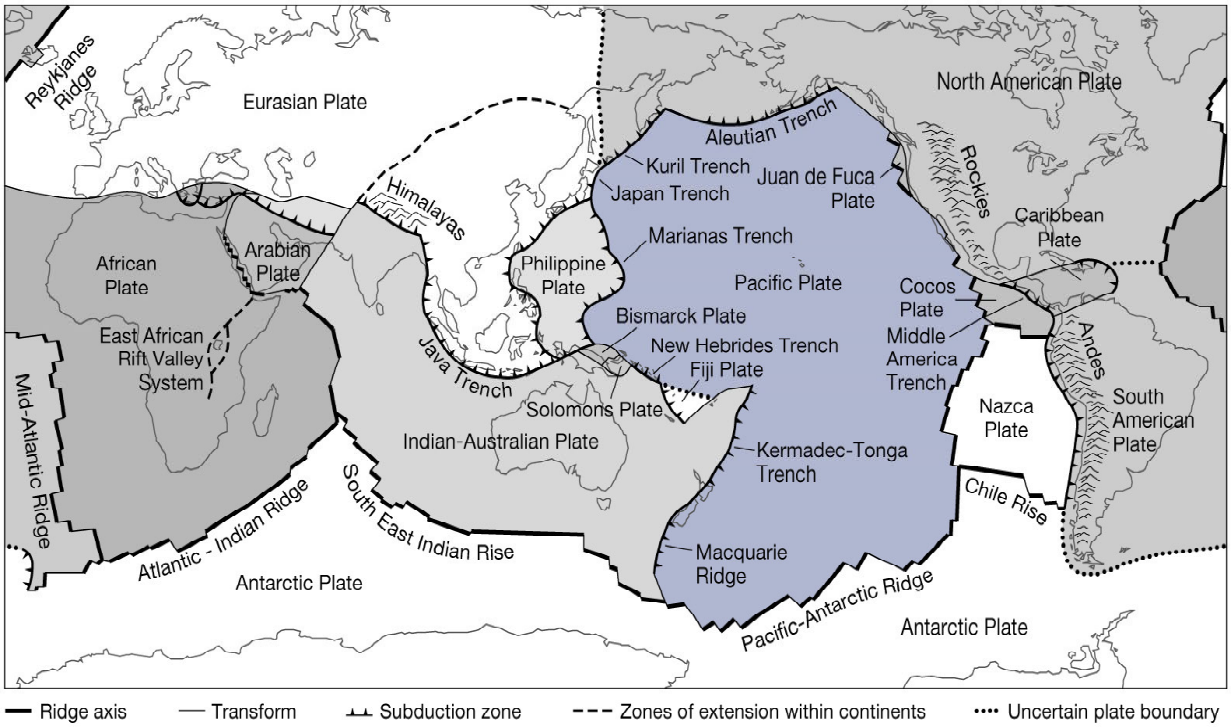
  3. prediction
     - example:
       - if the sea floor was being created at the middle, then it must be older at the edges *(was that true?)*

- if this process was ongoing over geologic history, then there should be past evidence of older continental separations and collisions
- *were these found? → yes, the Appalachian Mountains, for example*

4. testing and debate
   - example:
     - collect the ocean floor rocks and determine their ages
     - re-examine the continental margins and older geology
     - debate any alternative hypotheses/data

5. formulate a theory
   - example:
     - mantle convection *(driving source)* causes upwelling and separation at the mid-ocean ridges
     - this drives the movement of the sea floor *(the spreading)*
     - which "drags" the continents along
     - collisions form mountain belts *(continent – continent)* and volcanoes *(continent – sea floor)*
     - separation forms mid-ocean ridges and subduction destroys older ocean crust
     - process has operated for most of Earth's history

     - ***important to understand: a theory is as close to scientific fact as possible***



modern-day plate boundary map

- assuming that Plate Tectonics continues
  - what do you think that the Earth will look like in the future?