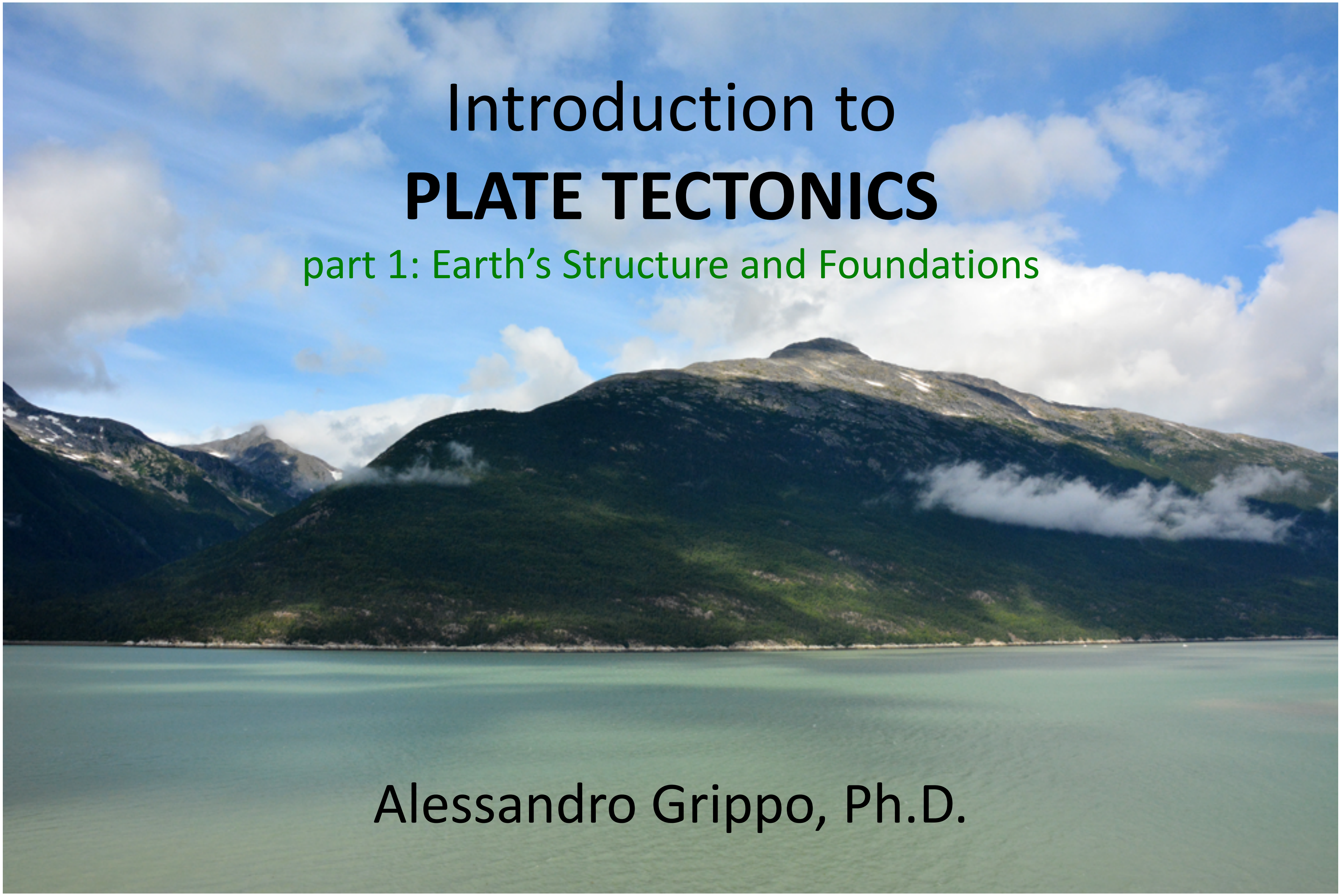
Introduction to **PLATE TECTONICS**

part 1: Earth's Structure and Foundations

Alessandro Grippo, Ph.D.



Mountains along a transform fault: the Lynn Canal in the Alaska panhandle

Skagway, Alaska

Earth is subject to change

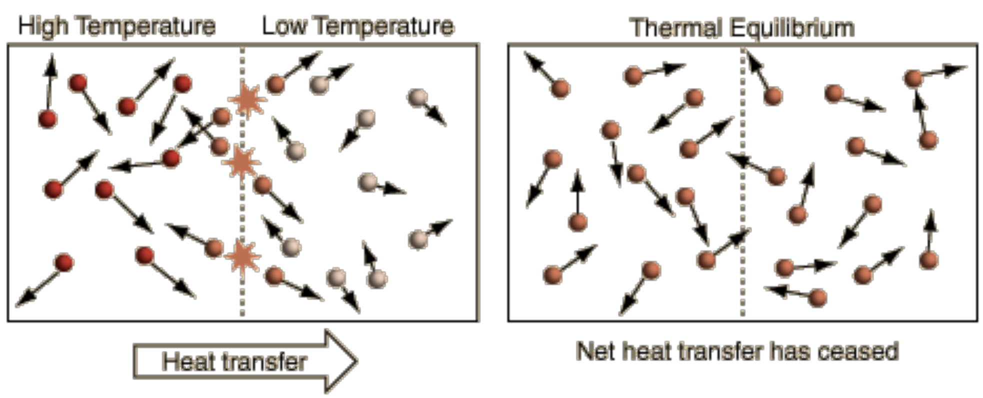
- Earth changes in time
- Earth changes in space

- Energy for change comes (as heat) from:
  - an external source (the Sun)
  - an internal source (radioactive decay in Earth's core and mantle)

- Heat from the Sun: weathering & erosion
  - atmospheric and oceanic circulation, water cycle, erosion, “smoothing” of outer surface
- Heat from radioactivity: plate tectonics
  - building of oceans, mountains, continents; volcanoes and earthquakes, “roughing” of the outer surface

Heat vs. Temperature

- Heat
  - energy transfer from a body to another due to a difference in temperature
- Temperature
  - a measure of the average kinetic energy of the molecules that make up a substance



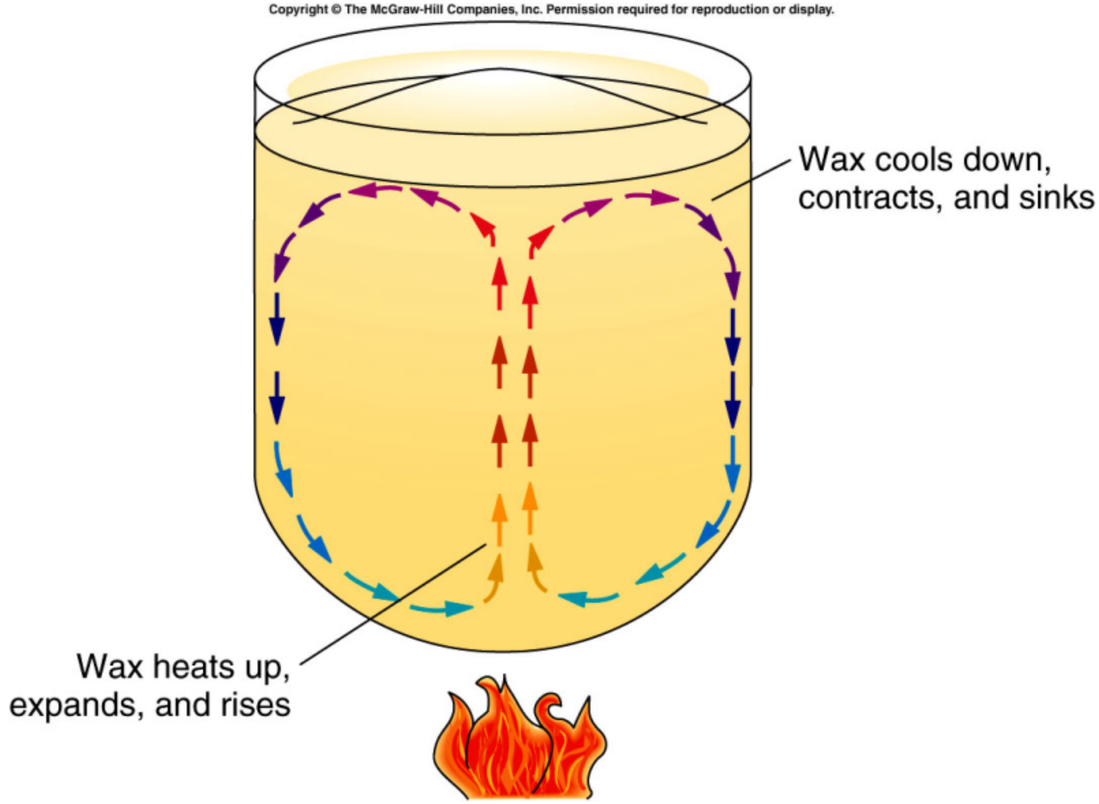
How Does Heat Travel?

Heat can travel (transfer) in three different ways:

- **Radiation**
  - Heat energy is felt from a hot object at a distance (around a fire, basking in the sun, etc.)
- **Conduction**
  - Heat energy is felt by touching a hot object (a hot pan, hot water, etc.)
- **Convection**
  - Heat energy is transferred in bulk motion or flow of a fluid mass (a lava lamp, the asthenosphere, etc.)

modeling convection

A



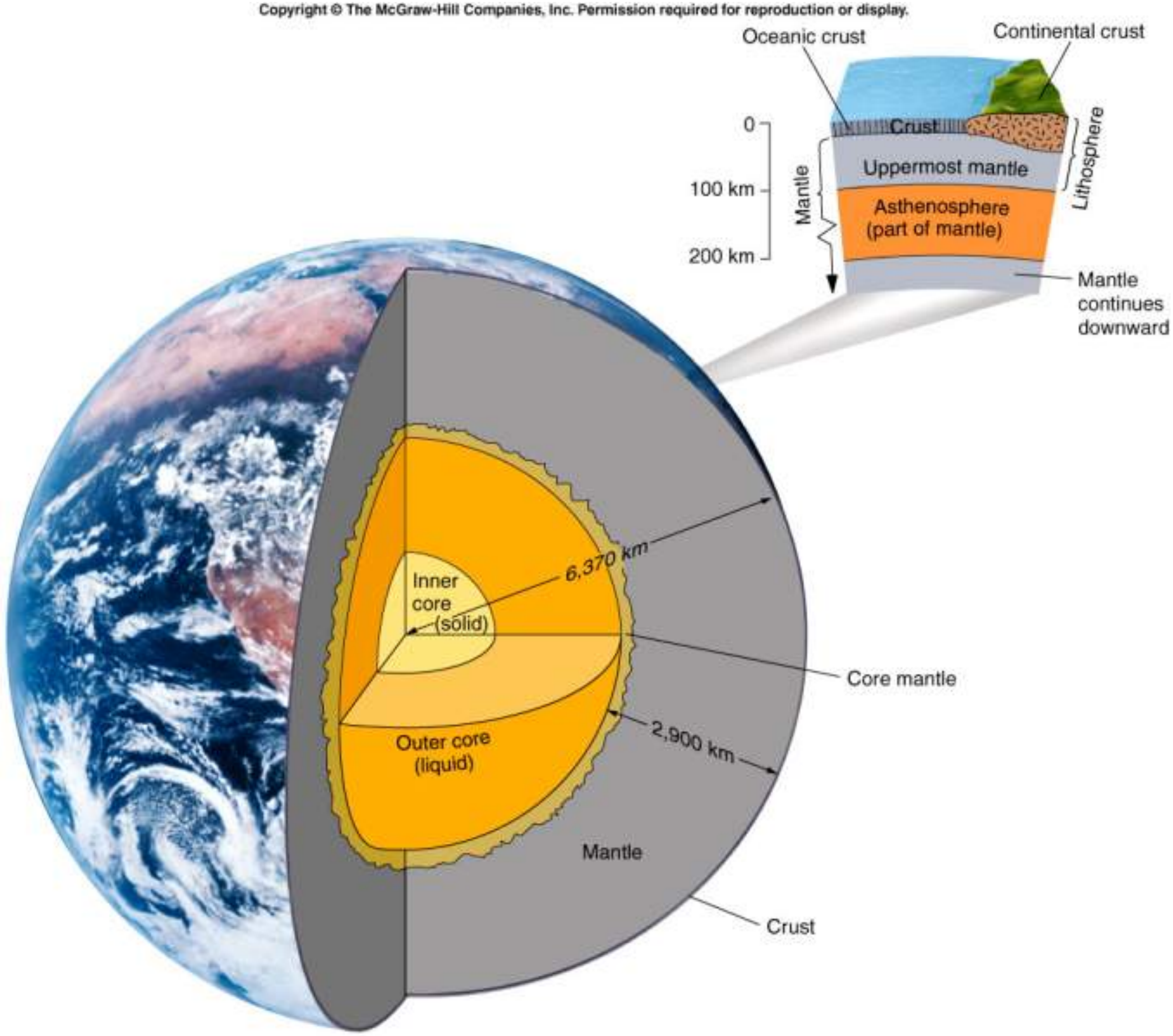
Earth's Interior

Two ways to look at things

- Concentric spheres differentiated based on chemical composition (made of different rocks), from inside outward:
  - Core
  - Mantle
  - Crust
    - Oceanic Crust
    - Continental Crust

- Concentric spheres differentiated based on physical behavior (different kinds of rocks which behave in different ways), from inside outward:
  - Inner and Outer Core
  - Mesosphere
  - Asthenosphere
  - Lithosphere

Earth’s Interior



Chemical (compositional) differentiation

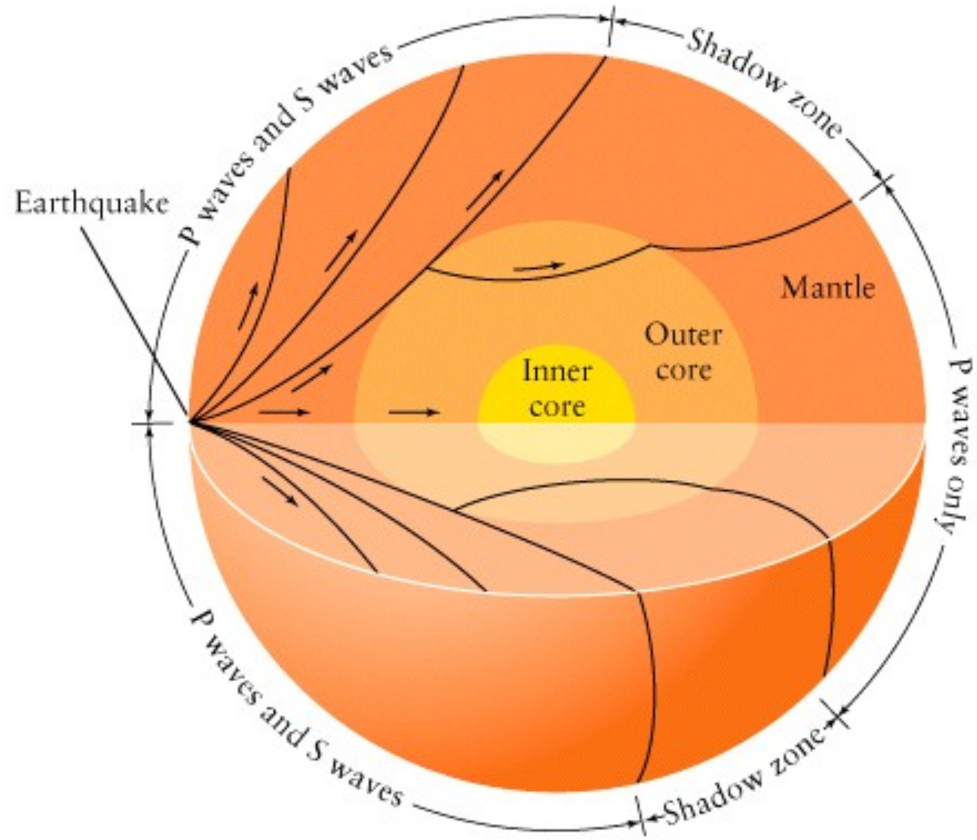
- **Crust** (~3-70 km thick)
  - Very thin outer rocky shell of Earth
    - Continental crust - thicker and less dense
    - Oceanic crust - thinner and more dense
- **Mantle** (~2900 km thick)
  - Hot solid that flows slowly over time; Fe-, Mg-, Si-rich minerals
- **Core** (~3400 km radius)
  - Mostly Iron (Fe)
    - Outer core - metallic liquid
    - Inner core - metallic solid

How do we know about Earth's layers?

- Not by drilling: we do not have the technology to reach the core or the mantle)
  - deepest well is about 11 km (11,000 m or ~ 7 mi)
  - thickness of the crust:
    - oceanic crust: around 5 km
      - cannot drill through it because we have to start from ocean surface: 5 km of ocean above it
    - continental crust: up to 80 km – too thick to drill

  - we have never seen the mantle or the core in place

- We know about Earth's interior through the study of seismic waves
- Waves are refracted (change path and speed) where materials have different densities



- P (primary) and S (secondary) waves
  - P waves are faster than S waves
  - S waves do not travel through liquids
  - S waves do not reach past the “shadow zone”
  - S waves are stopped (reflected) at the mantle/core boundary
    - This implies that the outer core is liquid

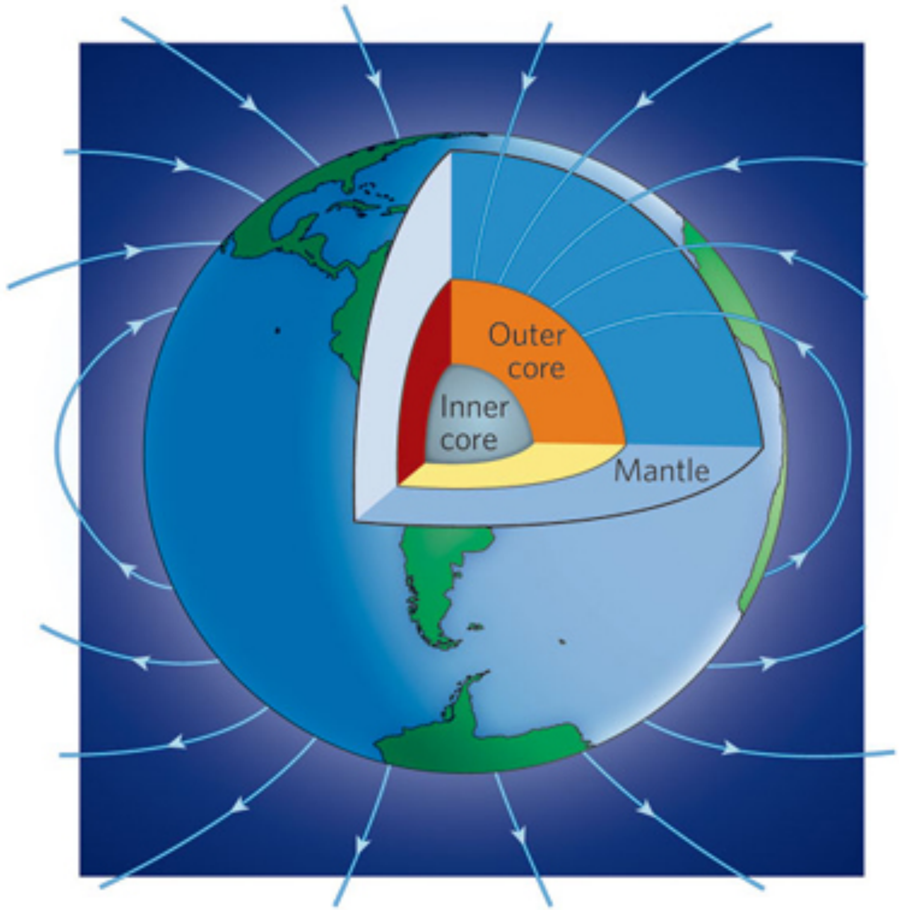
  - The pattern of P and S waves refraction tells us where these changes occur

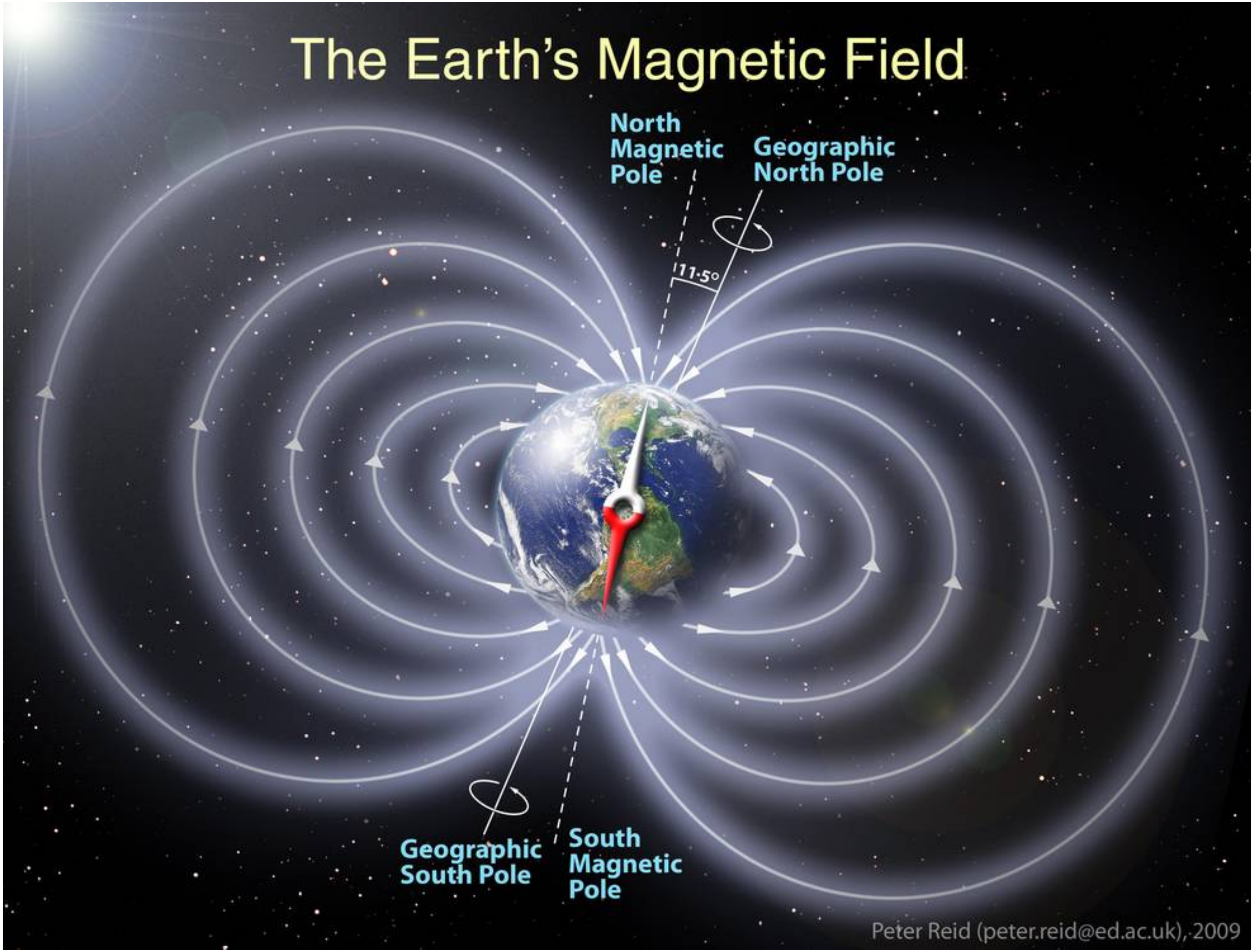
- Earth's core is made of Iron (Fe) and Nickel (Ni)
- The inner core is solid while the outer core is liquid
- Metals like Fe are kept together by a chemical bond called metallic bond
- In metallic bonds, electrons are free to roam
- When electrons roam, they create an electrical current

- In a block of iron these currents cancel each other out
- If the outer core is liquid, and Earth rotates around its axis, the iron itself is in motion
- If the iron is in motion, it will then create an electrical current
- An electrical current would also create a magnetic field

Earth's Magnetic Field

- the spinning of Earth:
  - causes a metallic liquid outer core to move
  - creates an electrical field
  - that generates Earth's magnetic field



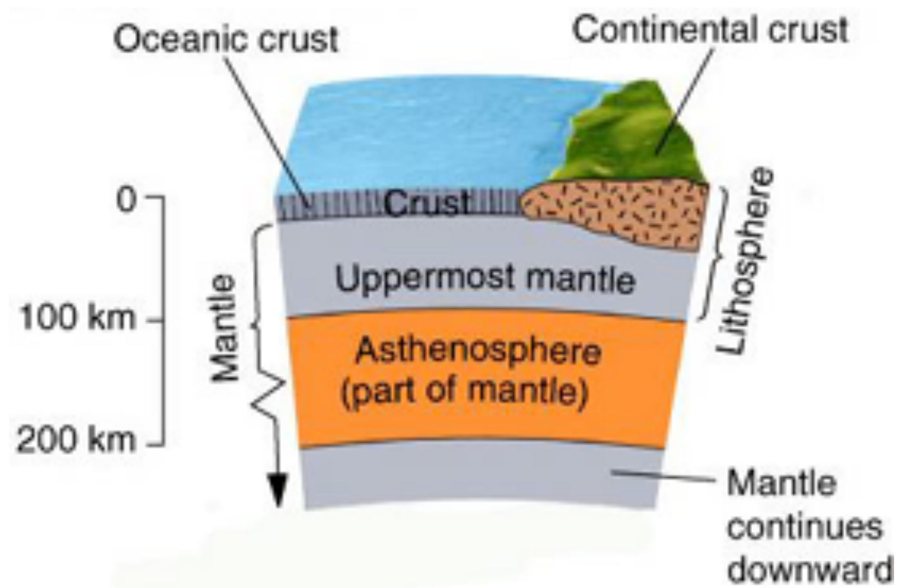

The Earth's Magnetic Field
North Magnetic Pole
Geographic North Pole
11·5°
Geographic South Pole
South Magnetic Pole
Peter Reid (peter.reid@ed.ac.uk), 2009

Why do we need to know about Earth's Magnetic Field?

- Earth's Magnetic Field:
  - protects us (life) from damaging solar radiation
  - can be recorded in certain rocks, particularly those forming at the bottom of the ocean
  - its properties change from place to place on Earth, and can be identified
  - In the end, it is very useful in geological studies

Physical (mechanical) differentiation

- Mechanical Layers
  - *Lithosphere* (~100 km thick)
    - Rigid/brittle outer shell of Earth
    - Composed of both crust and uppermost mantle
    - Makes up Earth's tectonic "plates"
  - *Asthenosphere*
    - Plastic (capable of flow) zone on which the lithosphere "floats"



definition of **PLATE TECTONICS**

- The surface of Earth is broken down in a series of **LITHOSPHERIC PLATES**, that move around passively, dragged by **CONVECTION IN THE ASTHENOSPHERE**
- There are seven major plates (North America, South America, Pacific, Eurasia, Africa, Antarctica, India-Australia) and a variety of smaller ones

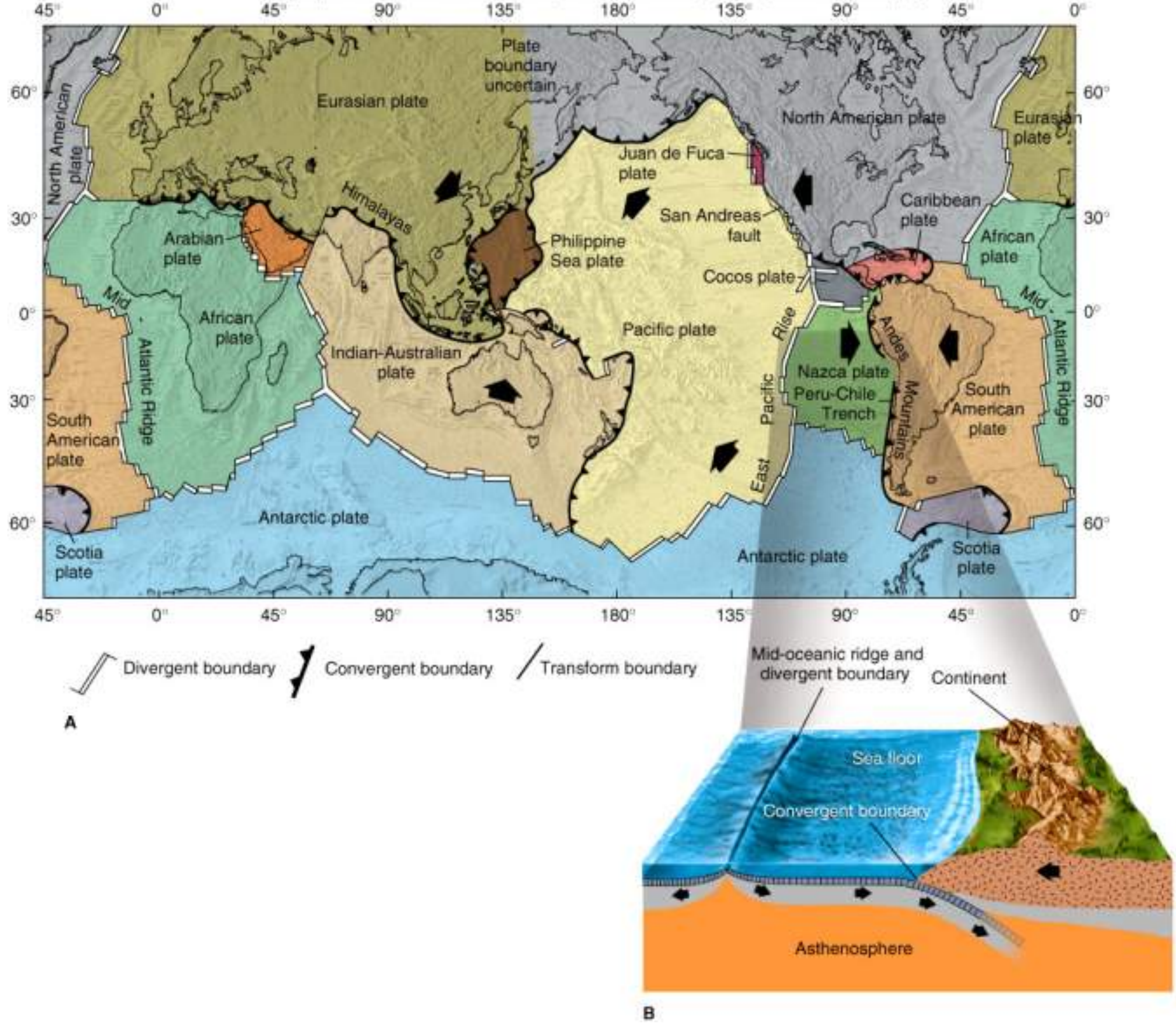


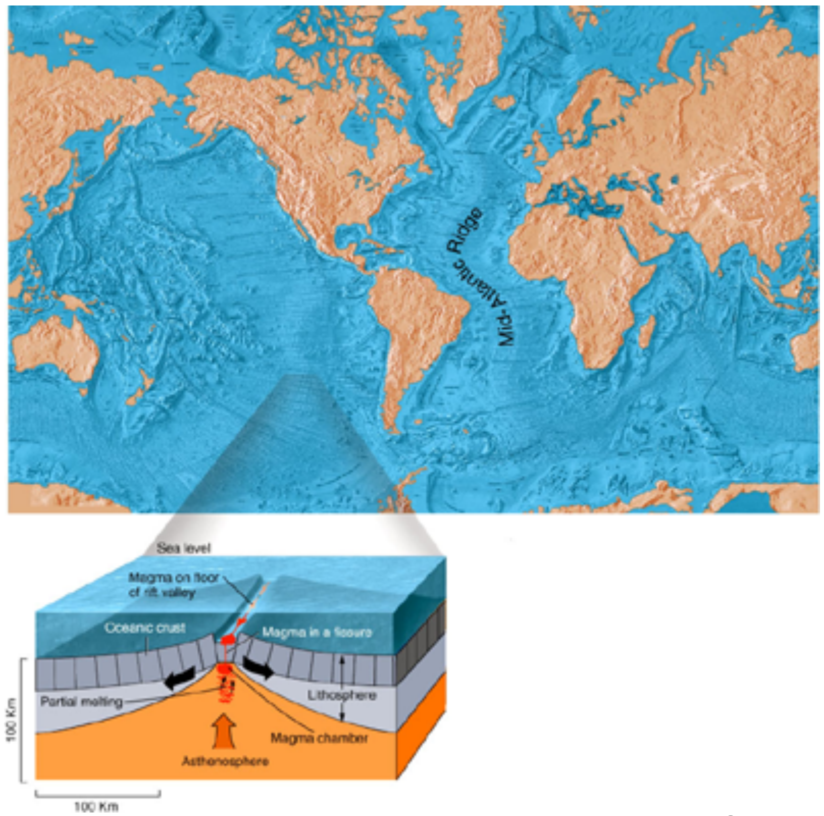
Plate boundary uncertain
Eurasian plate
North American plate
Eurasian plate
Juan de Fuca plate
Himalayas
San Andreas fault
Caribbean plate
Arabian plate
Philippine Sea plate
African plate
Cocos plate
Mid Atlantic Ridge
African plate
Pacific plate
East Pacific Rise
Andes Mountains
Indian-Australian plate
Nazca plate
Peru-Chile Trench
South American plate
Antarctic plate
Scotia plate
Divergent boundary
Convergent boundary
Transform boundary
A
Mid-oceanic ridge and divergent boundary
Continent
Sea floor
Convergent boundary
Asthenosphere
B

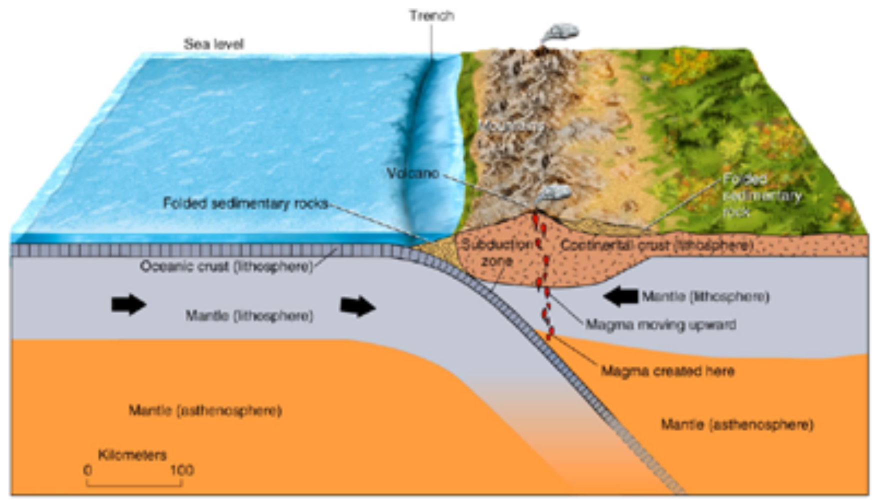
- Continental Drift Hypothesis
  - Originally proposed in early 1910s in order to explain the “fit of continents”, common rock types and fossils across ocean basins, etc.
  - Insufficient evidence found for driving mechanism; hypothesis rejected
- Plate Tectonics Theory
  - Originally proposed in the late 1960s
  - Included new understanding of the seafloor and a good explanation of the driving force behind motion
  - Describes lithosphere as being broken into plates that are in motion
  - Explains origin and locations of volcanoes, fault zones, mountain belts

Plate Boundaries

- Divergent boundaries
  - Plates move apart, away from each other
  - Magma (molten rock) rises, cools into a rock, and forms new lithosphere
  - Typically expressed as mid-oceanic ridges
- Transform boundaries
  - Plates slide past one another
  - Fault zones (transform faults) and earthquakes mark boundary
  - Example: San Andreas Fault in California
- Convergent boundaries
  - Plates move toward each other, or collide
  - Mountain belts, powerful earthquakes and volcanoes common
  - Oceanic plates may sink back into the mantle along a subduction zone, typically marked by a deep ocean trench

The three kinds of plate boundaries





Convergent Boundary

Divergent and Transform Boundaries

The oceanic crust forms continuously at a mid-oceanic ridge

The ocean expands and the age of the crust increases away from the ridge

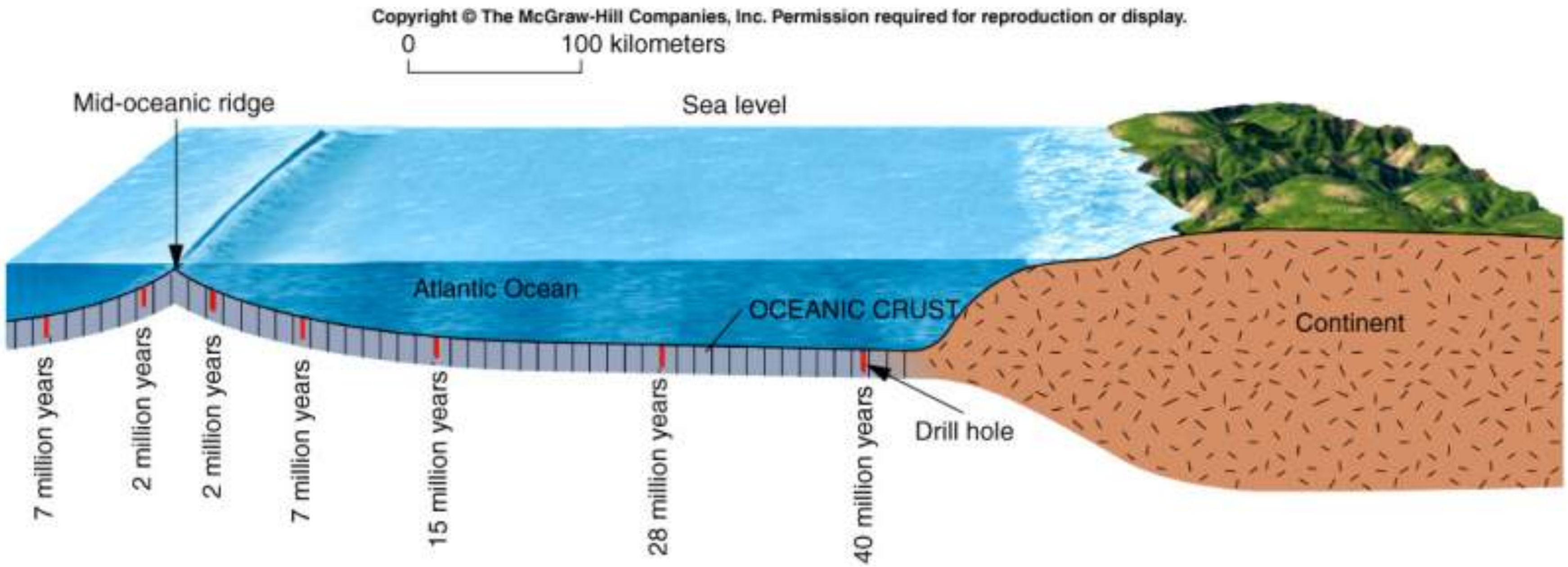


Plate Tectonics

end of part 1

The Andes: a mountain chain formed by collision between two plates
Road from Santiago, Chile to Mendoza, Argentina