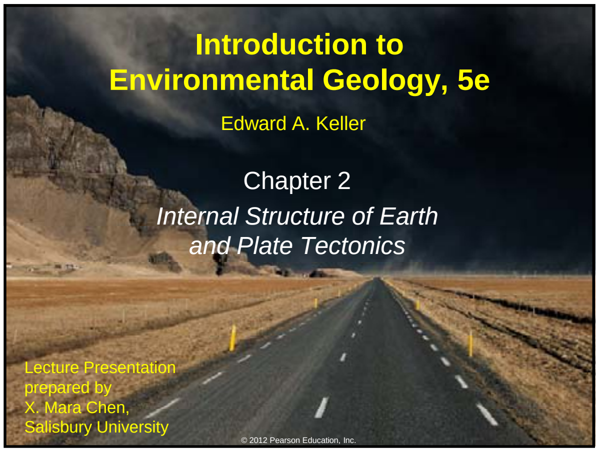


Case History: Two Major CA Cities

- San Andreas fault: a transform plate boundary between the North American and the Pacific plates
- Two major cities on the opposite sides of the fault: Los Angeles and San Francisco
- Many major earthquakes related to the fault system
- Loss of many lives and billions of property damages due to earthquakes
- New construction and retrofitting of infrastructures has become more expensive
- When will be the next “big one” and what to do? How to deal with the potential consequence?

Internal Structure of Earth

- Earth’s location as said in the sitcom *Third Rock from the Sun*
- The Earth is layered and dynamic: Interior differentiation and concentric layers
- Chemical model by composition and density (heavy or light): Crust, mantle, core, and Moho discontinuity between the crust and mantle
- Physical property model (solid or liquid, weak or strong): Lithosphere (crust and upper rigid mantle), asthenosphere, mesosphere, liquid outer core, inner solid core

Study of Earth’s Interior Structure

- Knowledge primarily through the study of seismology
- Seismology: Study of earthquakes and seismic waves
- Examining the paths and speeds of seismic waves through reflection and refraction
- Magma likely generated in the asthenosphere
- Slabs of lithosphere have apparently sunk deep into the mantle
- Variability of lithosphere thickness reflects changes in its age and history

Seismic P Wave

- Primary or push-pull wave, travels like sound wave
- Direction of rock particle vibration parallel to that of wave propagation
- Fastest rates of propagation, first arrival to the seismograph
- Body wave travels through Earth interior and all media—solid and liquid

Seismic S-Wave

- Secondary or shear waves
- The direction of particle vibration perpendicular to that of propagation
- Propagates slower than P waves
- Body wave, propagating through Earth's interior, but not its liquid layers

Seismic Waves and Internal Structures

- Earth's interior boundaries: Sudden changes in the speed of seismic waves
- Different characteristics: Different rates and paths of wave propagation
- *Asthenosphere*: Low velocity zone, major source of Earth magma
- Outer Core: Liquid, no S wave transmits through it

Model of Earth's Interior

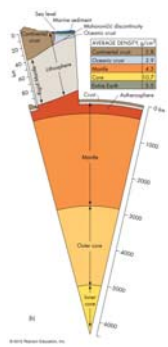
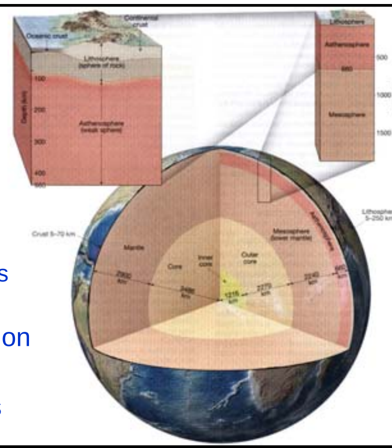


Figure 2.2b

Internal Structure of Earth

Divided into layers based on:

1. Composition
2. Physical properties



Internal Dynamics of Earth

- Evidence
  - Earth's landscape
  - Dynamic phenomena: earthquakes, volcanoes
- Plate Tectonics: Hypothesis and Theory
  - Continental drift
  - Seafloor spreading
  - Plate tectonics – a unifying theory

Dynamic Earth—Evidence

- Mountain belts (continental mountain ranges and oceanic ridges)
- Earthquake distribution: Concentrated zones
- Earthquake occurrences over time
- Volcanism in space: Concentrated zones
- Volcanism over time

Continental Drift (1)

- 1910s Alfred Wegener proposed idea
- Pangaea (Pan-jee-ah): All land, unified super-continent
- Two parts of Pangaea: Laurasia and Gondwana
- Pangaea drifting apart: ~ 200 mya

Continental Drift (2)

- Same fossils across both sides of the Atlantic Ocean

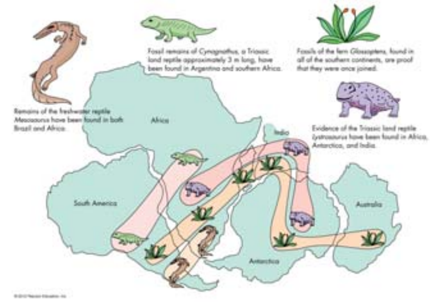


Figure 2.18

Continental Drift (3)

- Rock distribution and Paleozoic Glaciations

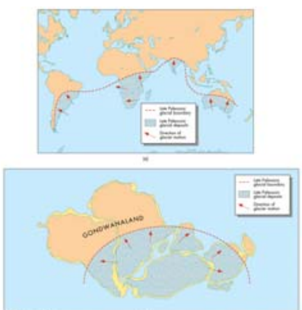


Figure 2.19

Seafloor Spreading (1)

- Lack of mechanism for continental drift
- 1950s and early 1960s, ocean expedition increased knowledge of oceanography
- In 1960s, Harry Hess proposed seafloor spreading
  - Seafloor not a single static piece
  - Mid-oceanic ridges, or spreading centers where new crust is formed and seafloor spreads

Seafloor Spreading (2)

- Paleomagnetic data
  - Dipolar magnetic field
  - Magnetic field recorded by iron-bearing igneous rocks
  - Striking symmetrical magnetic anomaly stripes
- Age of seafloor rocks: Progressively younger toward the mid-oceanic ridge
- Thickness of seafloor sediments: Progressively thinner toward the ridge

Seafloor Spreading (3)

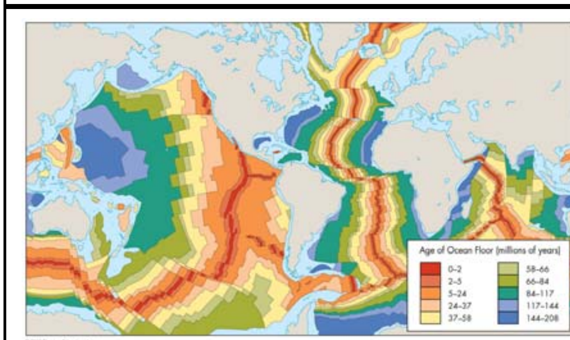


Figure 2.15

Plate Tectonics (1)

- A unified theory: Study the dynamic creation, movement, and destruction processes of plates
- Plates: Fragments of lithosphere
- Plates move in relation to each other at varied rates
- No major tectonic movements within plates
- Dynamic actions concentrated along plate boundaries
- Plate boundaries: Defined by the areas of concentrated seismic and volcanic activities, rifts, faults, and mountain ridges

Plate Tectonics (2)

- Three major types of plate boundaries
- Divergent: plates moving apart and new lithosphere produced in mid-oceanic ridge
- Convergent: plates collide, subduction and mountain building
- Transform: two plates slide past one another
- Earth interior convection is mechanism for plate tectonics

Plate Tectonics (3)

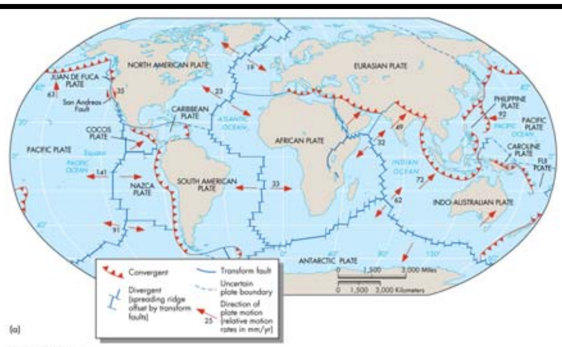


Figure 2.4a

Plate Tectonics (3)

TABLE 2.1 Types of Plate Boundaries: Dynamics, Results, and Examples

Plate Boundary	Plates Involved	Dynamics	Results	Example
Divergent	Usually oceanic	Spreading. The two plates move away from one another, and molten rock rises up to fill the gap.	Mid-ocean ridge forms, and new material is added to each plate.	African and North American plate boundary (Figure 2.4a) Mid-Atlantic Ridge
Convergent	Ocean–continent	Oceanic plate sinks beneath continental plate.	Mountain ranges and a subduction zone are formed with a deep trench. Earthquakes and volcanic activity are found here.	Nazca and South American plate boundary (Figure 2.4a) Andes Mountains Peru-Chile Trench

Table 2.1 (1 of 2)

Plate Tectonics (3)

TABLE 2.1 Types of Plate Boundaries: Dynamics, Results, and Examples

Plate Boundary	Plates Involved	Dynamics	Results	Example
Convergent	Ocean–ocean	Older, denser, oceanic plate sinks beneath the younger, less dense oceanic plate.	A subduction zone is formed with a deep trench. Earthquakes and volcanic activity are found here.	Fiji plate (Figure 2.4a) Fiji Islands
Convergent	Continent–continent	Neither plate is dense enough to sink into the asthenosphere; compression results.	A large, high mountain chain is formed, and earthquakes are common.	Indo-Australian and Eurasian plate boundary (on land) (Figure 2.4a) Himalaya Mountains
Transform	Ocean–ocean or continent–continent	The plates slide past one another.	Earthquakes are common. May result in some topography such as linear troughs and uplifts (often appearing as lines [faults] at nearly right angle to the ridge).	North American and Pacific plate boundary (Figures 2.10 and 2.21) San Andreas fault

Table 2.1 (2 of 2)

Plate Tectonics (4)

- Divergent plate boundary
  - Plates move away from each other
  - Mid-oceanic ridges
  - Continental rift valleys
  - Creates new seafloors
  - Extensional stress and shallow earthquakes
  - Basaltic volcanism

Plate Tectonics (5)

- Convergent plate boundary
  - Plates collide with each other and three subtypes (c-c, c-o, o-o)
  - C-C boundary: Major young mountain belts and shallow earthquakes
  - C-O boundary: Major volcanic mountain belts, subduction zone and oceanic trench, earthquakes
  - O-O boundary: Subduction zone, deep oceanic trench, volcanic island arc, wide earthquake zones

Plate Tectonics (6)

- Transform plate boundary
  - Locations where the edges of two plates slide past one another
  - Spreading zone is not a single, continuous rift offset by transform faults
  - Most transform plate boundaries are within oceanic crust, some occur within continents
  - Famous transform plate boundary on land is the San Andreas fault

Plate Boundary

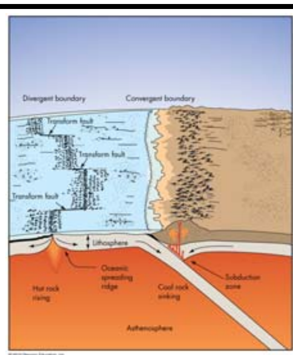


Figure 2.5

Plate Motion

- Plates move a few centimeters per year: about the growth rate of human fingernails
- The rates of movement changes over time
- North American plate along the San Andreas fault about 3.5 cm (1.4 in.) per year
- When rough edges along the plate move quickly, an earthquake may be produced
- Often slow creeping movement
- The direction of movement changes too (see Figure 2.4a)
- Wilson Cycle: The cyclic nature of plate tectonics

Wilson Cycle

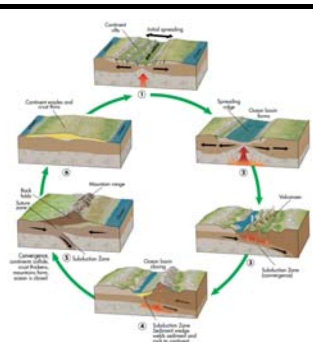


Figure 2.23

Hot Spots (1)

- Places on Earth: Volcanic centers with magma source from deep mantle, perhaps near the core-mantle boundary
- Hot spots can be on continents and oceans, Yellowstone and Hawaii
- Forming a chain of volcanoes over a stationary hot spot: Example, the Hawaiian–Emperor Chain in the Pacific Ocean
- The bend of a seamount chain over a hot spot representing the change of plate motion

Hot Spots (2)

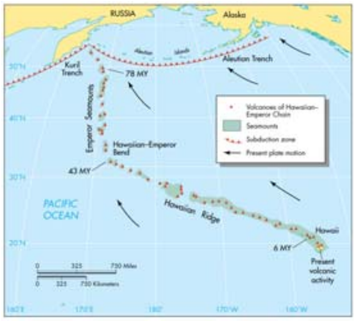


Figure 2.16a

Plate Tectonics and Environmental Geology

- Significance of tectonic cycle
  - Global zones of resources (oil, gas, and mineral ores)
  - Global belts of earthquakes and volcanic activities
  - Impacts on the landscape and global climates
  - Geologic knowledge on plate tectonics: Foundation for urban development and hazard mitigation

Tectonics and Environmental Geology

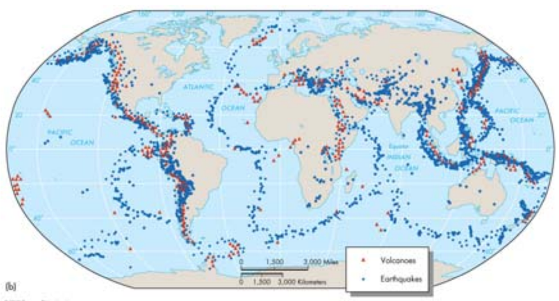


Figure 2.4b

Critical-Thinking Topics

- Assume the Pangaea never broke up, how might today's environments be different?
- What are the major differences in plate tectonic settings between the U.S. eastern and western coasts?
- Will the tectonic cycle ever stop? Why or why not?
- Why is most seismic and volcanic energy released along the Pacific rim?
- Does plate tectonics play a role in shaping your local environment?