1 **Introduction to Environmental Geology, 5e**
Chapter 2
Internal Structure of Earth and Plate Tectonics

2 **Plate Tectonics: summary in haiku form**
Alfred Wegener
gave us Continental Drift.
Fifty years later…

3 **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?

4 **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

5 **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

6 **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

7 **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

8 **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
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- *Asthenosphere*: Low velocity zone, major source of Earth magma
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- Outer Core: Liquid, no S wave transmits through it

9 **Model of Earth's Interior**

10 **Internal Structure of Earth**

Divided into layers based on:

1. Composition
2. Physical properties

11 **Internal Dynamics of Earth**

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

12 **Dynamic Earth—Evidence**

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

13 **Continental Drift (1)**

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

14 **Continental Drift (2)**

- Same fossils across both sides of the Atlantic Ocean

15 **Continental Drift (3)**

- Rock distribution and Paleozoic Glaciations
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16 **Seafloor Spreading (1)**

- Lack of mechanism for continental drift
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- 1950s and early 1960s, ocean expedition increased knowledge of oceanography
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- 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

17 **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
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- Thickness of seafloor sediments: Progressively thinner toward the ridge

18 **Seafloor Spreading (3)**

19 **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

20 **Plate Tectonics (2)**

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

21 **Plate Tectonics (3)**

22 **Plate Tectonics (3)**

23 **Plate Tectonics (3)**

24 **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
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25 **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

26 **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

27 **Plate Boundary**

28 **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

29 **Wilson Cycle**

30 **Hot Spots (1)**

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

31 **Hot Spots (2)**

32 **Plate Tectonics and Environmental Geology**

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

33 **Tectonics and Environmental Geology**

34 **Critical-Thinking Topics**

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

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