

## UNIT 4

The theory of plate tectonics explains Earth's geological processes

### TOPIC 4.1

What ideas, observations, and evidence led to the theory of plate tectonics?



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#### Topic 4.1: What ideas, observations, and evidence led to the theory of plate tectonics?

- Juan de Fuca Ridge:
  - Chain of mountains underneath the Pacific ocean
  - Slabs of Earth's crust slowly move apart, forming new ocean floor
  - Scientists study the ocean floor to help them make predications about where and when earthquakes could occur



Scientists place instruments (cameras, seismometers) in the ocean to study the ocean floor and monitor changes.

**TOPIC 4.1** What ideas, observations, and evidence led to the theory of plate tectonics?

**Concept 1: Scientists debated how to interpret the shapes and positions of Earth's continents.**

- Until the mid-1900s:
  - Geologists thought that continents had been in the same locations since Earth formed (fixism)



Figure 4.1: A map of the world from the 1800s.

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**Wegener and The Continental Drift Hypothesis**

- 1912: Alfred Wegener
  - Noticed that some of the continents looked like they could fit together like a puzzle
  - Found evidence (rock, climate, and fossil information) to support the idea that the continents were once joined together



Figure 4.1: A map of the world from the 1800s.

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### Wegener and The Continental Drift Hypothesis

- Wegener proposed the continental drift hypothesis
  - 200 million years ago: The continents were connected as a supercontinent called Pangaea
  - Greek: *pan* means “all”; *gaea* means “world”
  - Over time, the continents moved apart



Figure 4.2: A map of Pangaea. Arrows indicate direction of movement.

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### Wegener's Hypothesis is Rejected

- Scientists initially rejected Wegener's hypothesis
  - Wegener could not explain how continents could move
  - Scientists could not imagine what forces could be large enough to make a continent move
- Wegener's hypothesis was revisited decades later once information about the ocean floor was discovered



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## Discussion Questions

- In your own words, describe the continental drift hypothesis.
- How did Wegener support his hypothesis? Why do you think he chose this type of information?



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## Discussion Questions

- Why was the continental drift hypothesis rejected?



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**Concept 2: Technology helps scientists make inferences about the different layers of Earth.**

- There is about 6350 km between you and the centre of the Earth
  - Scientists cannot observe the interior of the Earth directly (no tools can probe that distance)

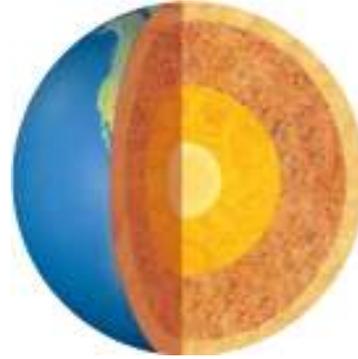


Figure 4.3: A model of Earth, showing its layers.

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**TOPIC 4.1** What ideas, observations, and evidence led to the theory of plate tectonics?

**Concept 2: Technology helps scientists make inferences about the different layers of Earth.**

- To infer Earth's structure:
  - Scientists study energy waves that travel through the interior during earthquakes
  - Speed and behaviour of waves are affected by the material they pass through

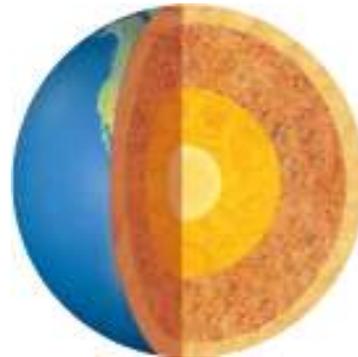


Figure 4.3: A model of Earth, showing its layers.

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### Earth's Layers: Crust

- Thin layer of solid rock surrounding Earth
- Oceanic crust: thinner; mostly basalt
- Continental crust: thicker; mostly granite

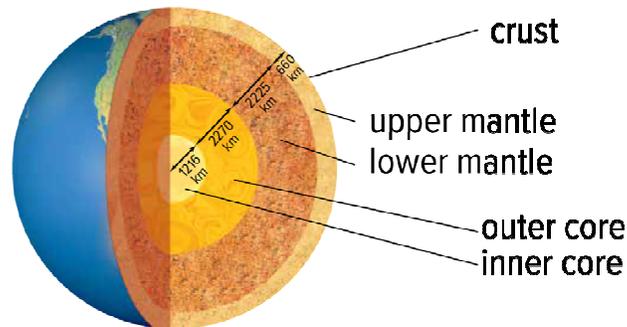


Figure 4.3

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### Earth's Layers: Mantle (Upper Mantle)

- Upper mantle:
  - Top part is solid
  - Bottom part is made of rock that is like soft taffy (can flow slowly)

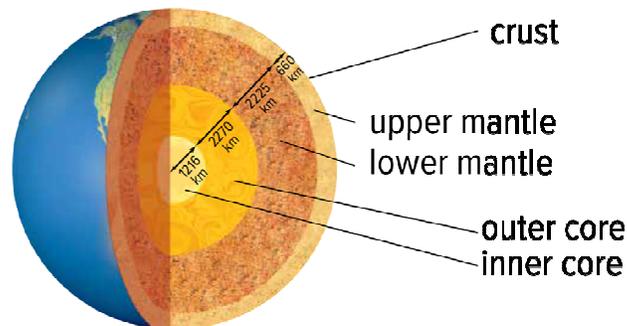


Figure 4.3

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## Earth's Layers: Mantle (Lower Mantle)

- Lower mantle:
  - Made of denser, more solid material than upper mantle

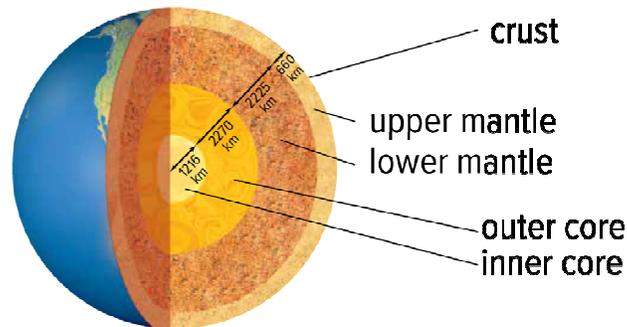


Figure 4.3

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## Earth's Layers: Outer Core

- The only layer that is liquid

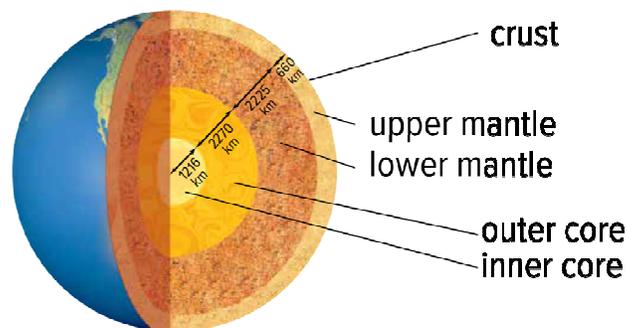


Figure 4.3

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## Earth's Layers: Inner Core

- Deepest layer
- Hottest layer (more than 5000°C)
- Solid because the core material it is under extreme pressure

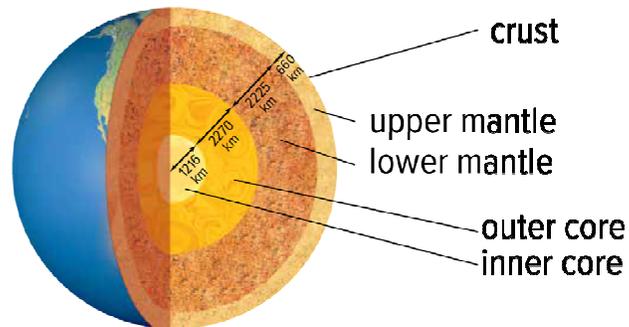


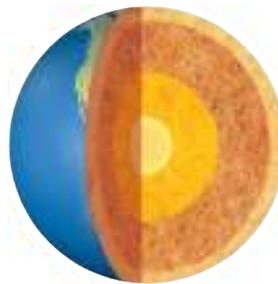
Figure 4.3

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## Discussion Questions

- In what way does the structure of Earth support the idea that continents can move?



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**Concept 3: Studies of the ocean floor revealed where new rock is made.**

- The ocean floor consists of
  - **Mid-ocean ridges:** mountain ridges along the ocean floor
  - **Trenches:** deep valleys in the ocean floor



Figure 4.4: The ocean floor consists of mid-ocean ridges and deep sea trenches.

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**Ocean Floor: Mid-Ocean Ridges and Trenches**

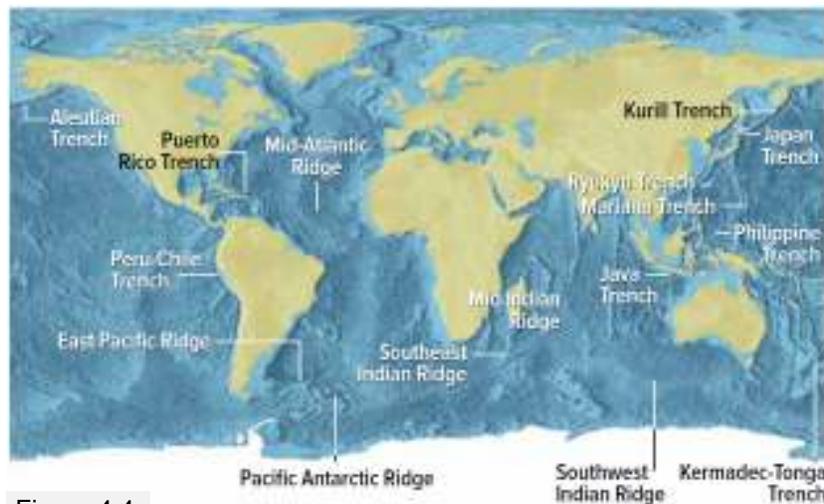


Figure 4.4

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### Ocean Floor: Mid-Ocean Ridges and Trenches

- **Mid-ocean ridges:**
  - Circle the Earth (~60 000 km long)
  - As high as 3 km above the ocean floor
  - Earthquakes and volcanic eruptions are common along the ridges
  
- **Trenches:**
  - Long, narrow depressions (valleys) in the ocean floor
  - Thousands of kilometers long and deep

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### Making New Rock on the Ocean Floor

- Ocean floor near mid-ocean ridges is younger than ocean floor farther away from ridges

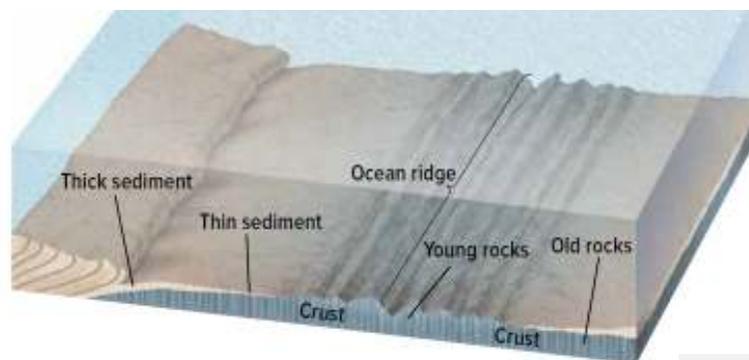


Figure 4.5

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### Making New Rock on the Ocean Floor

- Sediment gets thicker as you move farther away from the mid-ocean ridge
- Suggests that ocean floor is younger closer to the mid-ocean ridge

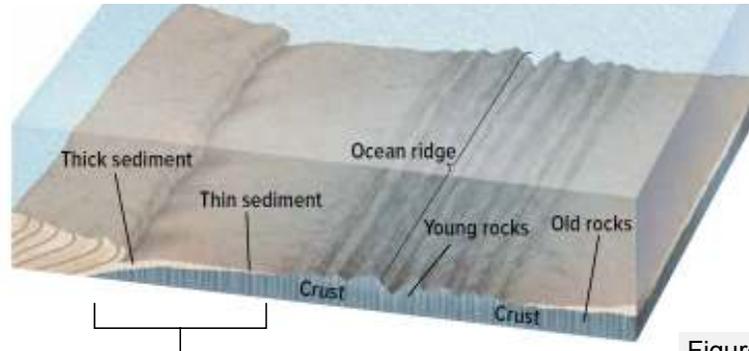


Figure 4.5

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### Making New Rock on the Ocean Floor

- Ocean rocks closer to a mid-ocean ridge are younger than ocean rocks farther from a ridge

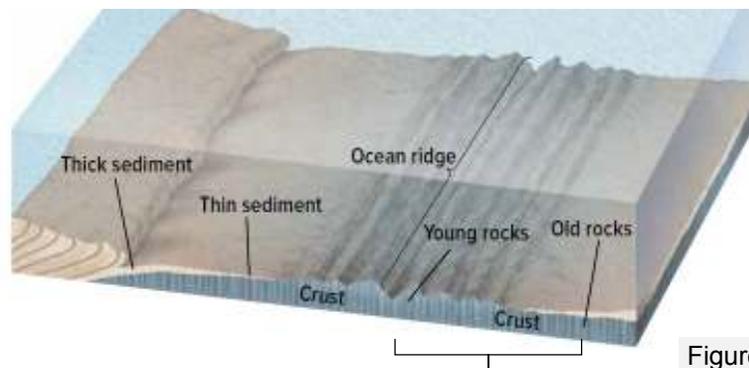


Figure 4.5

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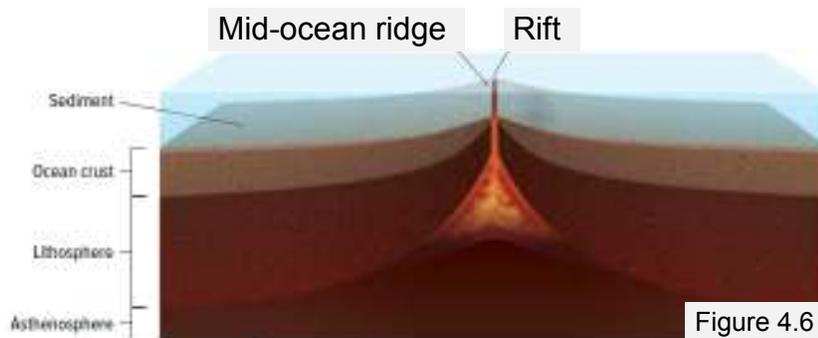
### Making New Rock on the Ocean Floor

- 1962: Harry Hess
  - Suggested that new ocean crust is made at mid-ocean ridges in a process called sea floor spreading
  - **Sea floor spreading**: process of magma rising to the surface at mid-ocean ridges to form new ocean crust

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### Sea Floor Spreading: Making New Oceanic Crust



- **Mid-ocean ridge**: higher than surrounding areas
- **Rift**: a crack in the valley at the centre of the ridge; magma (molten rock) inside the Earth rises to fill the crack

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### Sea Floor Spreading: Making New Oceanic Crust

- Magma erupts on the ocean floor and rises up the rift
- Magma cools, hardens into new rock, and pushes older rock away from the ridge
- Process is repeated over millions of years
- Results in formation of new oceanic crust

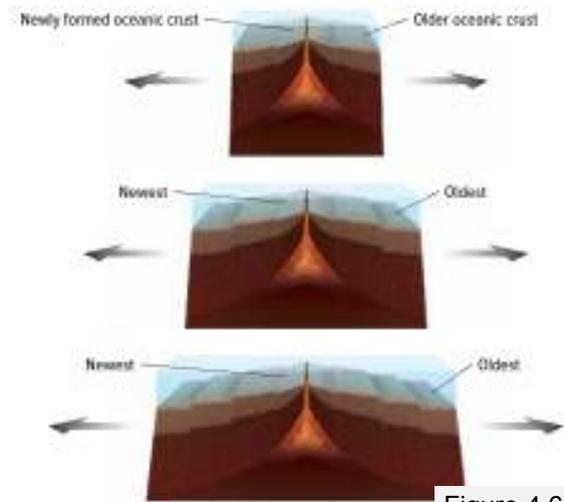


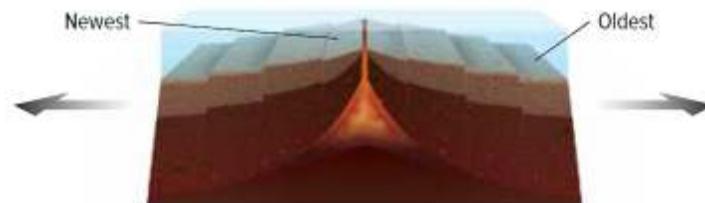
Figure 4.6

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### Sea Floor Spreading and Moving Continents

- Sea floor spreading led to the understanding of how continents move
  - Continents can be carried by the widening ocean floor during sea floor spreading (like a conveyor belt)
  - Provided support for Wegener's continental drift hypothesis



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## Discussion Questions

- In two or three sentences, describe how the discoveries of mid-ocean ridges and the ages of ocean rock support the idea that the ocean floor is spreading apart.
- Describe the process of sea floor spreading.



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## Concept 4: The theory of plate tectonics provides a unified explanation for geological features and processes.

- Earth's surface is made of huge slabs of rock called **tectonic plates**
  - Large plates that float slowly on a layer of fluid-like rock in the Earth's mantle
  - Move very slowly (~2.5 cm per year, about the same rate your fingernails grow)



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## Tectonic Plates

- 12 major tectonic plates, and many smaller ones, that fit together



Figure 4.7

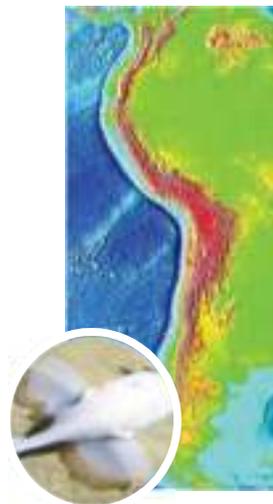
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## Interaction of Tectonic Plates

- Activity of mid-ocean ridges and trenches is related to how the boundaries (edges) of the tectonic plates interact
  - Example: Peru-Chile trench was formed with the Nazca plate moved under the South American plate
    - Many unique organisms live in this trench

Figure 4.8: Peru-Chile trench. This snailfish (inset) was discovered in 2010 in this trench.



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## Plate Tectonics – A Unifying Theory

- **Theory of plate tectonics:** the lithosphere is broken into large plates that interact and cause geologic activities
  - Explains how and why continents move
  - Explains how and why sea floor spreading occurs
  - Explain how, why, and where earthquakes, volcanoes, and the formation of mountains occur

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**TOPIC 4.1** What ideas, observations, and evidence led to the theory of plate tectonics?

### Summary: What ideas, observations, and evidence led to the theory of plate tectonics?

- Scientists debated how to interpret the shapes and positions of Earth's continents.
- Technology helps scientists make inferences about the different layers of Earth.
- Studies of the ocean floor revealed where new rock is made.
- The theory of plate tectonics provides a unified explanation for geological features and processes.



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