Lesson B2
Seafloor Spreading and Paleomagnetism

Guiding Question:

Why is ocean crust so much younger than continental crust?

Key Concepts

- The theory of seafloor spreading states that new ocean crust is continually being formed, and that this crust is slowly carried away from its point of origin over a period of time.
- The study of the repeated reversal of the Earth's magnetic poles over time has provided convincing evidence of seafloor spreading.

Objective:

To explore how magnetic studies and age information provide evidence for seafloor spreading that explains why oceanic crust is younger than continental crust.

Introducing the Lesson:

Bats use it. Dolphins use it. The commercial and recreational fishing industries also use sonar (from **SO**und **N**avigation **A**nd **R**anging) to locate the fish they want to catch. The sonar systems used as part of a 1950's seafloor mapping expedition were instrumental in the discovery of the mid-oceanic ridge system, the world's longest chain of mountains. At 40,000 kilometers (approximately 25,000 miles) in length, the mid-oceanic ridge is a continuous chain of mountains running through every ocean around the globe.

What is the relationship between seafloor spreading and the world's longest chain of mountains? How does this connect with plate tectonics? Use graphic organizer **B-K-W-L-Q** on page 245 to compile students' ideas, existing knowledge, and questions about mid-ocean ridges and seafloor spreading.

In this lesson, students will explore the phenomenon of seafloor spreading and the evidence it provides to support the theory of plate tectonics.

Time Required

Main Lesson:
45 minutes

Digging Deeper (optional)

Interactive Animation:
5 minutes

History Link:
5 minutes

History Link:
5 minutes

Science Skills

Estimating
Problem solving
Measuring
Making inferences
Drawing conclusion
Communicating ideas

Vocabulary

Seafloor spreading
Magnetic reversal
Curie temperature
Paleomagnetism
Normal polarity
Reversed polarity

Assessment

Pretest: Contents Brainstorming, on page 244

B-K-W-L-Q, on page 245

Science Background

Seafloor Spreading

Extensive mapping of the seafloor occurred during WWII because submarines needed accurate data for safe navigation. These studies continued after the war, and led to the discovery of ocean ridges and ocean trenches.

Ocean ridges: These are large oceanic mountain chains with narrow central valleys extending the length of an entire ocean. These mid-ocean ridges connect to other ranges of mid-oceanic ridges that extend around the entire planet.

Ocean trenches: These are deep-sea trenches thousands of kilometers (miles) long and many kilometers (miles) deep. They are often found at continental edges or along island chains. Most ocean trenches are located in the Pacific Ocean.

The seafloor sediment layer was much thinner than expected. None of the sediment samples were more than 180 million years old. This is very young compared to the age of continental crust, which is measured in billions of years.

American geologist Harry Hess (1906–1969) explained the lack of old oceanic crust in 1962. Hess' theory of **seafloor spreading** states that hot magma from Earth's mantle rises up through the mid-oceanic ridges. This magma cools and flows sideways, forming new seafloor. Hot magma continues to rise from the mid-oceanic ridge, constantly producing new oceanic crust. The older crust becomes denser as it slowly cools and sinks, gradually building up the mid-oceanic ridges. Eventually, this newly formed ocean crust is carried away from the mid-oceanic ridge by the spreading seafloor. It is recycled millions of years later when it returns to the mantle by descending into the deep ocean trenches. Persuasive evidence to support seafloor spreading soon followed Hess' hypothesis.

Magnetic Reversal and the Curie Temperature

A compass needle points toward the north magnetic pole. It is little known that 800,000 years ago, the same compass needle would have pointed south instead of north. This is because the magnetic poles have reversed direction. The magnetic poles have reversed themselves a number of times in Earth's geologic history between **normal polarity** (i.e., the north and south magnetic poles are in the orientation that they are today), and **reversed polarity** (i.e., the north and south magnetic poles are in the opposite orientation than they are today). This is known as **magnetic reversal**.

Evidence for magnetic reversal comes from a physical property of magnetic materials known as the **Curie temperature** (T_C). Magnetic minerals lose their magnetism when their temperature exceeds the Curie temperature. Different magnetic materials have different Curie temperatures. As these materials cool below their Curie temperature, magnetic grains in the material align themselves with the magnetic poles. As magnetic materials solidify, a record of their magnetic orientation is "frozen" into them. Magnetite, a common compound of iron-bearing rocks like basalt, and the major component of oceanic crust, is commonly used to show this reversal.

Paleomagnetism

The Curie temperature provides a record of Earth's magnetic field orientation. Studies of different-aged rock give information about past strength and orientation of the Earth's magnetic properties. This study is known as **paleomagnetism**.

Paleomagnetism helped explain an unusual observation from the 1950s. Magnetic studies revealed that the ocean floor was comprised of parallel bands of crust having alternating magnetic polarity. These magnetic bands were symmetric about the mid-oceanic ridge.

British scientists Fred Vine and D. H. Matthews explained the phenomenon of **magnetic striping** in 1963. They suggested the magnetic striping was the signature of paleomagnetism. Their proposal stated that magma flowing from the mid-oceanic ridges preserved the then-current orientation of Earth's magnetic poles as the magma cooled below its Curie temperature. Seafloor spreading carried new oceanic crust away from the mid-ocean ridge. Magnetic reversals show up as bands of alternating polarity in the slowly spreading seafloor. The symmetric banding is the result of seafloor spreading on both sides of a mid-oceanic ridge. This explanation of magnetic striping by paleomagnetism convinced scientists that new oceanic crust was being continually formed at mid-oceanic ridges. Seafloor spreading was accepted as a reality.

Drilling and the Age of the Seafloor

Oceanic crust is younger than continental crust. Clear maps of seafloor age were produced in the late 1960s when underwater drilling technology developed as part of offshore oil exploration activity. Scientific research vessels such as the *Glomar Challenger* adapted this drilling technology. Oceanic drilling by the *Glomar Challenger* between 1968 and 1983 produced the first accurate data of seafloor age.

Glomar Challenger data showed a clear progression of increasing age with distance from the mid-ocean ridge. Sediment next to the ridge was youngest. The oldest sediment was farthest away and close to continental shelves. This age progression in seafloor sediment corroborated the theory of seafloor spreading.

Learning Activity

Students will use the software to measure the separations of mid-oceanic ridges and continental shelves, and approximate the maximum age of the seafloor. They will calculate the average rate of seafloor spreading and compare spread-ing rates and seafloor ages on opposite sides of the mid-oceanic ridge. Students will also locate Earth's greatest amount of old oceanic crust.

Seafloor Spreading and Paleomagnetism Interactive Animation

This animation shows the pattern of magnetic reversals on either side of a mid-ocean ridge as a key piece of evidence supporting the theory of plate tectonics. A geomagnetic timescale was produced by combining magnetic reversal data with the age data of the rocks (radiometric dating) in the seafloor.

Learning Support

Build confidence	English language learners	ELL: Extended vocabulary
Explore NOAA's research mission to the Galapagos Spreading Center, part of the Pacific Ocean's mid-oceanic ridge system, at: http://oceanexplorer.noaa.gov/explorations/05galapagos/welcome.html	Vocabulary Cards, on page 255	Magnetic

Digging Deeper

Word Link

Paleomagnetism

First used in 1854, paleomagnetism is formed from the root word paleo which is derived from the ancient Greek word palaio, meaning ancient. The word paleomagnetism literally means ancient magnetism.

Did You Know? 1

The Mariana Trench in the Pacific Ocean has a depth far greater than the height of the world's tallest mountain. Mt. Everest is 8,848 meters (29,035 feet) high. The Mariana Trench is 10,971 meters (36,000 feet) deep.

Did You Know? 2

Over 15 years, the *Glomar Challenger* traveled 375,632 nautical miles, investigated 624 sites, and drilled 19,119 core samples, with a total core length of 97,056 meters (318,425 feet). The name *Glomar* is a contraction of Global Marine.

History Link

The Curie temperature is named in honor of French physicist Pierre Curie (1859–1906). In 1895, he discovered that magnetic materials lose their magnetic properties above a certain critical temperature.

Time required: 5 minutes

Travel Link

Iceland is the only place in the world where people can visit the Mid-Atlantic Ridge and remain above the ocean surface.

Time required: 5 minutes

Evidence of Learning

Upon completion of this lesson, students should have a basic understanding of how magnetic and age studies of the seafloor have contributed to our understanding of the process of plate tectonics. Lesson activities, along with the provided graphic organizer activities and learning review questions, will give you evidence that students can:

- Describe how new ocean crust is continually forming and moving slowly away from its point of origin
- Explain how magnetic striping on the seafloor provides evidence of seafloor spreading
- Relate how seafloor spreading corroborates plate tectonic theory

Review Questions and Answers

1) What two major geologic features about the oceans were discovered as a result of studies that commenced during WWII?

These studies revealed the existence of an underwater ridge of mountains that completely circled the globe. They also revealed the presence of deep-sea trenches, usually near the margins of continents or island chains around the Pacific, which had a depth of several kilometers (several miles).

2 a) According to these studies, what was the maximum age of the seafloor?

None of the sediment or rock samples taken were older than 180 million years.

b) Why was this result so significant?

This was significant because the age of the ocean floor was significantly less than the age of continental crust. Continental crust had ages measured in billions of years.

3) Why is the Curie temperature such a significant property of magnetic materials?

Magnetic materials lose all magnetic properties when the surrounding temperature is above the Curie temperature. As the material solidifies at temperatures below the Curie temperature, the orientation of the Earth's magnetic poles becomes "frozen" in the material's magnetic grains.

4 a) How did Vine and Matthews explain the phenomenon of magnetic striping on the ocean floor?

They stated that the magnetic striping was due to paleomagnetism. The striping revealed magnetic reversals in the Earth's poles as oceanic crust moved away from the mid-oceanic ridges by seafloor spreading.

b) Why was the Vine and Matthews explanation of magnetic striping considered to be so significant?

It was the piece of evidence that finally convinced scientists that seafloor spreading was a reality since it clearly demonstrated that new oceanic crust was constantly being created at the mid-oceanic ridges.