SCIENCE

Lessons 1–2

Year 9

Topic: Developing the theory of plate tectonics

Examining the evidence

Today you will:

- understand how evidence links to the development of the theory of plate tectonics from continental drift hypothesis
- compare the location of tectonic events with the location of current plate boundaries
- understand the limitations in the evidence for continental drift hypothesis
- produce a timeline that demonstrates the development of evidence.

Resources

Digital

Slideshow — Evidence for continental drift hypothesis

Video — Tectonic plate movements (5:31)

Find and prepare

Sheet 1 — World map

Sheet 2 — Wegener's puzzling evidence

Sheet 3 — 2012: Magnetic pole reversal happens all the (geologic) time

Science journal

Key terms

continental drift, continental shelf, Earth's polarity, magnetic striping, Mid-Atlantic Ridge, mid-ocean ridge, ocean trench, Pacific Ring of Fire, Pangaea, plate boundaries, sea floor spreading, seisometer, tectonic plate

For definitions and explanations of terms, please see the Glossary.

Keep the **Glossary** for reference throughout these lessons.

Science start-up

Examine continents and their shapes

In Year 8 Science, you would have looked at the structure of Earth from inner core to crust. We live on the crust at the top of these layers. Think back to Year 8 and what you remember about the features of each layer of Earth.

Let's examine some ideas about the continents and their shapes. Our continents sit on top of the mantle and sometimes experience effects from that hot, semi-liquid part of Earth.

1. Open **Sheet 1 —** World map and look at the shapes of the continents.

   You may or may not have noticed this before, but don't the coastlines on either side of the Atlantic Ocean appear as though they could roughly fit together?

   a. In the table below, list land masses (continents, countries and islands) on each side of the Atlantic Ocean that have complementary coastlines. One example is done for you.

Left side	Right side
Canada	Greenland

   In 1596, Dutch map maker Abraham Ortelius suggested that North and South America had in the past been torn away from Europe and Africa. Most scientists at the time ignored the idea.

   b. What reason might explain the matching coastlines?

   Complementary coastlines alone was not convincing evidence. During this lesson, you will learn about other evidence that was used to support the notion that continents have moved.

Department of Education and Training
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Lesson

Examine evidence for continental drift hypothesis

Fossil evidence

Under certain conditions, the remains of dead organisms such as bones, teeth, scales, shells or hair, may be preserved in layers of sedimentary rock or coal. Sometimes impressions of footprints or leaves may also be preserved. These preserved remains and impressions provide scientists with fossil evidence of organisms that were living in a particular area at a particular time in the past.

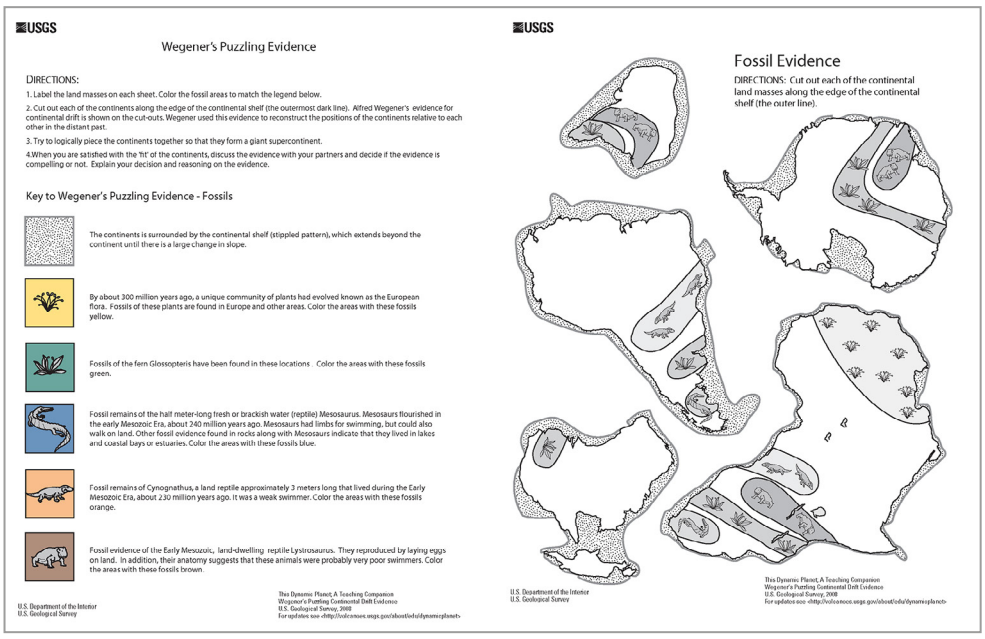
Today's kangaroos and eucalyptus trees have no natural way to move to the other side of an ocean. Kangaroos and most eucalyptus trees are native only to the Australian continent. You might expect the same to apply to the organisms which formed fern and reptile fossils back in the Permian and middle Triassic periods (235–300 millions of years ago). Let's look at some patterns of fossils.

2. Open **Sheet 2 —** Wegener's puzzling evidence and follow the directions provided. Use the fossil evidence to connect the land masses and form a supercontinent.

Note

The labels for the land masses are Africa, South America, India, Antarctica and Australia.

For the purposes of the activity, the land masses are referred to as 'continents' because in geological history they were part of a supercontinent that split apart. Be aware that presently, some of these land masses continue to be separate continents, such as Australia and Antarctica, while others, like India, are once again part of a larger geographical continent (e.g. Asia).



USGS

Wegener's Puzzling Evidence

DIRECTIONS:

1. Label the land masses on each sheet. Color the fossil areas to match the legend below.
2. Cut out each of the continents along the edge of the continental shelf (the outermost dark line). Alfred Wegener's evidence for continental drift is shown on the cut-outs. Wegener used this evidence to reconstruct the positions of the continents relative to each other in the distant past.
3. Try to logically piece the continents together so that they form a giant supercontinent.
4. When you are satisfied with the 'fit' of the continents, discuss the evidence with your partners and decide if the evidence is compelling or not. Explain your decision and reasoning on the evidence.

Key to Wegener's Puzzling Evidence - Fossils

The continents is surrounded by the continental shelf (stippled pattern), which extends beyond the continent until there is a large change in slope.

By about 300 million years ago, a unique community of plants had evolved known as the European flora. Fossils of these plants are found in Europe and other areas. Color the areas with these fossils yellow.

Fossils of the fern Glossopteris have been found in these locations . Color the areas with these fossils green.

Fossil remains of the half meter-long fresh or brackish water (reptile) Mesosaurus. Mesosaurs flourished in the early Mesozoic Era, about 240 million years ago. Mesosaurs had limbs for swimming, but could also walk on land. Other fossil evidence found in rocks along with Mesosaurs indicate that they lived in lakes and coastal bays or estuaries. Color the areas with these fossils blue.

Fossil remains of Cynognathus, a land reptile approximately 3 meters long that lived during the Early Mesozoic Era, about 230 million years ago. It was a weak swimmer. Color the areas with these fossils orange.

Fossil evidence of the Early Mesozoic, land-dwelling reptile Lystrosaurus. They reproduced by laying eggs on land. In addition, their anatomy suggests that these animals were probably very poor swimmers. Color the areas with these fossils brown.

U.S. Department of the Interior
U.S. Geological Survey

This Dynamic Planet, A Teaching Companion
Wegener's Puzzling Continental Drift Evidence
U.S. Geological Survey, 2008
For updates see <http://volcanoes.usgs.gov/about/edu/dynamicplanet>

USGS

Fossil Evidence

DIRECTIONS: Cut out each of the continental land masses along the edge of the continental shelf (the outer line).

U.S. Department of the Interior
U.S. Geological Survey

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Extract from : *This dynamic planet: a teaching companion* (US Geological Survey, 2008), p.10
http://volcanoes.usgs.gov/vsc/file_mngr/file-139/This_Dynamic_Planet-Teaching_Companion_Packet.pdf

3. Look at the patterns of where the fossils are found.

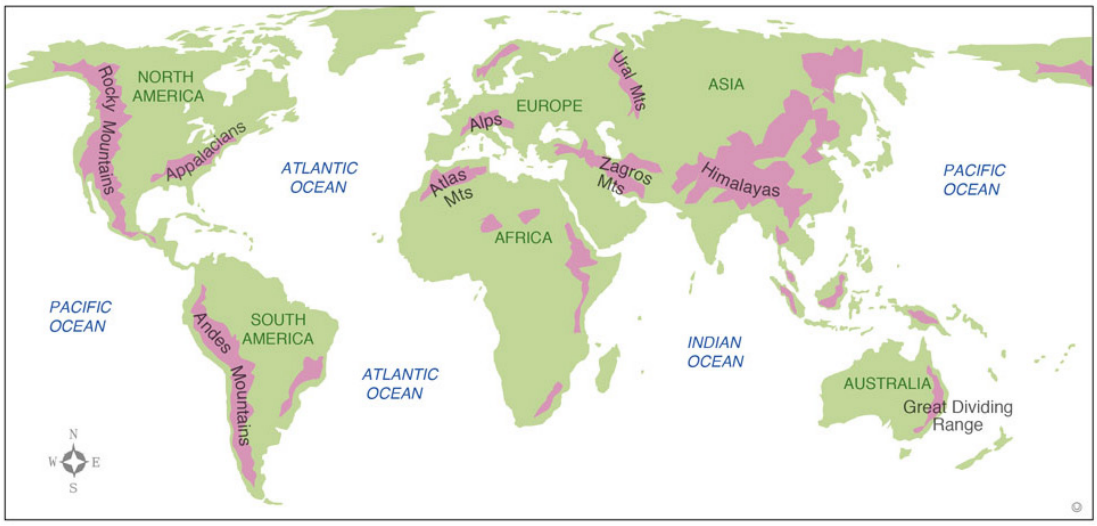
   What do you think could be the explanation for the distribution of fossils shown on the map?

Geological evidence

In Year 8 Science, you learned that there are many different types of rocks. Is it just a great coincidence that rocks on coastlines of continents on the opposite sides of oceans match? Not only do rock types match, but there are rock formations which appear to have been divided by separation of continents.

The map below shows the positions of some present-day mountain ranges which all formed at the same time out of the same types of rock. The mountains to which this applies are the Appalachians in North America, the Atlas mountains in Africa and mountains in Ireland, Scotland and Scandinavia in the far north of Europe.

World map of mountain ranges



4. Is it possible that the mountain ranges of interest on the map could have at one time been part of a single mountain range? Explain the reason/s for your answer.

Climate evidence

Large coal deposits form where there were tropical climates with high rainfall. A lot of dead vegetation and plankton sinks to the bottom of lakes or swamps where bacteria have used up all of the oxygen. The organic sediment can be pressed into sedimentary rock and eventually coal. In cold climates, plant growth is slower, oxygen dissolves more easily into water and coal doesn't form. However, large coal deposits exist in cold areas such as Britain, North America and Antarctica where the present climate would prevent coal formation. Within these coal deposits are found the fossils of tropical organisms.

Ice glaciers around the world begin in alpine conditions and creep downhill. In lower altitudes, the temperature increases and the glacier melts. No glaciers exist in warm climates. In the summer, when glaciers retreat a little, the rocks underneath a glacier show a recognisable scratch pattern where the ice and rocks were dragged over the surface. These glacier scratch patterns have been found in present-day tropical areas and even deserts in Africa, South America, India and Australia.

5. a. What explanation can you offer for the climatic evidence presented above?

Alfred Wegener was a German meteorologist and astronomer who lived from 1880 to 1930. Wegener was not the first person to recognise the significance of this evidence nor was he the first person to suggest that the continents had separated and moved. He was the first person to put together evidence from geography, geology and biology into a strong argument supporting the hypothesis of continental drift. Wegener went further to suggest that all continents on Earth were originally joined in the supercontinent Pangaea. According to Wegener, Pangaea split up into separate continents which have mostly been moving apart ever since. Wegener presented his hypothesis in 1912.



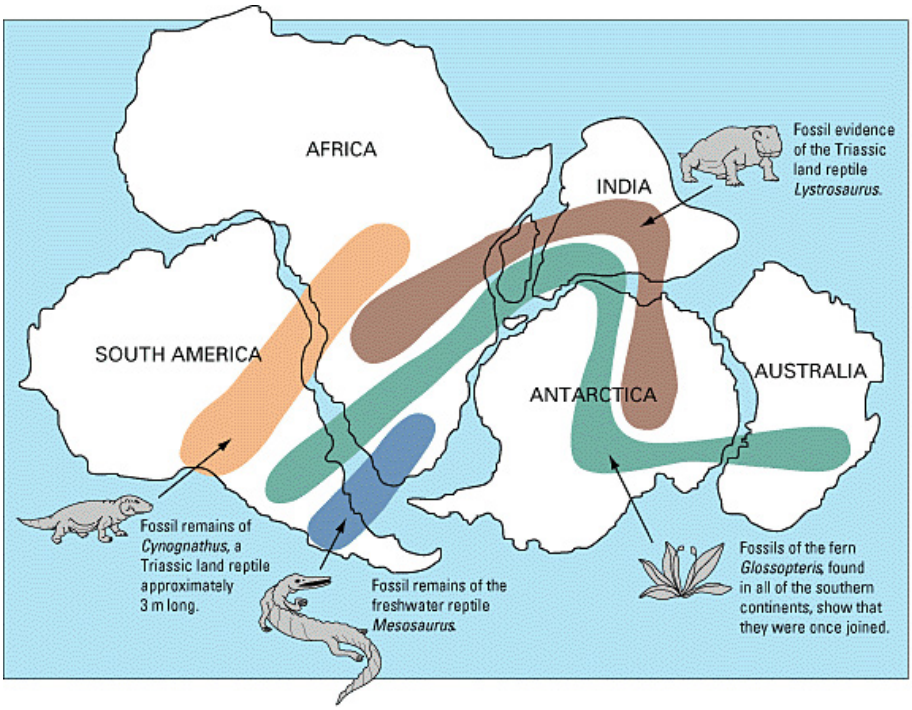
Alfred Wegener, circa 1925, http://commons.wikimedia.org/wiki/File:Alfred_Wegener.jpg

b. Compare the supercontinent you made using **Sheet 2** to the diagram called 'Fossil evidence for continental drift' below. Your diagram may be slightly different. Why do you think this may be?

The original supercontinent first split into two different supercontinents. The southern continents, or Antartica, Australia, South America, India and Africa, made up the supercontinent Gondwanaland, while Europe, Asia and North America made up the supercontinent of Laurasia.

The following diagram shows fossil evidence used by Wegener to support his continental drift hypothesis.

Fossil evidence for continental drift



United States Geological Survey, http://pubs.usgs.gov/gip/dynamic/continents.html

6. Wegener's continental drift hypothesis was ridiculed as impossible by most of the scientific community. Wegener however was convinced that he was right and he spent almost the next 30 years looking for even more evidence.

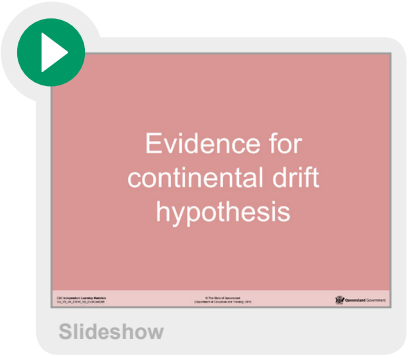
   a. Explain Wegener's hypothesis.

   b. List the pieces of evidence (from the diagrams) that supported Wegener's continental drift hypothesis. Is this enough to convince you of his theory? Discuss with another person.

   c. Why do you think Wegener's hypothesis was rejected and ridiculed by other scientists?

Wegener died in the snow in 1930 while on an expedition to Iceland to collect more evidence for his hypothesis. At the time of Wegener's death, continental drift had few supporters. The main problem was that nobody could believe that there were forces in Earth that could push continents through or across rock on the ocean floor. It would be another two decades before the weight of mounting evidence began to sway the thinking of the scientific community.

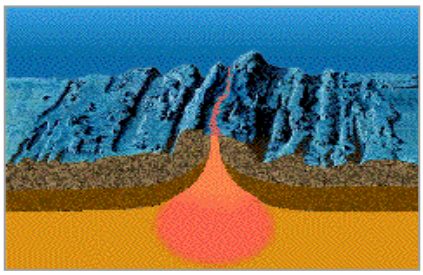
7. View the **Slideshow — Evidence for continental drift hypothesis**. This slideshow summarises the evidence the scientist Alfred Wegener used in 1912 to develop the theory that continents move over time.



Examine later evidence that led to the development of the theory of plate tectonics

Mid-ocean ridges

Although the ocean depth was known to vary, it wasn't until 1925 that the use of echo sounding confirmed that there is a 4 km high mountain range running along the Atlantic Ocean floor between Africa and Europe and North and South America. The significance of this mid-ocean ridge was not realised until the 1950s.


i.

Convection currents under the crust

In 1929, Arthur Holmes provided an explanation of how convection currents under Earth's crust could be causing the continents to move but this still did not convince the scientific community that Wegener's hypothesis was right. Arthur Holmes' theory will be the focus of the next lesson.

Sea floor spreading

During World War II, scientists discovered that submarines caused minute variations in Earth's magnetic field. Technology was developed to detect these variations. Later, in the 1950s, the same technology was used to measure magnetism in rocks on the ocean floor, providing evidence of *sea floor spreading*. This evidence was significant in convincing the scientific community to accept Wegner's hypothesis.

Measurement of the magnetic alignment of the magnetite minerals in Basalt rocks triggered the theory of sea floor spreading. Other evidence helped to confirm the theory. Oil drilling technology improved so that during the 1960s a lot of rock samples were available for testing. It was found that very young rock existed close to mid-ocean ridges and the age of rock increased with distance away from mid-ocean ridges.

8. a. Go to the **Website — Earth and space science** alcearthscience.weebly.com/seafloor-spreading.html. Open and view the fifth video *Magnetic reversals and sea floor spreading*.

   b. Read **Sheet 3 —** 2012: Magnetic pole reversal happens all the (geologic) time

i. United States Geological Survey, http://geomaps.wr.usgs.gov/parks/animate

9. Use the information in the video and **Sheet 3** to answer the following questions.

   a. Explain how the discovery of magnetic striping provides evidence of sea floor spreading.

   b. How does determining the age of rock samples provide further evidence in support of sea floor spreading?

   c. Explain why you think sea floor spreading was convincing evidence that continents could move.

Explore tectonic plate boundaries

In the early 1960s, a nuclear weapons treaty was agreed to by several nations. To monitor compliance with the terms of the treaty, many seismometers were employed around the world to detect any nuclear explosions that occurred and to help provide evidence that treaty responsibilities were being met.

A **seismometer** is an instrument that measures the movement of Earth's crust.

Three seismometers in different locations can pinpoint the source of the shaking (explosion or earthquake).

Using these seismometers, the positions of earthquakes and volcanoes were plotted. As this data was collated in the 1960s, a pattern instantly appeared.

10. Watch the **Video — Tectonic plate movements** and then answer the questions below. This video explores how Earth's crust is divided into tectonic plates and explains the types of tectonic plates and how they move.

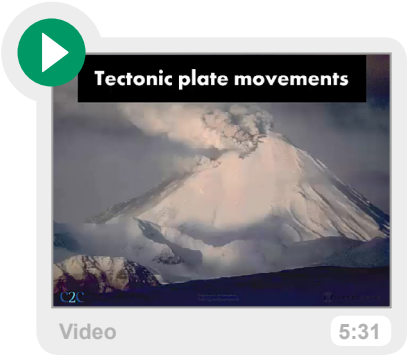


Image: https://commons.wikimedia.org/wiki/File:Dds40-097_large.jpeg

a. Volcanoes and earthquakes occur mostly at plate boundaries. Explain why.

b. Describe the three different ways in which the boundary of one plate interacts with the boundary of another plate. Explain what happens at each boundary.

Centuries passed between the time when **continental drift** was first proposed until it was finally accepted in the 1960s. **Alfred Wegener** is considered the most important contributor to the development of modern **plate tectonic theory**. Wegener accumulated important evidence from several scientific fields to support his hypothesis. Earth's crust is composed of several **tectonic plates** being moved about by currents in the semi-molten material below the crust.

In the next lesson, you will have an opportunity to examine the processes that move tectonic plates.