UNIT 4 - TEACHING INVESTIGATION 4

WHEN AND WHY DO PEOPLE ACCEPT A THEORY?

Process Overview

Note: This can be treated as a one-day or two-day activity

1. **Part 1 (Day 1)**
   Explore, Read, and Analyze Texts – Establish the purpose of the Investigation, have students identify the question, read the texts in the Investigation Library, and apply disciplinary concepts to develop an answer to the Investigation question. This could be part of one class or even be assigned as homework.
2. **Part 2 (Day 2)**
   Communicating Conclusions (Investigation Writing) – Give students **no more than 50 minutes** to complete a five- to six-paragraph essay (about 2 pages) responding to the Investigation question. Do not assign as homework. Please make sure this is an in-class activity. Allow students to use their work from the prewriting activity to help them during the in-class writing time.

Note: You are, of course, free to use this Investigation any way you want. That is, you might add or subtract texts from the Library, extend the time students work on the question, or adjust the ways they communicate their conclusions. However, sticking to the suggested process helps prepare students for the Investigations you'll submit to BHP Score, and also mimics some standardized testing environments.

Purpose

Historical Purpose of the Investigation: A central question in both the history of science and our everyday lives is when should people accept new ideas as credible and warranted? In short, when and why should people accept a theory? Plate tectonics provides a good case to explore this idea. The theory met stiff resistance within the scientific community when Alfred Wegener first proposed it, largely because Wegener was not a geologist. Slowly, as more evidence accumulated and ideas were shifted, adjusted, and changed, the scientific community came to regard it as fact, even though it was once met with ridicule.

Pedagogical Purpose of the Investigation: This Investigation asks students to consider how a hypothesis — sometimes a ridiculed idea — becomes a theory that is widely accepted within the scientific community. In addition, this Investigation adds a layer of knowledge about plate tectonics and the evidence that supported Wegener's and others' claims. The Library introduces students to texts that explain the scientific theory of continental drift and that document the scientific community's reaction to this theory. It's a great chance to help students understand the collective process of questioning, testing, and eventually accepting a scientific theory. Such collective testing of ideas — peer review at its best — is an important feature of collective learning. In this Investigation, it's very important that students pay attention to *when* documents were published and how each exhibits the transition from skepticism to scientific confidence.

Framing the Problem: Discussing the Driving Question and Capturing Students' Initial Conjectures

First, make sure students are familiar with the Investigation question: How and why do theories become generally accepted?

Then, introduce students to the problem framing.

Did you ever have a hunch that something was true, but no one else agreed with you? Were you able to prove that you were right?

To explain an observed phenomenon, scientists often begin with a hypothesis — their best guess, or conjecture—about why and how it occurs. Then, they gather information to see if there is enough evidence to prove their hypothesis true. Sometimes a scientific hypothesis generates a lot of controversy, especially when it is in its early stages of being tested. Often, hypotheses turn out to be incorrect, and we either never hear about them or they are soon forgotten. But if sufficient evidence is found to support the hypothesis, or if there is enough evidence to rule out competing hypotheses, the hypothesis becomes a theory — a likely explanation of the observed phenomenon.

The theory of plate tectonics offers an interesting case study in how an idea goes from being widely rejected to widely accepted within the scientific community. This Investigation asks you to examine Alfred Wegener's continental-drift hypothesis and trace the steps of his claims from disputed hypothesis to accepted theory. Why did scientists initially question Wegener's idea? Why did they eventually accept continental drift as part of the theory of plate tectonics? What role did intuition, logic, authority, and evidence play in this story?

Part 1 – Explore, Read, and Analyze Texts

As always, students should begin with their initial thinking about what is necessary for a scientific or historical idea to be accepted as fact. Capture their conjectures —best guesses — about what makes a community of scholars agree that something is true. Ask the following:

1. Think about a time when you came to believe something was true, and then use your journal to answer these questions: When did you come to believe it? How did you decide it was true? Did you have doubts? How did you put your doubts to rest?
2. Then, take a look at a map of the Earth. Do you see any pattern to the arrangement of continents? Do you think continents may have been in different locations and arrangements in the past, or do you expect that the surface of Earth has always looked like it does today?

Analyzing Documents and Making Claims

Have students read the materials in the Investigation Library to gather information about how geologists came to accept the idea of continental drift. Ask them to take notes about the different arguments that have been made to support or deny the idea of continental drift, and have them trace their thinking along the way. Then, have them review what they discovered about how continental drift came to be accepted. Make sure they use the chart provided to identify the important steps in when and why people accepted the theory of plate tectonics.

Then, ask students to make a timeline illustrating the key events in the history of the theory of plate tectonics. Identify important points that led to the general acceptance of this view and its impact on the modern scientist's understanding of the Earth. As always, remind students to draw on information from the Investigation Library. Please have students list the texts that they used to make their timelines; doing so will reinforce the habit of referencing and citing texts as evidence rather than simply pulling information from texts. Also, ask students to link this to other Big History concepts (such as complexity, collective learning, and claim testers.)

Part 2 –Communicating Conclusions

Students can now use the timeline tool to write a five- to six-paragraph essay explaining when and why people accept a theory, using plate tectonics as a case study. Make sure they support their claims with logic and evidence and that they refer to the specific documents or sources from which they're getting their information. They should be able to trace the major steps that scientists took in developing and accepting the theory of plate tectonics.

Remind students to use information from texts, disciplinary or Big History concepts, and evidence to support their argument. Remind students to reference the texts or sources they use to support their argument. They should also reference when and by whom the documents were written.

Give students **no more than 50 minutes** to complete a five- to six-paragraph essay responding to the Investigation question. Do not assign as homework. Please make sure this is an in-class activity. Allow students to use their work from the prewriting activity to help them during the in-class writing time.

UNIT 4 - INVESTIGATION 4

WHEN AND WHY DO PEOPLE ACCEPT A THEORY?

Purpose

A central question in both the history of science and our everyday lives is when should people accept new ideas as credible and warranted? In short, when and why should people accept a theory? Plate tectonics provides a good case to explore this idea. The idea met stiff resistance within the scientific community when Alfred Wegener first proposed it, largely because Wegener was not a geologist. Slowly, as more evidence accumulated and ideas were shifted, adjusted, and changed, the scientific community came to regard it as fact, even though it was once met with ridicule.

Process

Framing the Problem: Discussing the Driving Question and Capturing Your Initial Conjectures

First, make sure you are familiar with the Investigation question: How and why do theories become generally accepted?

Then, read the problem framing:

Did you ever have a hunch that something was true, but no one else agreed with you? Were you able to prove that you were right?

To explain an observed phenomenon, scientists often begin with a hypothesis — their best guess, or conjecture— about why and how it occurs. Then, they gather information to see if there is enough evidence to prove their hypothesis true. Sometimes, a scientific hypothesis generates a lot of controversy, especially when it is in its early stages of being tested. Often, hypotheses turn out to be incorrect, and we either never hear about them or they are soon forgotten. But if sufficient evidence is found to support the hypothesis, or if there is enough evidence to rule out competing hypotheses, it becomes a theory — a likely explanation of the observed phenomenon.

The theory of plate tectonics offers an interesting case study in how an idea goes from being widely rejected to widely accepted within the scientific community. This Investigation asks you to examine Alfred Wegener's continental-drift hypothesis and trace the steps of his claims from disputed hypothesis to accepted theory. Why did scientists initially question Wegener's idea? Why did they eventually accept continental drift as part of the theory of plate tectonics? What role did intuition, logic, authority, and evidence play in this story?

Part 1 – Explore, Read, and Analyze Texts

Begin by gathering your initial thinking about what is necessary for a scientific or historical idea to be accepted as fact. Capture your own conjectures — your best guesses — about what makes a community of scholars agree that something is true.

1. Think about a time when you came to believe something was true, and then use your journal to answer these questions: When did you come to believe it? How did you decide it was true? Did you have doubts? How did you put your doubts to rest?
2. Then, take a look at a map of the Earth. Do you see any pattern to the arrangement of continents? Do you think continents may have been in different locations and arrangements in the past, or do you expect that the surface of Earth has always looked like it does today?

Analyzing Documents and Making Claims

Read the materials in the Investigation Library to gather information about how geologists came to accept the idea of continental drift. Take notes about the different arguments that have been made to support or deny the idea of continental drift, and trace your thinking along the way. Then, review what you discovered about how continental drift came to be accepted. Make sure you use the chart provided to identify the important steps in when and why people accepted the theory of plate tectonics.

Now, make a timeline illustrating the key events in the history of the theory of plate tectonics. Identify important points that led to the general acceptance of this view and its impact on the modern scientist's understanding of the Earth. Make sure to show how Wegener's continental-drift hypothesis influenced and was influenced by the development of plate tectonics theory.

As always, remember to draw on information from the Investigation Library. List the texts that you used to make your timeline; doing this will reinforce the habit of referencing and citing texts as evidence rather than simply pulling information from texts. Also link this to other Big History concepts (such as complexity, collective learning, and claim testers.)

Part 2 – Communicating Conclusions

Use the timeline tool to write a five- to six-paragraph essay explaining when and why people accept a theory, using plate tectonics as a case study. Make sure you support your claims with logic and evidence, and refer to the specific documents or sources from which you're getting your information. You should be able to trace the major steps that scientists took in developing and accepting the theory of plate tectonics.

Remember to use information from texts, disciplinary or Big History concepts, and evidence to support your argument. Remember to reference the texts or sources you use to support your argument. You should also reference when and by whom the documents were written.

When and why do people accept a theory?

Year	1910	1911			
What happened?	Wegener noticed that the continents seem to fit together like pieces of a puzzle				
Why is this important in helping you explain when and why people accept a theory?					
What document(s) provides this information?					

4

INVESTIGATION LIBRARY

TEXT 01

ALFRED WEGENER'S CONTINENTAL-DRIFT HYPOTHESIS

In 1915, Alfred Wegener (1880–1930) published hypothesis of continental drift in his book *The Origin of the Continents and Oceans*. He was not the first to observe that certain continental coastlines fit together like pieces of a puzzle (see figure below), but Wegener drew on a broader range of disciplines, such as geology, oceanography, and paleontology, than earlier supporters of the idea had. This attracted widespread attention and led to robust debate among scientists.

The continental-drift hypothesis proposed that Earth's continents had once been connected but had moved slowly apart and across Earth's surface over millions of years. Basing his argument on the matching coastlines of continents and the similarity of fossil and rock types on continents separated by oceans, Wegener wrote the following:

> The concept of continental drift first came to me as far back as 1910, when considering the map of the world, under the direct impression produced by the congruence of the coastlines on either side of the Atlantic. At first I did not pay attention to the idea because I regarded it as improbable. In 1911, I came quite accidentally upon a report in which I learned of paleontological evidence for a former land bridge between Brazil and Africa. As a result I undertook a cursory examination of relevant research in the fields of geology and paleontology, and this provided immediately such weighty collaboration that a conviction of the fundamental soundness of the idea took root in my mind. The basic "obvious" supposition that the relative position of the continents has never altered must be wrong. The continents must have shifted. South America must have lain alongside Africa and formed a unified block which was split in two; the two parts must then have become increasingly separated over a period of millions of years.

Source

Modified from Alfred Wegener, *The Origin of the Continents and Oceans*, 4th ed., trans. John Biram (New York: Dover Publications, 1966) 1, 17.

TEXT 02

WEGENER'S DIAGRAMS

Wegener included this diagram of continental movement in his 1915 book.

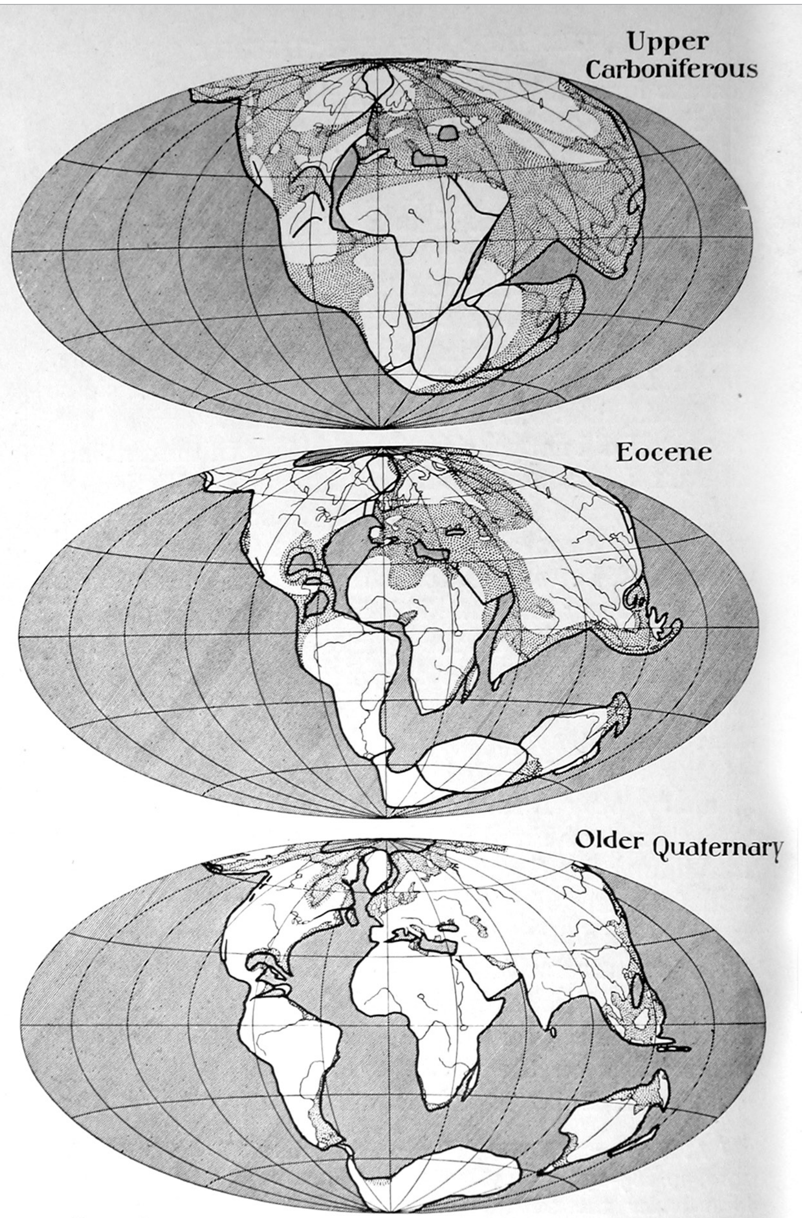


Fig. 1.—Reconstructions of the map of the world for three periods according to the Displacement Theory. Lined—Ocean; dotted—Shallow seas; present-day outlines and rivers only for the purpose of identification. Latitude and Longitude arbitrary (being that of contemporary Africa).

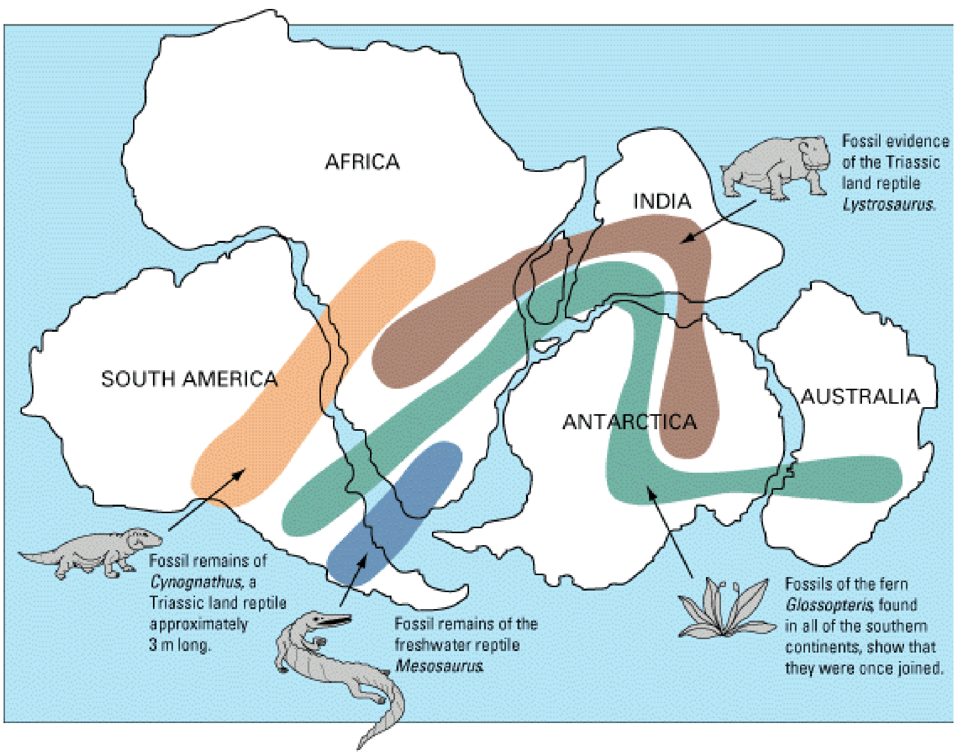
Source

Alfred Wegener. *The Origins of Continents and Oceans* (New York: E.P. Dutton, 1924).

TEXT 03

CONTINENTAL DRIFT AND FOSSIL DISTRIBUTION

When Wegener proposed his continental-drift hypothesis, he knew that similar fossil remains had been found on different continents. This diagram illustrates this point.



Source

The Dynamic Earth, U.S. Geological Survey: Washington D.C.. Available online at http://pubs.usgs.gov/publications/text/continents.html

TEXT 04

RESPONSE TO WEGENER'S HYPOTHESIS

Most scientists found serious flaws in Wegener's hypothesis, and many dismissed it outright. One major weakness was that Wegener failed to provide a mechanism, or an explanation for how the continents moved. Still, some scientists thought that the continental-drift hypothesis could be very important and needed to be explored further. These passages represent some of the discussions scientists had about Wegener's hypothesis.

From G.W. Lamplugh:

> It may seem surprising that we should seriously discuss a theory which is so vulnerable. Yet Wegener's hypothesis is of real interest to geologists, because it has struck an idea that has been floating in their minds for a long time. The underlying idea that the continents may not be fixed has in its favor certain facts which give every geologist a [liking] towards it in spite of Wegener's failure to prove it.
>
> We are discussing his hypothesis seriously because we should like him to be right, and yet I am afraid we have to conclude that in essential points he is wrong. But the underlying idea may yet bear better fruit.

From Mr. F. Debenham:

> I believe we are all ready to be kind to the germ of the theory. In fact, most people are rather anxious that something of the sort should be proved. We have to thank Professor Wegener for a great deal in bringing it forward and offering himself as a target for bullets.
>
> Not for the first time perhaps, but for the first time boldly, Wegener has come forward with a theory which deals with the distribution of the continents in a bold way and offers himself for sacrifice; and he is certainly getting it.

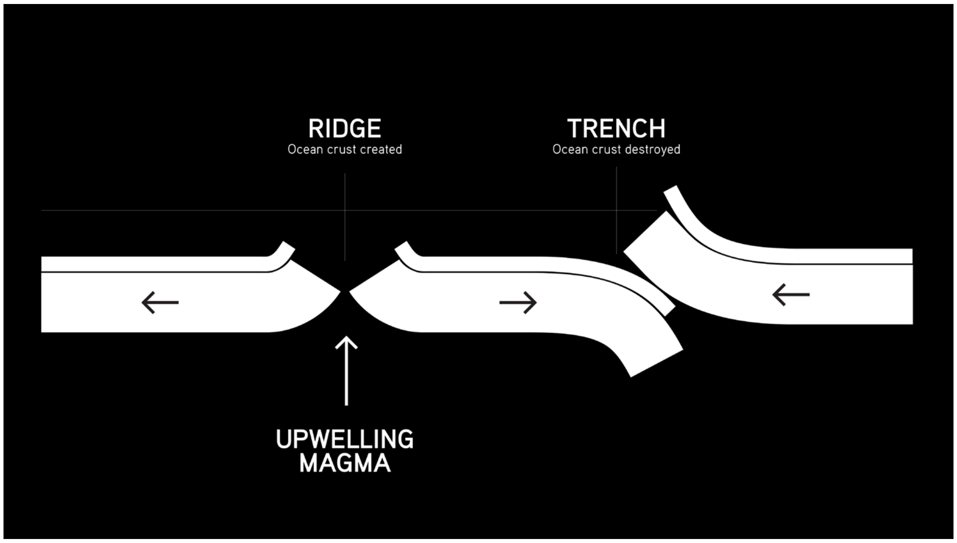
Source

Modified from G. W. Lamplugh, R. D. Oldham, F. Debenham, Harold Jeffreys, Dr. Evans, and C. S. Wright, "Wegener's Hypothesis of Continental Drift: Discussion." *The Geographical Journal* 61:3 (1923): 188–94.

TEXT 05

MORE EVIDENCE OF CONTINENTAL DRIFT: SEAFLOOR SPREADING

Following the initial controversy over Wegener's continental-drift hypothesis, there was little written about it for several decades. In the 1950s, the newly developed field of paleomagnetism (the study of Earth's magnetic field) proved that the continents had once been positioned differently by uncovering certain minerals known to form in alignment with Earth's polarity that pointed in easterly or westerly directions instead of
north or south. But until an adequate *mechanism* to move the continents was found, many scientists remained unconvinced. Then, in 1959, a U.S. Navy officer and Princeton geology professor named Harry Hess (1906–1969), who had used sonar during World War II to map vast areas of the Pacific bottom, wrote a paper explaining a process he called seafloor spreading: molten rock seeps up from the Earth's interior through mid-ocean ridges (undersea mountain chains), spreads out to create new ocean floor, and then sinks back into the Earth's interior through oceanic trenches. This would prove to be the mechanism for continental drift that scientists had been longing for.

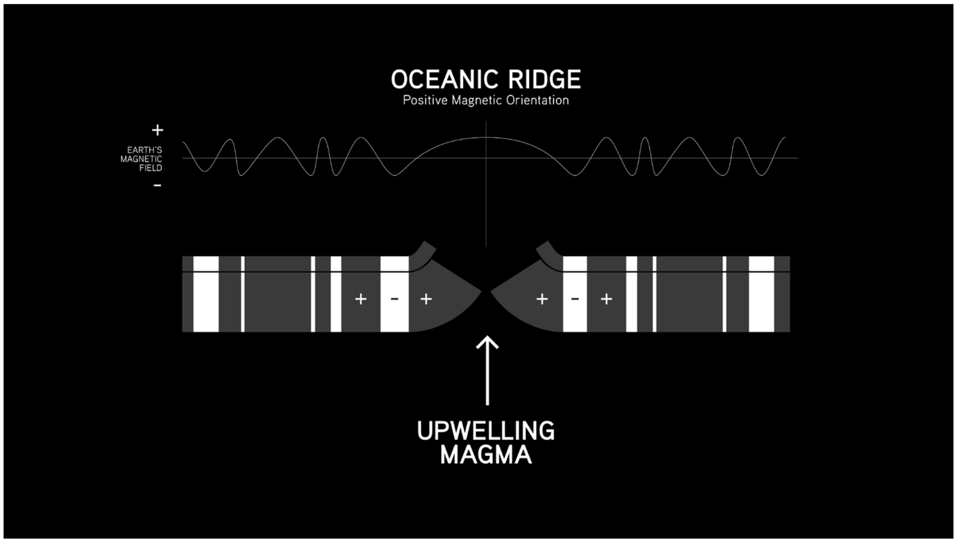


The Big History Project figure above illustrates Hess's model of seafloor spreading. New ocean floor is formed by volcanic magma spewing through mid-ocean ridges. Older ocean floor is forced away from the ridge until it is finally pushed below continental plates at ocean trenches. New ocean floor created at ridges moves continents away from one another; the sinking of ocean floor into trenches (a process called subduction) moves continents toward one another. Seafloor spreading made continental drift a plausible idea.

TEXT 06

IMPORTANCE OF THE VINE-MATTHEWS-MORLEY HYPOTHESIS

Like Wegener, Hess initially encountered resistance to his hypothesis because ocean-floor data was scarce at the time. This soon changed. Paleomagnetists had determined that Earth's magnetic field sometimes flips its orientation, on average every 450,000 years. Such a flip, or "reversal," means that at times in the past a compass needle would have pointed south instead of north. This led geophysicist Fred Vine and geologists Lawrence Morley and Drummond Matthews to propose the Vine-Matthews-Morley hypothesis in 1963: If new oceanic floor is continually being created at mid-ocean ridges, ocean-floor rocks should record past reversals of the magnetic field. Subsequent research by geophysicist Walter C. Pitman confirmed the Vine-Matthews-Morley hypothesis. The figure below illustrates their idea.



Walter C. Pitman studied the magnetic orientation of the ocean floor on either side of the Pacific-Antarctic Ridge. The black stripes represent parts of the seafloor that formed when the orientation of Earth's magnetic field was "normal" (as it is in our times) and the white stripes represent parts of the seafloor that formed when the magnetic field was "reversed." The pattern confirms the seafloor-spreading hypothesis.

Source

Modified from Vine, F. J., and Matthews, D. H., "M*agnetic Anomalies Over Oceanic Ridges.*" Nature, (1963),199, 947-949.

TEXT 07

ACCEPTANCE OF CONTINENTAL DRIFT

Confirmation of the Vine-Matthews-Morley hypothesis proved that the seafloor spreads as Hess had claimed. This helped validate Wegener's continental-drift hypothesis. It was also important to the development of plate tectonics theory, which describes the large-scale motions of the lithosphere. The lithosphere is the Earth's outermost shell, which consists of the crust and a portion of the underlying mantle. The following passages are from two scholars writing about the continental drift debate. Both of their articles were featured in *Nature* magazine, the world's most cited interdisciplinary science journal.

From Henry Frankel:

> Plate tectonics provides Earth scientists with a new framework. Because continents are more buoyant than the sea floor, they remain on the Earth's surface where they move about, collide, break apart and form new aggregates. Geologists, palaeoclimatologists and biogeographers also quickly exploited the continental-drift aspect of plate tectonics. Besides applying continental drift to problems in their specialty, they offered reconstructions and traced geological matches between formerly joined continents. Plate tectonics has shown that the question "How can continents plough through a rigid sea floor?," the nemesis of continental drift, is not the question to ask. Rather, the key question is "What forces drive the plates?" Unlike continental drift, plate tectonics has not been rejected because the empirical support for plate tectonics provided by confirmation of Vine-Matthews-Morley is so much stronger than what was available for continental drift. Moving plates, like evolving species, have become accepted as fact.

From Fred Vine:

> The advent of new and independent evidence suggestive of drift, from paleomagnetic studies, resuscitated the idea in the late fifties and sixties, and subsequently the post-war investment in marine geology and geophysics paid off in the form of providing compelling evidence for seafloor spreading and hence continental drift. By the late 1960s the vast majority of geologists and geophysicists were convinced that continental drift was a reality.

Sources

Modified from H. Frankel, "From Continental Drift to Plate Tectonics." *Nature* 335 (1988): 127–30.

Modified from F. V. Vine, "The Continental Drift Debate." *Nature* 266 (1977): 19–22.

Analysis of texts in this investigation

Text Name	Lexile Measure[1]	Common Core Stretch Grade Band[2]	Mean Sentence Length	Flesch Ease[3]
Wegener's continental-drift hypothesis	1330	9–10	22.85	35.3
Wegener's diagrams	930	4–5	12	4.3
Continental drift and fossil distribution	920	4–5	11.5	26.3
Response to Wegener's hypothesis	1060	6–8	17.19	56
Seafloor spreading	1310	9–10	20.78	36.9
Vine-Matthews-Morley hypothesis	1060	6–8	14.12	27.2
Acceptance of continental drift	1300	9–10	18.06	31.4

[1] 1 Lexile measure indicates the reading demand of the text in terms of its semantic difficulty and syntactic complexity. The Lexile scale generally ranges from 200L to 1700L. The Common Core emphasizes the role of text complexity in evaluating student readiness for college and careers.

[2] We are using the Common Core "stretch" grade bands. The Common Core Standards advocate a "staircase" of increasing text complexity so that students "stretch" to read a certain proportion of texts from the next higher text complexity band.

[3] In the Flesch Reading Ease test, higher scores indicate that the material is relatively easy to read while lower scores indicate greater difficulty. Scores in the 50–70 range should be easily understood by 13- to 15-year-olds, while those in the 0–30 range are appropriate for university graduates.