

C THEORETICAL MODELS: CONTINENTAL DRIFT

This is a lesson aimed at helping students to develop their understanding of the role of theoretical models in science.

Resources for students

Downloaded from www.nuffieldfoundation.org/aboutscience

OHT C0.1 Aims of the lesson

Teachers' sheet C1.1 Continental drift theory: historical background (2 sheets)

OHT C1.2 Explanations for the similarity of fossil distribution

OHT C1.3a/b A brief history of continental drift theories

Students' sheet C2.1a Polar wandering paths

OHT C2.2a Polar wandering paths (2 sheets)

Students' sheet C2.1b Mid-ocean ridges

OHT C2.2b Major ocean ridges

Students' sheet C2.1c Mid-ocean faults

OHT C2.2c Mid-ocean faults (2 sheets)

Students' sheet C2.2d Plate tectonic model

OHT C2.2d Plate tectonic model

Students' sheet C2.1e Paleomagnetic data

OHT C2.2e Paleomagnetic data (2 sheets)

Students' sheet C2.2f Eltanin survey ship: Magnetic data

OHT C2.2f Eltanin profile

Students' sheet C3.1 Summary sheet

Teachers' notes (separate download)

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C THEORETICAL MODELS: CONTINENTAL DRIFT**Aims of the lesson**

In this lesson you will have the chance to think about the following issues.

- 1** How scientists decide whether to accept a new theoretical model.
- 2** The link between theoretical models and experimental data.

C THEORETICAL MODELS: CONTINENTAL DRIFT

CONTINENTAL DRIFT THEORY: HISTORICAL BACKGROUND

1 Early suggestions

Although some early geologists suggested the possibility that the continents may not always have been in their current position, for the purpose of this task we will begin the story in the early part of the 20th century. At this time, the majority of geologists believed there was little horizontal movement of continents. There was compelling evidence of large vertical movements in the formation of mountains, but this was thought to be due to a gradual contraction of the Earth as it cooled as opposed to the current view that mountain chains are formed by tectonic plate collisions.

2 Frank Taylor's theory

In 1910 Frank Taylor published a theory of continental drift. He suggested that in the past the Earth had been spherical with massive continents at the poles. His theory was that these continents had been dragged apart by gravity when at some point in geological history the Earth captured its moon. The implausible catastrophic nature of the mechanism proposed by Taylor led his theory to be largely ignored.

3 Alfred Wegener's theory

Soon after in 1912 Alfred Wegener, a German meteorologist, proposed a more coherent theory of continental drift. He described the following evidence which he thought supported the idea of continental drift:

- the apparent match between the coastlines of South America and Africa;
- the presence of identical fossils on both continents;
- matching areas of rock strata on both continents.

4 Criticisms of Alfred Wegener's theory

There was considerable criticism of his theory. In brief the main criticisms were:

- the lack of a plausible mechanism to explain how the continents might move;
- alternative explanations for the fossil evidence in the form of land bridges, which have now sunk, or occasional migrations across oceans (see OHT C1.2).

C THEORETICAL MODELS: CONTINENTAL DRIFT**CONTINENTAL DRIFT THEORY: HISTORICAL BACKGROUND CONTINUED***5 Arthur Holmes's theory*

In 1944 Arthur Holmes, who was more convinced by continental drift than some, suggested a mechanism that could move continents. His idea was that convection currents circulating beneath the earth's crust caused the continents to drift. He also presented further evidence of drift. He showed that the location of glacial sediments in various equatorial continents fell within a polar ice cap if the continents were fitted back together into a super-continent.

The idea of continental drift was still seen as a competing theory to more established ideas, but one that explained some key problems. At this stage, it was thought that the continents pushed through the ocean sediments. However, if this were true, there would be evidence of these 'marks' on the ocean floor. No such evidence had been found.

6 Interpretation of new evidence

Throughout the 1950s there was a boom in oceanography. A great deal of data was gathered about the relatively unknown deep ocean floor. In the main this was led by American geophysical surveys as a fact-gathering exercise.

It was not influenced by attempts to support or refute theories of continental movement. In fact, most of the survey data came from groups who generally opposed continental drift. There was some debate between scientists, but in terms of advancement of either competing theory this was a dormant period.

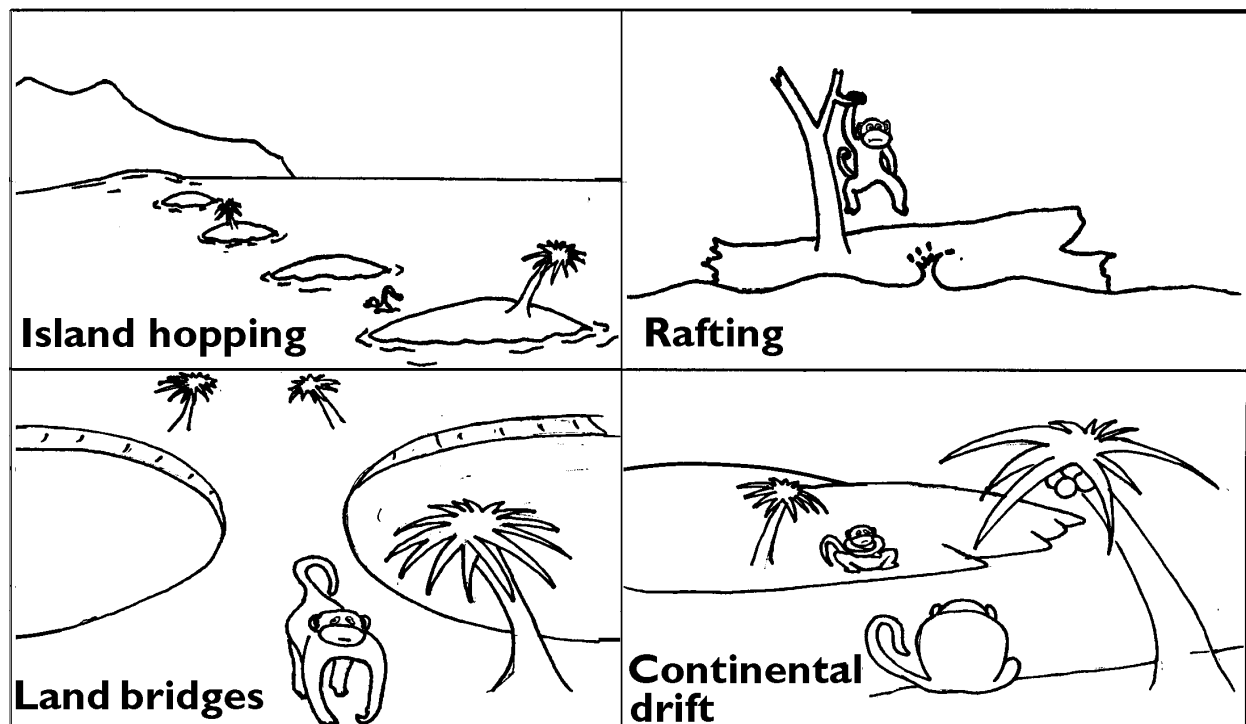
It was in the 1960s that evidence emerging from the new field of paleomagnetism began to be interpreted using continental drift. In doing so this evidence gave weight to the idea of drifting continents. It is this evidence that students are asked to present.

C THEORETICAL MODELS: CONTINENTAL DRIFT**Explanations for the similarity of fossil distribution**

Alfred Wegener argued that the similarity in the fossils of South America and Africa was evidence that the continents were once joined and had drifted apart.

Critics of Wegener suggested alternative explanations for the evidence that did not involve drifting continents.

These four pictures show alternative explanations: which do you think are plausible?



C THEORETICAL MODELS: CONTINENTAL DRIFT**A brief history of continental drift theories**

<1900 Some geologists have suggested the possibility of large-scale continental movement, but most hold the view that this is due to the contraction of the Earth.

1910 Frank Taylor publishes a theory of continental drift, but it is largely ignored because it involves an implausible mechanism.

1912 Alfred Wegener publishes a more coherent evidence-based theory of continental drift.

1912–40 Widespread criticism of Wegener's theory centred on:

- the lack of a plausible mechanism to explain how continents move;
- the lack of expected marks on the ocean floor if the continents had shifted apart;
- the existence of alternative explanations.

continued

C THEORETICAL MODELS: CONTINENTAL DRIFT**A brief history of continental drift theories** *continued*

1944 Arthur Holmes suggests a mechanism for continental drift based on convection currents in the Earth's mantle.

1950–60 There is a post-war boom in oceanography, particularly in America where there was a lot of opposition to continental drift. This generated a lot of new evidence about the ocean floor.

C THEORETICAL MODELS: CONTINENTAL DRIFT

POLAR WANDERING PATHS

Following the introduction by your teacher giving the background to the lesson, your task is to recreate the arguments of this period in the role of delegates at a scientific conference at which some new pieces of evidence are being presented.

Below are briefing notes describing the evidence you are to present to the conference. You will need to study this carefully so that you can present your evidence clearly. You are also provided with an overhead transparency that will help you to explain your evidence.

At the end of the ‘conference’ you will be asked to discuss how the body of evidence as a whole supports the model, if at all. You will need to listen carefully to the evidence from other delegates and ask questions if you do not understand it.

The Evidence

When igneous rocks form they cool from a molten magma until they solidify. As they do so, iron minerals in them become orientated in line with the Earth’s magnetic field.

Once the rocks are solid they do not change their orientation. The orientation they assume depends on the latitude at which they are formed.

In your research you have measured the orientation of these minerals in rocks of differing ages from the same location.

If both the continent and the magnetic pole haven’t moved, the magnetic orientations should be the same. **They are not.**

This means that:

A either the magnetic pole moves around far more than previously thought; B or the continents have drifted to their current positions over millions of years.

If we assume interpretation **A**, the map in figure 1 on OHT C2.2A shows the apparent position of the magnetic pole over time, according to the records shown in European rocks.

If it is the poles which have moved, the line should be the same for all continents. The data for rocks in several continents are shown in figure 2 on OHT C2.2A. **They are clearly different.**

This finding could be explained if it is the *continents* that moved, not the *poles*, and the continents moved in different directions (interpretation **B**).

End your presentation with a comment on:

a whether this piece of evidence alone would convince you that the continents have drifted;

b whether more evidence is needed before you would accept the theory of continental drift.

C THEORETICAL MODELS: CONTINENTAL DRIFT

POLAR WANDERING PATHS are derived from the orientation of magnetism in rocks. The magnetism of a rock indicates the relative direction of the poles from the location of the rock when it was formed.

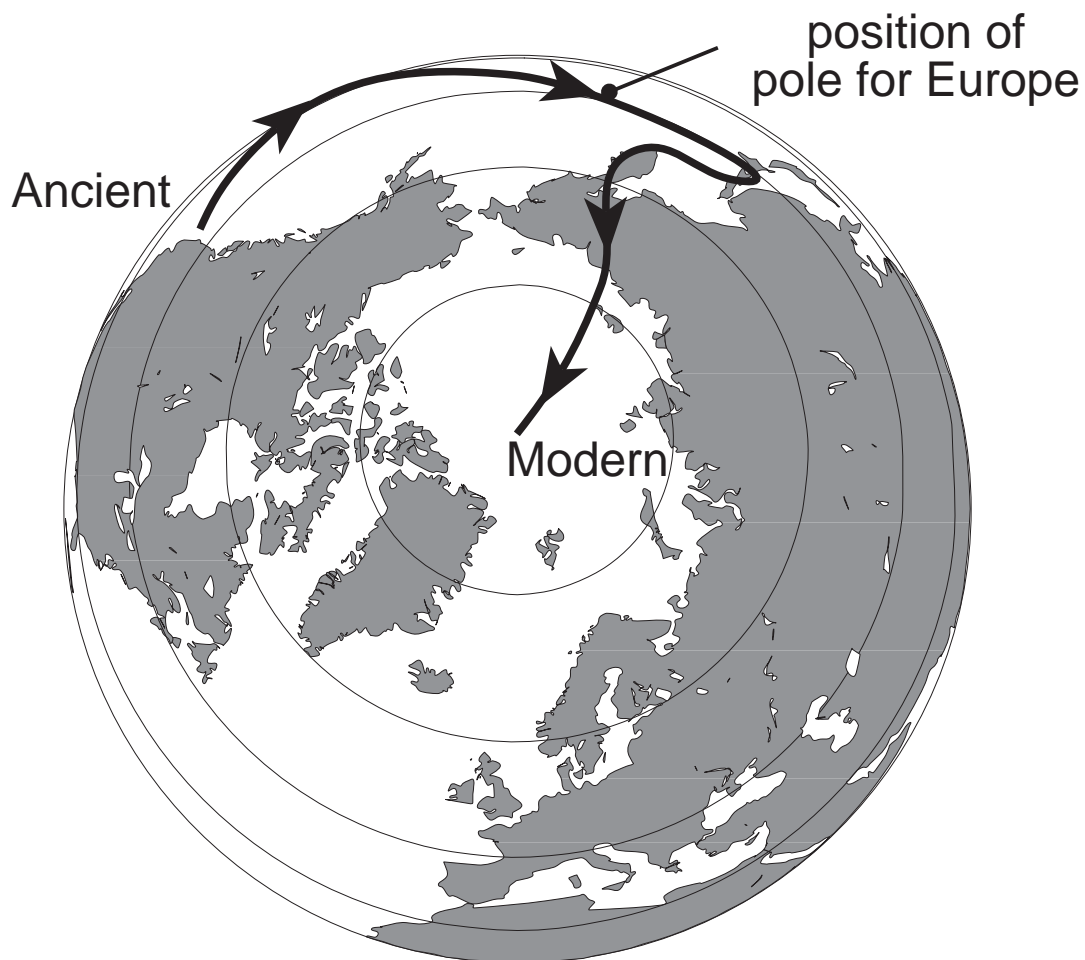


Figure 1

Polar wandering path for European rocks.

The path shows the positions of the magnetic pole assuming no continental drift occurred.

continued

C THEORETICAL MODELS: CONTINENTAL DRIFT

POLAR WANDERING PATHS are derived from the orientation of magnetism in rocks. The magnetism of a rock indicates the relative direction of the poles from the location of the rock when it was formed.

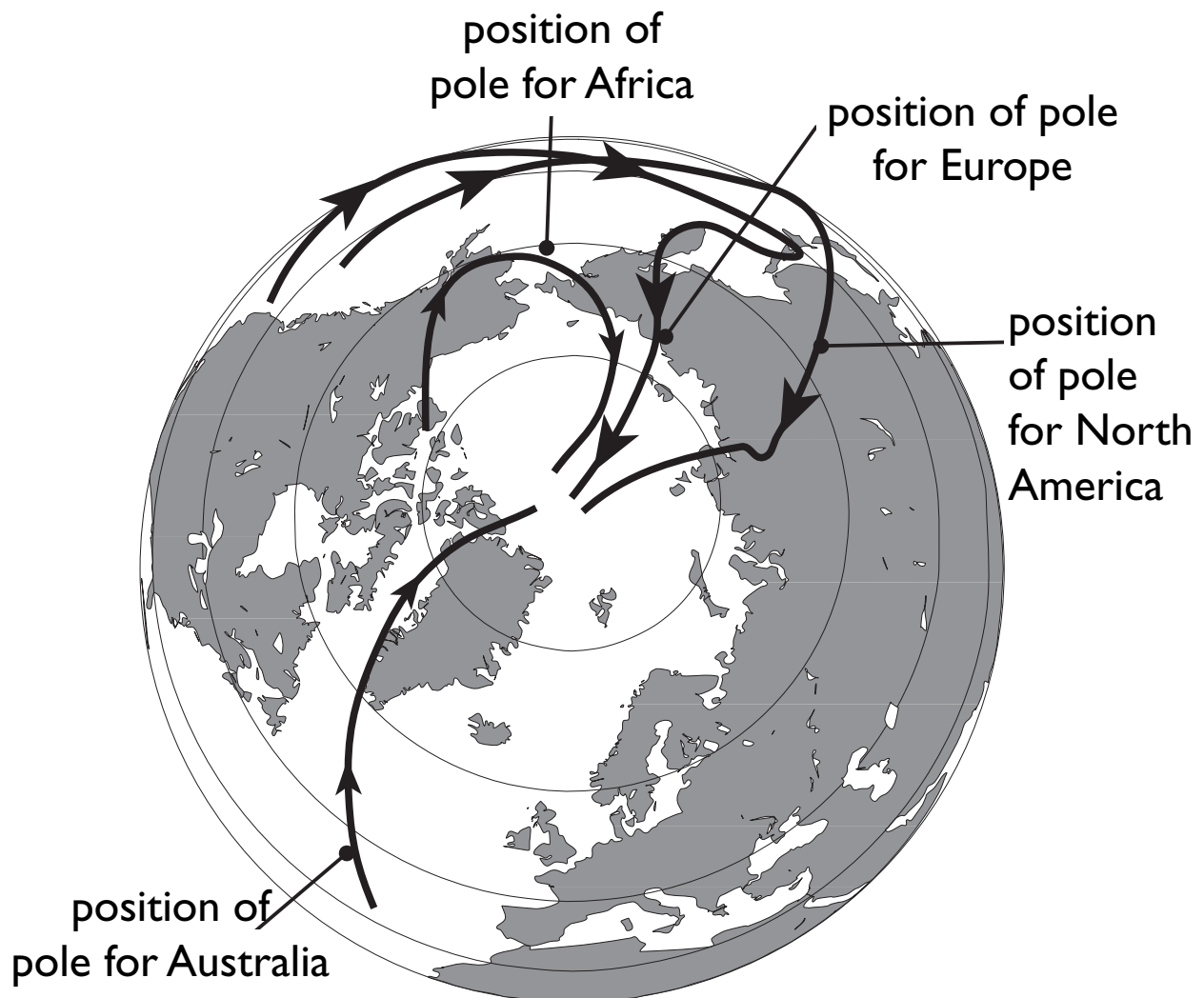


Figure 2
Polar wandering paths for rocks in several continents over the same period. Note the differences in the tracks. If the continents have not drifted we would expect these tracks to be the same.

C THEORETICAL MODELS: CONTINENTAL DRIFT

MID-OCEAN RIDGES

Following the introduction by your teacher which described the background to the lesson, your task is to recreate the arguments of this period in the role of delegates at a scientific conference at which a number of new pieces of evidence are being presented.

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The Evidence

Geophysical surveys over the last few years have given us a more detailed picture of the ocean floor. Your evidence comes from these surveys.

The surveys show the presence of a raised ridge along the **centre of many oceans** (figure 1 on OHT C2.2B).

In some places these have a **rift** (like a wide crack or fissure) along the centre of the ridge (figure 2 on OHT C2.2B).

The ridges are offset by large faults (figure 2 on OHT C2.2B) that indicate a high level of **activity in the crust along the ridges**.

How the pattern of these ridges is interpreted depends on whether continental drift is accepted. They **could** be explained if the sea floor is spreading from the centre, where new crust is being formed.

End your presentation with a comment on:

a whether this piece of evidence alone would convince you that the continents have drifted;

b whether more evidence is needed before you would accept the theory of continental drift.

C THEORETICAL MODELS: CONTINENTAL DRIFT

Figure 1 Positions of the major ocean ridges

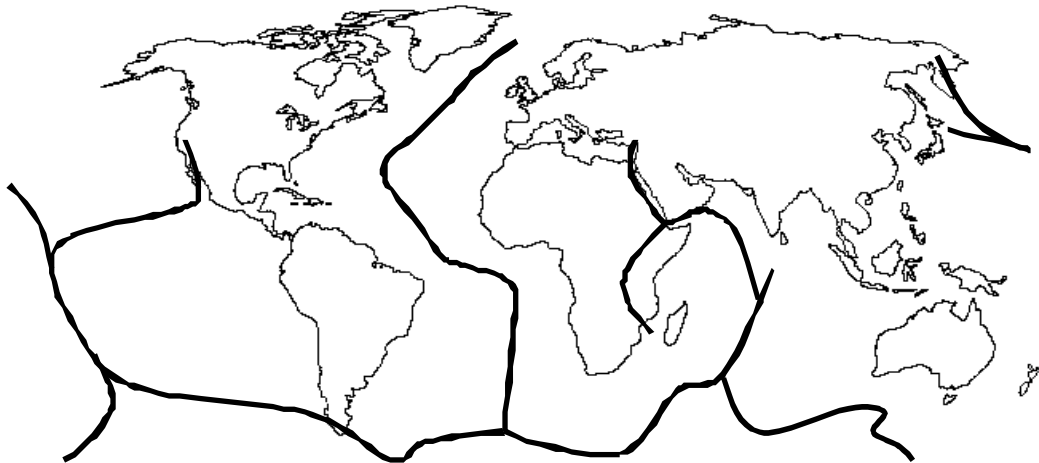
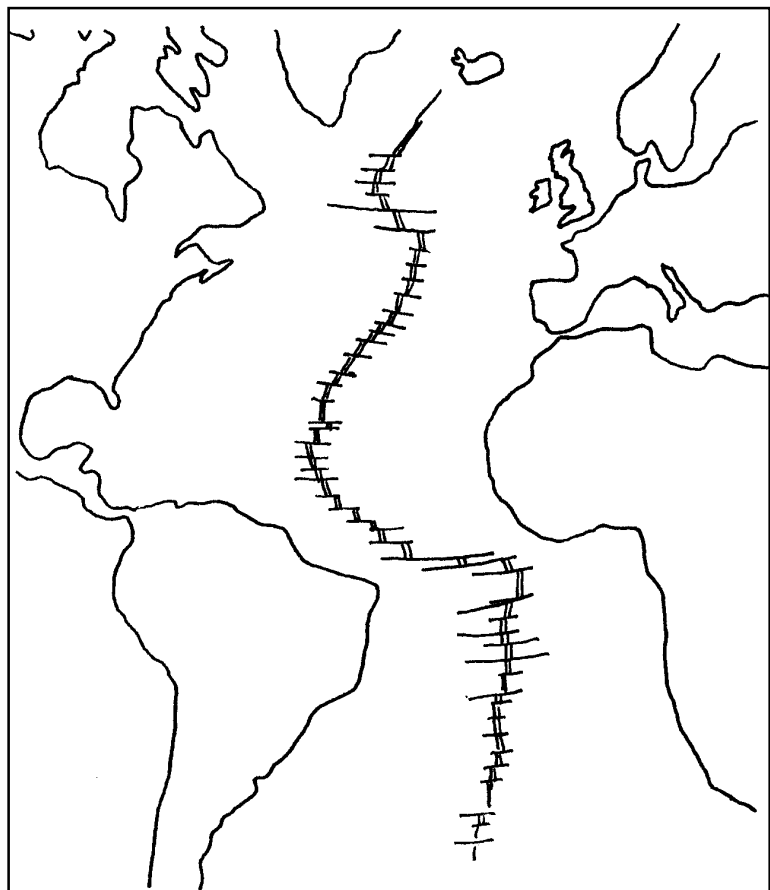


Figure 2
Map of the
Atlantic Ocean,
showing the central
rift and the large
faults displacing the
ridge.



C THEORETICAL MODELS: CONTINENTAL DRIFT

MID-OCEAN FAULTS

Following the introduction by your teacher which described the background to the lesson, your task is to recreate the arguments of this period in the role of delegates at a scientific conference at which a number of new pieces of evidence are being presented.

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The Evidence

The recently discovered ridges which run down the centres of many oceans are offset by large faults.

These **look like** transcurrent faults which form when the areas of rock move sideways past each other. See figure 1 on OHT C2.2c. The arrows indicate the direction the rocks would move in on either side of such a fault.

Your research project has used seismic surveys to determine the direction of movement along these faults. It is in the **opposite direction** to what was expected (figure 2 on OHT C2.2c).

This **could** be explained if the **ocean is spreading apart** from the centre of the ridge. See figure 2 on OHT C2.2c.

If this were the case it would also indicate that the continents move as well.

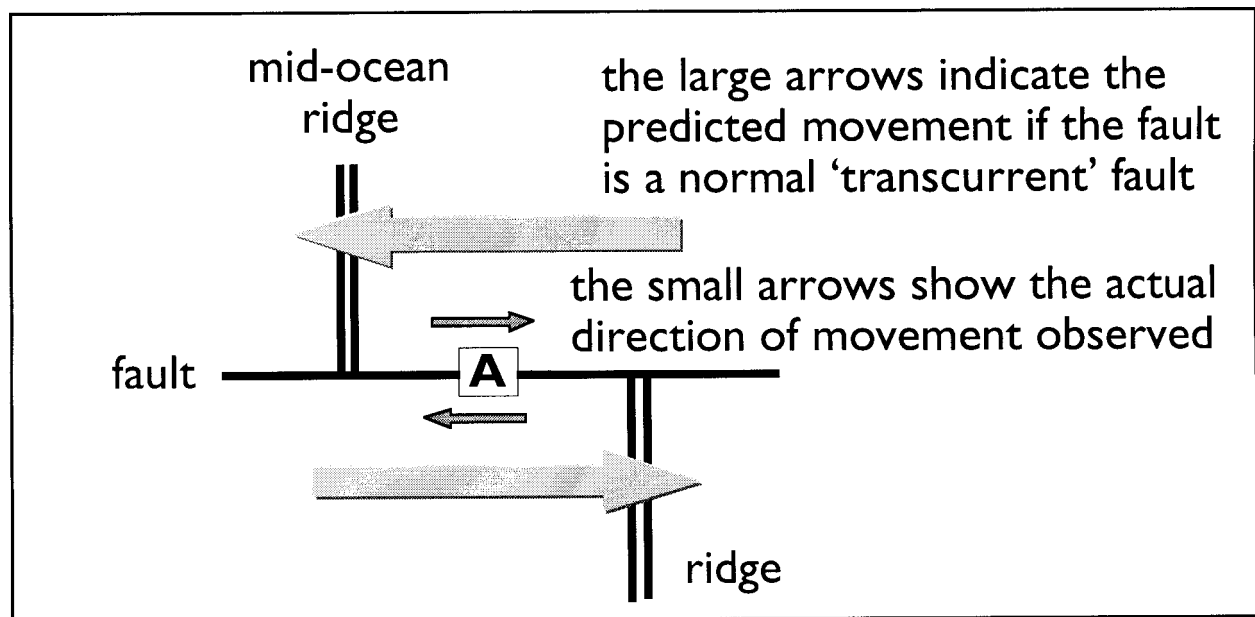
End your presentation with a comment on:

a whether this piece of evidence alone would convince you that the continents have drifted;

b whether more evidence is needed before you would accept the theory of continental drift.

C THEORETICAL MODELS: CONTINENTAL DRIFT**Mid-Ocean faults**

The diagram shows the movement along a normal fault. Note the direction of movement at A.

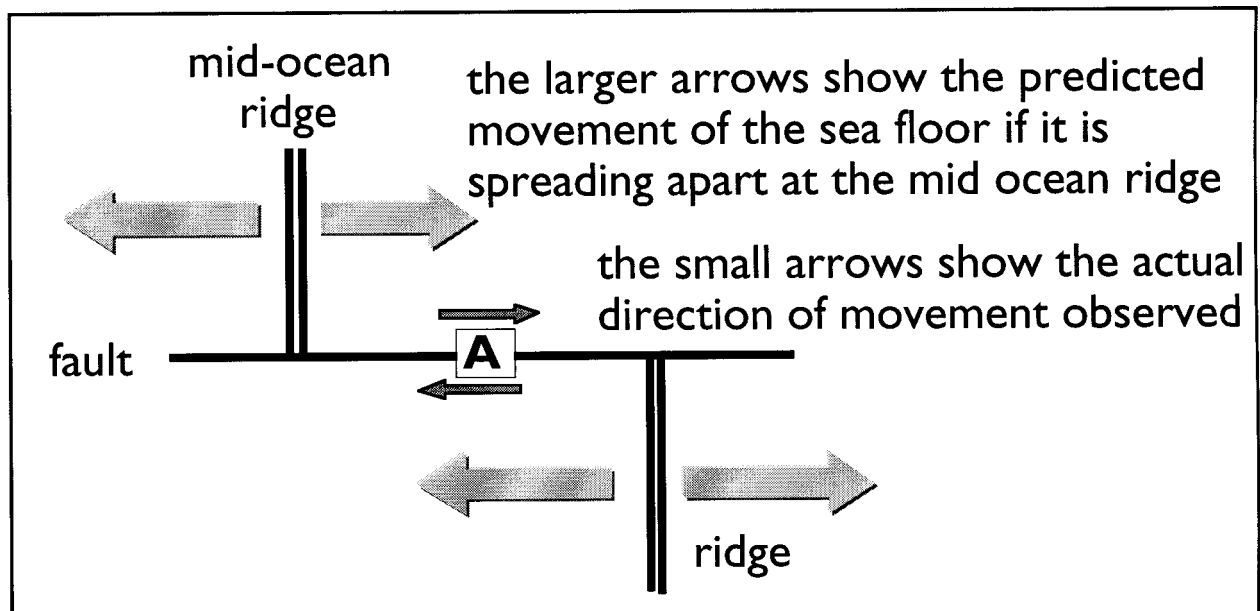


Seismic evidence shows the direction of movement at A is the reverse of that predicted.

continued

C THEORETICAL MODELS: CONTINENTAL DRIFT**Mid-Ocean faults** *continued*

This diagram shows how the actual directions of shear at A are explained if sea floor spreading is assumed.



C THEORETICAL MODELS: CONTINENTAL DRIFT

PLATE TECTONIC MODEL

Following the introduction by your teacher which described the background to the lesson, your task is to recreate the arguments of this period in the role of delegates at a scientific conference at which a number of new pieces of evidence are being presented.

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At the end of the 'conference' you will be asked to discuss how the body of evidence as a whole supports the model, if at all. You will need to listen carefully to the evidence from other delegates and ask questions if you do not understand it.

The Evidence

You have devised a model that you think explains how continents might drift. It is based on Arthur Holmes' idea that the movement is caused by convection currents below the crust.

The model is described in the first diagram on OHT C2.2c.

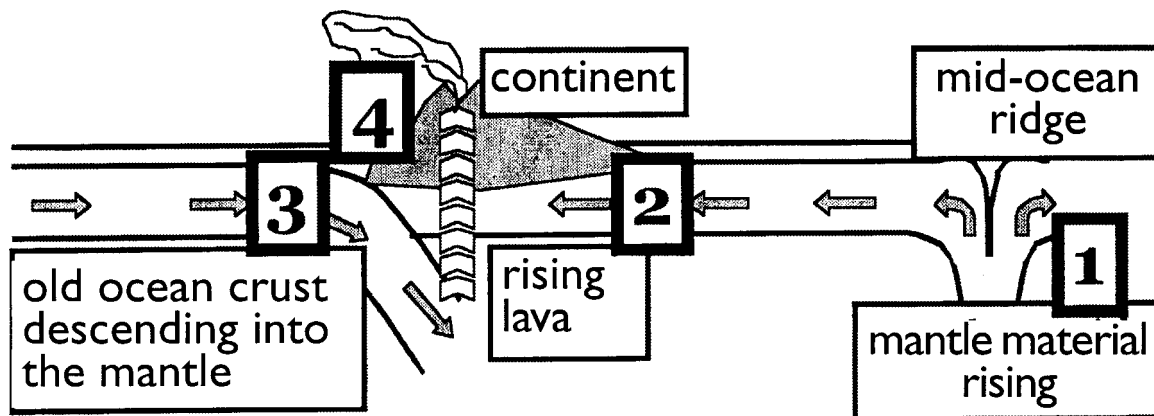
- 1** Material rises from the mantle at mid-ocean ridges, causing the sea floor to spread apart.
- 2** Continents are carried along on top of spreading oceanic crust.
- 3** When a continent collides with ocean crust spreading the opposite way, the ocean crust is forced back down into the mantle forming an ocean trench.
- 4** Where the continents meet crust spreading the opposite way, they are forced up into mountain ranges.

This model gives a **mechanism** that explains **how continental drift might occur**.

The model also shows that the continents do not have to plough through 'solid' oceanic crust. This has been a **criticism** of continental drift.

End your presentation with a comment on:

- a** whether this model alone would convince you that the continents have drifted;
- b** whether more evidence is needed before you would accept the theory of continental drift.

C THEORETICAL MODELS: CONTINENTAL DRIFT**A plate tectonic model**

1 Material rises from the mantle at mid-ocean ridges, causing the sea floor to spread apart.

2 Continents are carried along on top of spreading oceanic crust.

3 When a continent collides with ocean crust spreading the opposite way, the ocean crust is forced back down into the mantle forming an ocean trench.

4 Where the continents meet crust moving the opposite way, they are forced up into mountain ranges.

C THEORETICAL MODELS: CONTINENTAL DRIFT

PALEOMAGNETIC DATA

Following the introduction by your teacher which described the background to the lesson, your task is to recreate the arguments of this period in the role of delegates at a scientific conference at which a number of new pieces of evidence are being presented.

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The Evidence

Magnetic survey data shows the **pattern** of magnetic anomalies (differences in the direction and strength of magnetism) in the rocks of the ocean floor (OHT C2.2E, figure 1).

You have been impressed by the pattern of stripes that are **parallel to an ocean ridge**. They appear to be roughly symmetrical on either side of the ridge.

Your explanation of this **assumes** the idea of sea floor spreading.

You know that the Earth’s magnetic field has undergone periodic reversals through time. Figure 2 on OHT C2.2E shows the pattern of reversals over time shown in cores of sediment taken by other researchers.

Your interpretation of the patterns is that new rock forms at the ridge with its magnetism aligned to the Earth’s current field.

The **sea floor spreads apart** and more rock is formed at the centre of the ridge. When the earth’s magnetism reverses this is **recorded in the new rock as it spreads out from the ridge** (refer to OHT C2.2E figure 3 which shows how this might happen).

This theory explains the **apparent symmetry** in the bands on either side of the ridge (refer again to figure 1). There are similarities between the model in figure 3 and the data in figure 1.

End your presentation with a comment on:

a whether this piece of evidence alone would convince you that the continents have drifted;

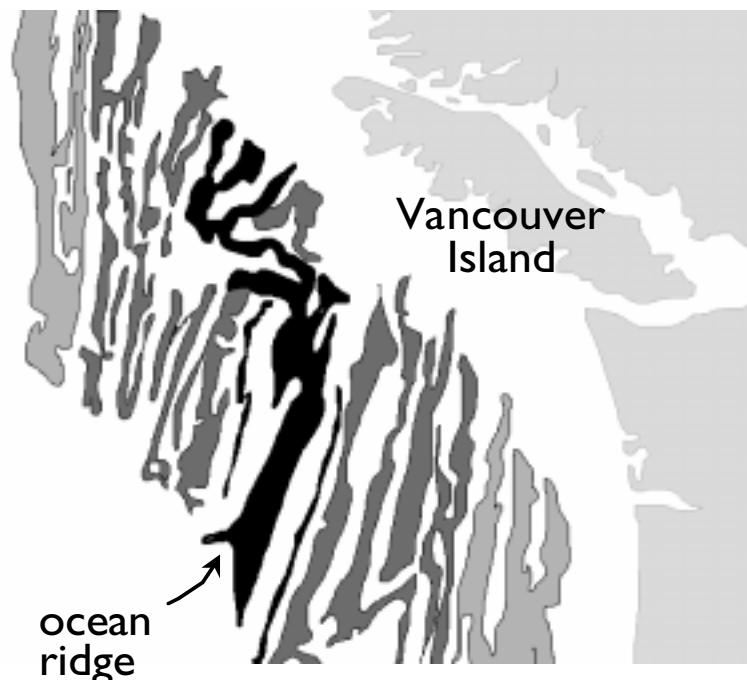
b whether more evidence is needed before you would accept the theory of continental drift.

C THEORETICAL MODELS: CONTINENTAL DRIFT**Paleomagnetic data**

The map shows an area of magnetic surveying off the coast of Vancouver Island. There is an ocean ridge through the centre of the data. This is marked on the map.

The bands show areas of contrasting direction of magnetism.

Figure 1



continued

C THEORETICAL MODELS: CONTINENTAL DRIFT

Paleomagnetic data

Figure 2 Here is a section of the magnetic polarity timetable for the last 3 million years.

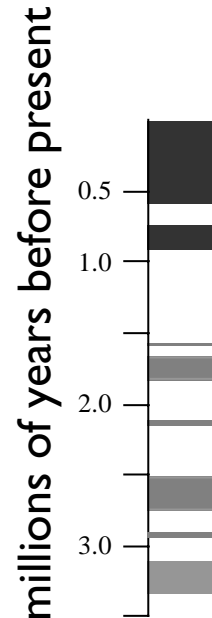
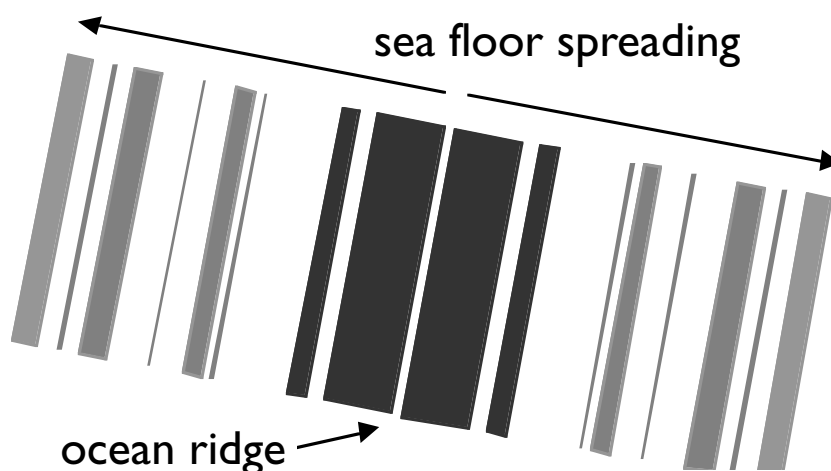


Figure 3 This diagram shows how the pattern of anomalies can be explained by sea floor spreading from a central ridge.



C THEORETICAL MODELS: CONTINENTAL DRIFT

ELTANIN SURVEY SHIP: MAGNETIC DATA

Following the introduction by your teacher which described the background to the lesson, your task is to recreate the arguments of this period in the role of delegates at a scientific conference at which a number of new pieces of evidence are being presented.

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The Evidence

You have been studying data on the pattern of magnetic anomalies gathered by a survey ship in the East Pacific.

The survey has collected data in **a profile across an ocean ridge**.

You have plotted the data as a profile of magnetic anomalies (top of OHT C2.2F). There is a very clear **symmetrical pattern either side of the ridge**.

You are aware of other research, which has linked these profiles to reversals of the earth's magnetic field.

Assuming the sea floor to be spreading, you have calculated the theoretical profile that would result from:

- a** the **known** pattern of reversals taken from cores of sediments;
- b** an **assumed rate of sea floor spreading**.

The theoretical profile is plotted at the bottom of OHT C2.2F.

You are impressed by the **similarity of the actual profile and the theoretical profile**. (You can demonstrate this by over laying the theoretical profile on top of the actual profile to show the match.)

End your presentation with a comment on:

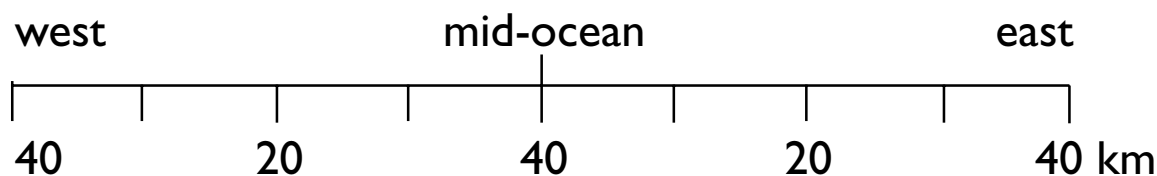
a whether this piece of evidence alone would convince you that the continents have drifted;

b whether more evidence is needed before you would accept the theory of continental drift.

C THEORETICAL MODELS: CONTINENTAL DRIFT

Eltanin profile

The profile shows the strength of magnetism across an ocean ridge in the East Pacific. The ridge is at the centre.



This is the theoretical profile calculated on the assumption of constant sea floor spreading and based on the expected pattern of reversals shown below it.

C THEORETICAL MODELS: CONTINENTAL DRIFT**Summary sheet**

Wegener's original theory was correct but not many people realised it at the time.

Some scientists were not convinced by continental drift because they did not agree with the interpretation their colleagues gave of the evidence.

Some scientists reacted against continental drift because it was a different way of thinking about geology.

American oceanographers spent a lot of time in the 1950s trying to prove that the plate tectonic theory was wrong.

American oceanographers collected data on the ocean floor to find out more about an unknown part of the world. They were not particularly interested in finding out if continental drift was correct.

A single compelling piece of evidence convinced most scientists that plate tectonic theory was correct.

A mechanism that explains what could cause continents to move was needed to convince scientists of the theory.

Most scientists eventually accepted continental drift because the theory was able to explain a number of surprising observations.