

## TECTONIC PLATES RESEARCH PACK

### Pack A

#### Basic information

- The scientist Alfred Wegener thought that all the land on Earth was once grouped together into one big mass, which he called Pangaea.
- He thought Pangaea had split up to form Earth's continents. These continents then drifted apart.
- He first suggested his 'Continental Drift' theory in 1912, and published a book about it in 1915.
- Wegener had no idea exactly *how* the continents could have moved.
- Most scientists at the time did not accept the Continental Drift theory. They thought it must be impossible for land to move from one place to another.
- There was some evidence for Wegener's theory:
  - Some fossils found in Europe were the same as fossils found in North America. This suggested that the two lands had once been joined together (how else could the animals have travelled such a long distance?).
  - The coastlines of Africa and South America seem to fit together like a jigsaw.
  - The same types of rocks were found in Africa and South America.
  - Coal is generally formed in tropical areas, but there is coal near the north pole.
- Other scientists thought that animals might have travelled between continents on 'land bridges', which later sank into the sea.
- They thought the 'fit' of the coastlines was coincidence.
- We now have a 'global positioning system' (GPS) using space satellites. This can actually measure the very slow movement of the continents, so now we know that continental drift *does* happen.

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#### SOURCE 1: The Ever-Changing Earth

from Pollard, J. and Schmit A., **WJEC Science**, Hodder Education, 2011

Scientists now know that the surface of the Earth, or lithosphere, is made up of seven large plates and some smaller ones, about 70 km thick, which move a few centimetres per year. This movement is called continental drift.

The idea of continental drift was put forward by Alfred Wegener (1880 – 1930), and the problems he had in getting his ideas accepted is a good example of how science works.

The continents of the Earth roughly fit together like a jigsaw. The coastlines of western Africa and eastern South America are a particularly good fit (see Fig 13.3).

To explain this, some people had suggested that the continents may have moved, but there was no clear evidence for this apart from the 'jigsaw fit'. Geologists in the 19th century actually did believe that continents had moved, but only up and down, not from side to side, as the Earth's surface cooled and contracted (there wasn't any evidence for that, either).

Alfred Wegener looked for evidence of continental drift, and found some:

- Rock formations on both sides of the Atlantic ocean are exactly the same.
- Similar or identical animal and plant fossils are found in areas now widely separated by oceans, e.g. a snail fossil has been found in Sweden, and also in Newfoundland in Canada, and there is no way a snail could swim the Atlantic!
- Certain fossils seemed to be in the 'wrong place' e.g. fossil remains of semi-tropical species in Northern Norway.

However, there was a weakness in Wegener's theory of continental drift. There was no known mechanism by which continents could plough their way through the Earth's crust without leaving any sort of 'trail'.

Wegener's model was not accepted at the time, and geologists proposed an alternative model to explain the strange distribution of fossils. They suggested that at some stage, 'land bridge' had existed between continents, so that animals and plants could move along them from one continent to another. These land bridges then disappeared (apparently without trace), leaving the continents isolated.

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## SOURCE 2: Wegener's theory

From:

[http://www.bbc.co.uk/schools/gcsebitesize/science/21c/earth\\_and\\_space/continentaldriftrev1.shtml](http://www.bbc.co.uk/schools/gcsebitesize/science/21c/earth_and_space/continentaldriftrev1.shtml)

Alfred Wegener proposed the theory of continental drift at the beginning of the 20th century. His idea was that the Earth's continents were once joined together, but gradually moved apart over millions of years. It offered an explanation of the existence of similar fossils and rocks on continents that are far apart from each other. But it took a long time for the idea to become accepted by other scientists.

## Before Wegener

Before Wegener developed his theory, it was thought that mountains formed because the Earth was cooling down, and in doing so contracted. This was believed to form wrinkles, or mountains, in the Earth's crust. If the idea was correct, however, mountains would be spread evenly over the Earth's surface. We know this is not the case.

Wegener suggested that mountains were formed when the edge of a drifting continent collided with another, causing it to crumple and fold. For example, the Himalayas were formed when India came into contact with Asia.

Wegener's evidence for continental drift was that:

- the same types of fossilised animals and plants are found in South America and Africa
- the shape of the east coast of South America fits the west coast of Africa, like pieces in a jigsaw puzzle
- matching rock formations and mountain chains are found in South America and Africa

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### SOURCE 3: Wegener and Continental Drift Theory

From: <http://www.scientus.org/Wegener-Continental-Drift.html>

Alfred Wegener was the scientist who championed the Continental Drift Theory through the first few decades of the twentieth century. Simply put, his hypothesis proposed that the continents had once been joined, and over time had drifted apart. The jigsaw fit that the continents make with each other can be seen by looking at any world map.

### Wegener and his Critics

The reactions by the leading authorities in the different disciplines was so strong and so negative that serious discussion of the concept stopped. The world had to wait until the 1960's for a wide discussion of the Continental Drift Theory to be restarted.

Why did Alfred Wegener's work produce such a reaction? Wegener did not even present Continental Drift as a proven theory. These modest goals did not spare him. One of Alfred Wegener's critics, the geologist R. Thomas Chamberlain, said :

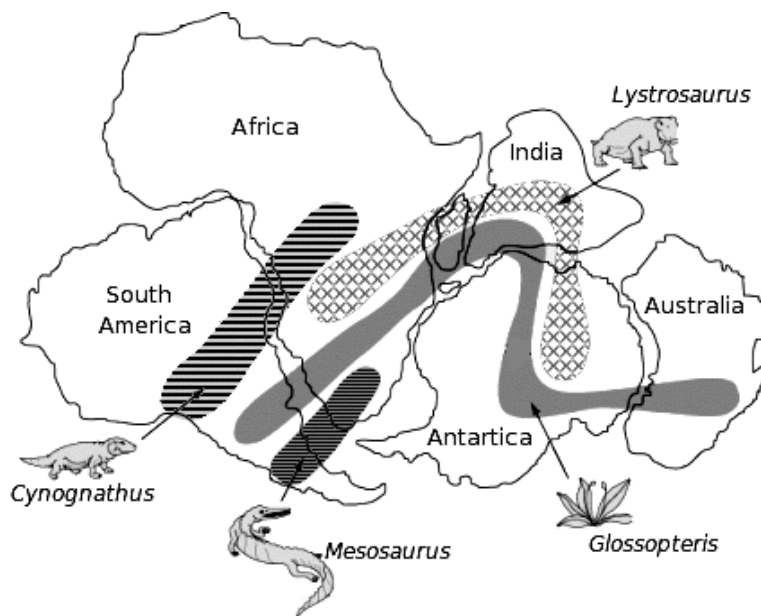
*"If we are to believe in Wegener's hypothesis we must forget everything which has been learned in the past 70 years and start all over again."*

He was right.

### Continental Drift Theory: Building the Case

In spite of the criticisms Wegener was able to keep Continental Drift part of the discussion until his death. He knew that any argument based simply on the jigsaw fit of the continents could easily be explained away as a coincidence. Wegener questioned why coal deposits, commonly associated with tropical climates, would be found near the North Pole and why the plains of Africa would show evidence of glaciation. Wegener also presented examples where fossils of exactly the same prehistoric species were distributed where you would expect them to be if there had been Continental Drift (e.g. one species occurred in western Africa and South America, and another in Antarctica, India and central Africa). The graphic below shows the striking distribution of fossils on the different continents.

Wegener also demonstrated an uncanny match of geology between eastern South America and western Africa.



### Continental Drift Theory: The Fatal Flaw

One would expect some scientists to resist ideas that would invalidate their life's work. But it doesn't explain all criticism of Wegener's ideas. Wegener presented very compelling arguments for Continental Drift but there were alternate explanations for some of his observations. To explain the unusual distribution of fossils in the Southern Hemisphere some scientists proposed there may once have been a network of land bridges between the different continents. To explain the existence of fossils of temperate species being found in arctic regions, the existence of warm water currents was proposed. Modern scientists would look at these explanations as

even less credible than those proposed by Wegener, but they did help to preserve the steady state theory.

New theories do not always arrive with all the t's crossed and i's dotted. Wegener did not have an explanation for how continental drift could have occurred. He proposed two different mechanisms for this drift, one based on the centrifugal force caused by the rotation of the earth and a 'tidal argument' based on the tidal attraction of the sun and the moon. These explanations could easily be proven inadequate and opened Wegener to ridicule because they were orders of magnitude too weak. Wegener really did not believe that he had the explanation for the mechanism, but that this should not stop discussion of a hypothesis. The scientists of the time disagreed.

The theory of plate tectonics is now well-established. Continental drift is happening as tectonic plates move, with earthquakes and volcanoes often occurring around their edges.

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#### **SOURCE 4: Later developments**

From: <http://scign.jpl.nasa.gov/learn/plate2.htm>

Paleomagnetic studies, which examine the Earth's past magnetic field, showed that the magnetic north pole seemingly wandered all over the globe. This meant that either the plates were moving, or else the north pole was. Since the north pole is essentially fixed, except during periods of magnetic reversals, this piece of evidence strongly supports the idea of plate tectonics.

Following World War II, even more evidence was uncovered which supports the theory of plate tectonics. In the 1960's a world-wide array of seismometers were installed to monitor nuclear testing, and these instruments revealed a startling geological phenomenon. It showed that earthquakes, volcanoes, and other active geologic features for the most part aligned along distinct belts around the world, and those belts defined the edges of tectonic plates.

These were some of the final pieces of the puzzle that led to the development of modern plate tectonic theory. Since its emergence in the 1960's, plate tectonic theory has gained wide-spread acceptance as the model of Earth processes.

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#### **SOURCE 5: Alfred Wegener and Plate Tectonics**

Adapted from: [http://www.indiana.edu/~geol105/images/gaia\\_chapter\\_3/wegener.htm](http://www.indiana.edu/~geol105/images/gaia_chapter_3/wegener.htm)

Close examination of a globe often results in the observation that most of the continents seem to fit together like a puzzle: the West African coastline seems to snuggle nicely into the east coast of South America and the Caribbean sea; and a similar fit appears across the Pacific. The fit is even more striking when the submerged continental shelves are compared rather than the coastlines.

In 1912 Alfred Wegener (1880-1930) noticed the same thing and proposed that the continents were once compressed into a single protocontinent which he called Pangaea (meaning "all lands"), and over time they have drifted apart into their current distribution. He believed that Pangaea was intact until the late Carboniferous period, about 300 million years ago, when it began to break up and drift apart. However, Wegener's hypothesis lacked a geological mechanism to explain how the continents could drift across the earth's surface as he proposed.

Searching for evidence to further develop his theory of continental drift, Wegener came across a paleontological paper suggesting that a land bridge had once connected Africa with Brazil. This proposed land bridge was an attempt to explain the well-known paleontological observation that the same fossilized plants and animals from the same time period were found in South America and Africa. The same was true for fossils found in Europe and North America, and Madagascar and India. Many of these organisms could not have travelled across the vast oceans that currently exist. Wegener's drift theory seemed more plausible than land bridges connecting all of the continents. But that in itself was not enough to support his idea. Another observation favouring continental drift was the presence of evidence for continental glaciation in the Pennsylvanian period. Lines called 'striae' left by the scraping of glaciers over the land surface indicated that Africa and South America had been close together at the time of this ancient ice age. The same scraping patterns can be found along the coasts of South America and South Africa.

Wegener's drift hypothesis also provided an alternate explanation for the formation of mountains (orogenesis). The theory being discussed during his time was the "Contraction theory" which suggested that the planet was once a molten ball and in the process of cooling the surface cracked and folded up on itself. The big problem with this idea was that all mountain ranges should be approximately the same age, and this was known not to be true. Wegener's explanation was that as the continents moved, the leading edge of the continent would encounter resistance and thus compress and fold upwards forming mountains near the leading edges of the drifting continents. The Sierra Nevada mountains on the Pacific coast of North America and the Andes on the coast of South America were cited. Wegener also suggested that India drifted northward into the Asian continent thus forming the Himalayas.

Wegener's inability to provide an adequate explanation of the forces responsible for continental drift and the prevailing belief that the earth was solid and immovable resulted in the scientific dismissal of his theories.