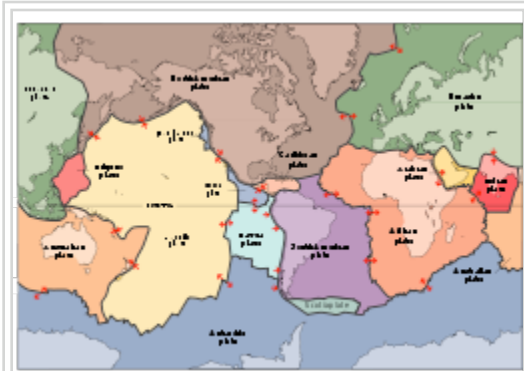


# Continental drift

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**Continental drift** is the movement of the Earth's continents relative to each other. The hypothesis that continents 'drift' was first put forward by Abraham Ortelius in 1596 and was fully developed by Alfred Wegener in 1912. However, it was not until the development of the theory of plate tectonics in the 1960s, that a sufficient geological explanation of that movement was understood. (This article gives an overview about the development of the continental drift hypothesis before 1950. For the contemporary theory, see the article plate tectonics.)



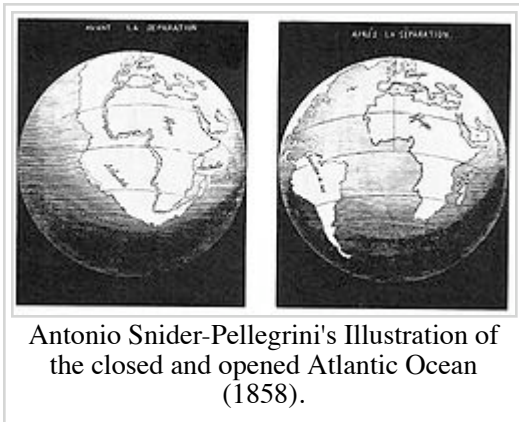
Plates in the crust of the earth, according to the plate tectonics theory

## Contents

- 1 History
  - 1.1 Early history
  - 1.2 Wegener and his predecessors
  - 1.3 Controversial years
- 2 Evidence
- 3 The debate
- 4 Notes
- 5 References
- 6 External links

## History

### Early history



In the 11th century, the Persian geologist, Abū Rayhān Bīrūnī (973-1048), observed the geology of India and discovered that the Indian subcontinent was once a sea and later became land. He attributed this the drifting of alluvium rather than continental drift.<sup>[1]</sup>

Abraham Ortelius (1596), Francis Bacon (1620), Benjamin Franklin, Antonio Snider-Pellegrini (1858), and others had noted earlier that the shapes of continents on opposite sides of the Atlantic Ocean (most notably, Africa and South America) seem to fit together. W. J. Kious described Ortelius' thoughts in this way:<sup>[2]</sup>

Abraham Ortelius in his work *Thesaurus Geographicus* ... suggested that the Americas were "torn away from Europe and Africa ... by earthquakes and floods" and went on to say: "The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three [continents]."

## Wegener and his predecessors

The hypothesis that the continents once formed a single landmass, broke up, and drifted to their present locations was fully formulated by Alfred Wegener in 1912.<sup>[3]</sup> Although Wegener's theory was formed independently and was more complete than those of his predecessors, Wegener later credited a number of past authors with similar ideas:<sup>[4]</sup><sup>[5]</sup> Franklin Coxworthy (between 1848 and 1890),<sup>[6]</sup> Roberto Mantovani (between 1889 and 1909), William Henry Pickering (1907)<sup>[7]</sup> and Frank Bursley Taylor (1908).

For example: the similarity of southern continent geological formations had led Roberto Mantovani to conjecture in 1889 and 1909 that all the continents had once been joined into a supercontinent (now known as Pangaea); Wegener noted the similarity of Mantovani's and his own maps of the former positions of the southern continents. Through volcanic activity due to thermal expansion this continent broke and the new continents drifted away from each other because of further expansion of the rip-zones, where now the oceans lie. This led Mantovani to propose an Expanding Earth theory which has since been shown to be incorrect.<sup>[8]</sup><sup>[9]</sup><sup>[10]</sup>

Some sort of continental drift without expansion was proposed by Frank Bursley Taylor, who suggested in 1908 (published in 1910) that the continents were dragged towards the equator by increased lunar gravity during the Cretaceous, thus forming the Himalayas and Alps on the southern faces. Wegener said that of all those theories, Taylor's, although not fully developed, had the most similarities to his own.<sup>[11]</sup>

Wegener was the first to use the phrase "continental drift" (1912, 1915)<sup>[3]</sup><sup>[4]</sup> (in German "die Verschiebung der Kontinente" - since Wegener presented and published in German, his ideas did not reach the majority of scientists until 1922, when his book was translated into English) and formally publish the hypothesis that the continents had somehow "drifted" apart. Although he presented much evidence for continental drift, he was unable to provide a convincing explanation for the physical processes which might have caused this drift. His suggestion that the continents had been pulled apart by

the centrifugal pseudoforce of the Earth's rotation was rejected as calculations showed that the force was not sufficient.<sup>[12]</sup>

## Controversial years

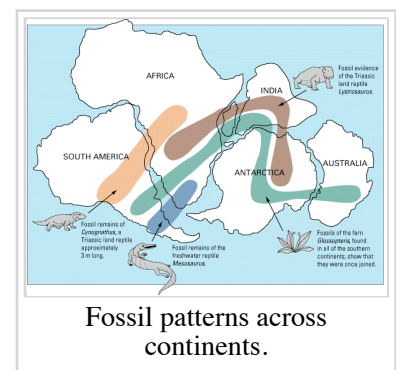
Wegener's hypothesis received support from South African geologist Alexander Du Toit as well as from Arthur Holmes, but was not generally supported due to the lack of a known driving force and the absence of other evidence. The possibility of continental drift gradually became accepted by the late 1950s; by the 1960s, geological research conducted by Robert S. Dietz, Bruce Heezen, and Harry Hess, along with a revision of the theory including a mechanism by J. Tuzo Wilson, led to widespread acceptance of the theory among geologists.

## Evidence

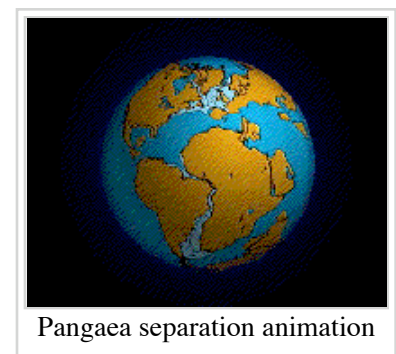
*For more details on this topic, see Plate tectonics.*

*Note: This section contains evidence available to Wegener's contemporaries and predecessors*

The notion that continents have not always been at their present positions was suggested as early as 1596 by the Dutch map maker Abraham Ortelius in the third edition of his work *Thesaurus Geographicus*. Ortelius suggested that the Americas, Eurasia and Africa were once joined and have since drifted apart "by earthquakes and floods", creating the modern Atlantic Ocean. For evidence, he wrote: "The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three continents." Francis Bacon commented on Ortelius' idea in 1620, as did Benjamin Franklin and Alexander von Humboldt in later centuries.



Evidence for continental drift is now extensive. Similar plant and animal fossils are found around different continent shores, suggesting that they were once joined. The fossils of the freshwater crocodile, found both in Brazil and South Africa, are one example; another is the discovery of fossils of the aquatic reptile *Lystrosaurus* from rocks of the same age from locations in South America, Africa, and Antarctica. There is also living evidence — the same animals being found on two continents. An example of this is a particular earthworm found in South America and South Africa.



The complementary arrangement of the facing sides of South America and Africa is obvious, but is a temporary coincidence. In millions of years, seafloor spreading, continental drift, and other forces of tectonophysics will further separate and rotate those two continents. It was this temporary feature which inspired Wegener to study what he defined as continental drift, although he did not live to see his hypothesis become generally accepted.

Widespread distribution of Permo-Carboniferous glacial sediments in South America, Africa, Madagascar, Arabia, India, Antarctica and Australia was one of the major pieces of evidence for the theory of continental drift. The continuity of glaciers, inferred from oriented glacial striations and deposits called tillites, suggested the existence of the supercontinent of Gondwana, which became a central element of the concept of continental drift. Striations indicated glacial flow away from the equator and toward the poles, in modern coordinates, and supported the idea that the southern continents had previously been in dramatically different locations, as well as contiguous with each other.

## The debate

Before geophysical evidence started accumulating after World War II, the idea of continental drift caused sharp disagreement among geologists. Wegener had introduced his theory in 1912 at a meeting of the German Geological Association. His paper was published that year and expanded into a book in 1915. In 1921 the Berlin Geological Society held a symposium on the theory. In 1922 Wegener's book was translated into English and then it received a wider audience. In 1923 the theory was discussed at conferences by Geological Society of France, the Geological Section of the British Association for the Advancement of Science, and the Royal Geological Society. The theory was carefully but critically reviewed in the journal *Nature* by Philip Lake.<sup>[13]</sup> On November 15, 1926, the American Association of Petroleum Geologists (AAPG) held a symposium at which the continental drift hypothesis was vigorously debated. The resulting papers were published in 1928 under the title *Theory of continental drift*. Wegener himself contributed a paper to this volume.<sup>[14]</sup>

One of the main problems with Wegener's theory was that he believed that the continents "plowed" through the rocks of the ocean basins. Most geologists did not believe that this could be possible. In fact, the biggest objection to Wegener was that he did not have an acceptable theory of the forces that *caused* the continents to drift. He also ignored counter-arguments and evidence contrary to his theory and seemed too willing to interpret ambiguous evidence as being favorable to his theory.<sup>[15]</sup> For their part, the geologists ignored Wegener's copious body of evidence as it contradicted their assumptions.

Plate tectonics, a modern update of the old ideas of Wegener about "plowing" continents, accommodates continental motion through the mechanism of seafloor spreading. New rock is created by volcanism at mid-ocean ridges and returned to the Earth's mantle at ocean trenches. Remarkably, in the 1928 AAPG volume, G. A. F. Molengraaf of the Delft Institute (now University) of Technology proposed a recognizable form of seafloor spreading in order to account for the opening of the Atlantic Ocean as well as the East Africa Rift. Arthur Holmes (an early supporter of Wegener) suggested that the movement of continents was the result of convection currents driven by the heat of the interior of the Earth, rather than the continents floating on the mantle. According to Carl Sagan,<sup>[16]</sup> it is more like the continents being carried on a conveyor belt than floating or drifting. The ideas of Molengraaf and of Holmes led to the theory of plate tectonics, which replaced the theory of continental drift, and became the accepted theory in the 1960s (based on data that started to accumulate in the late 1950s).

However, acceptance was gradual. Nowadays it is universally supported; but even in 1977 a textbook could write the relatively weak: "a poll of geologists now would probably show a substantial majority who favor the idea of drift" and devote a section to a serious consideration of the objections to the theory.<sup>[17]</sup>

## Notes

1. <sup>^</sup> A. Salam (1984), "Islam and Science", in C. H. Lai (1987), *Ideals and Realities: Selected Essays of Abdus Salam*, 2nd ed., World Scientific, Singapore, pp. 179-213:  
  

"But if you see the soil of India with your own eyes and meditate on its nature, if you consider the rounded stones found in earth however deeply you dig, stones that are huge near the mountains and where the rivers have a violent current: stones that are of smaller size at a greater distance from the mountains and where the streams flow more slowly: stones that appear pulverised in the shape of sand where the streams begin to stagnate near their mouths and near the sea—if you consider all this you can scarcely help thinking that India was once a sea, which by degrees has been filled up by the alluvium of the streams."
2. <sup>^</sup> Kious, W.J.; Tilling, R.I. [February 1996]. "Historical perspective", *This Dynamic Earth: the Story of Plate Tectonics*, Online edition, U.S. Geological Survey. ISBN 0160482208. Retrieved on 2008-01-29.
3. <sup>^</sup> <sup>a</sup> <sup>b</sup> Wegener, A. (1912), "Die Entstehung der Kontinente", *Peterm. Mitt.*: 185–195, 253–256, 305–309
4. <sup>^</sup> <sup>a</sup> <sup>b</sup> Wegener, A. (1929/1966), *The Origin of Continents and Oceans*, Courier Dover Publications, ISBN 0486617084
5. <sup>^</sup> Wegener, A. (1929), *Die Entstehung der Kontinente und Ozeane*, 4. Auflage, Braunschweig: Friedrich Vieweg & Sohn Akt. Ges.
6. <sup>^</sup> Coxworthy, F. (1848/1924), *Electrical Condition or How and Where our Earth was created*, London: W. J. S. Phillips
7. <sup>^</sup> Pickering, W.H (1907), "The Place of Origin of the Moon - The Volcani Problems", *Popular Astronomy*: 274–287
8. <sup>^</sup> Mantovani, R. (1889), "Les fractures de l'écorce terrestre et la théorie de Laplace", *Bull. Soc. Sc. Et Arts Réunion*: 41–53
9. <sup>^</sup> Mantovani, R. (1909), "L'Antarctide", *Je m'instruis. La science pour tous* **38**: 595–597
10. <sup>^</sup> Scalera, G. (2003), "Roberto Mantovani an Italian defender of the continental drift and planetary expansion", in Scalera, G. and Jacob, K.-H., *Why expanding Earth? – A book in honour of O.C. Hilgenberg*, Rome: Istituto Nazionale di Geofisica e Vulcanologia, pp. 71–74
11. <sup>^</sup> Taylor, F.B. (1910), "Bearing of the tertiary mountain belt on the origin of the earth's plan", *GSA Bulletin* **21** (2): 179-226, doi:10.1130/1052-5173(2005)015[29b:WTCCA]2.0.CO;2 Bearing of the tertiary mountain belt on the origin of the earth's plan]
12. <sup>^</sup> Plate Tectonics: The Rocky History of an Idea (<http://www.ucmp.berkeley.edu/geology/techist.html>)
13. <sup>^</sup> P. Lake, 'Wegener's Hypothesis of Continental Drift', *Nature* CXI, 1923a, pp. 226-228
14. <sup>^</sup> Friedlander, Michael W. (1995) *At the Fringes of Science*, pages 21-27, Westview, ISBN 0-8133-2200-6, 1998 edition with new epilog: ISBN 0-8133-9060-5
15. <sup>^</sup> William F. Williams, editor (2000) *Encyclopedia of Pseudoscience: From Alien Abductions to Zone Therapy* Facts on File p. 59 ISBN 0-8160-3351-X
16. <sup>^</sup> Sagan, Carl. (1997) *The Demon-Haunted World, Science As a Candle in the Dark*, Ballantine Books, ISBN 0-345-40946-9. 1996 hardback edition: Random House, ISBN 0-394-53512-X pp. 302-03
17. <sup>^</sup> Davis, Richard A. (1977) *Principles of Oceanography*, 2nd edition, Addison-Wesley, ISBN 0-201-01464-5

## References

- Le Grand, H. E. (1988). *Drifting Continents and Shifting Theories*. Cambridge University. ISBN 0-521-31105-5.

## External links

- A brief introduction to Plate Tectonics, based on the work of Alfred Wegener. ([http://www.ux1.eiu.edu/~cfjps/1300/cont\\_drift.html](http://www.ux1.eiu.edu/~cfjps/1300/cont_drift.html))

- Maps of continental drift, from the Precambrian to the future (<http://www.scotese.com/earth.htm>)
- Four main evidences of the Continental Drift theory (<http://kids.earth.nasa.gov/archive/pangaea/evidence.html>)
- Wegener and his proofs ([http://www.bbm.me.uk/portsdown/PH\\_061\\_History\\_b.htm](http://www.bbm.me.uk/portsdown/PH_061_History_b.htm))

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