

Antonio Snider-Pellegrini's Illustration of the closed and opened Atlantic Ocean (1858).

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.^[1]

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:^[2]

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.^[3] 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:^[4]^[5] Franklin Coxworthy (between 1848 and 1890),^[6] Roberto Mantovani (between 1889 and 1909), William Henry Pickering (1907)^[7] 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.^[8]^[9]^[10]

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.^[11]

Wegener was the first to use the phrase "continental drift" (1912, 1915)^[3]^[4] (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

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

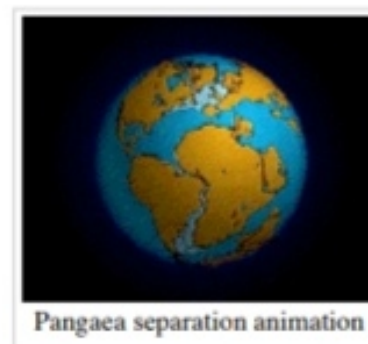
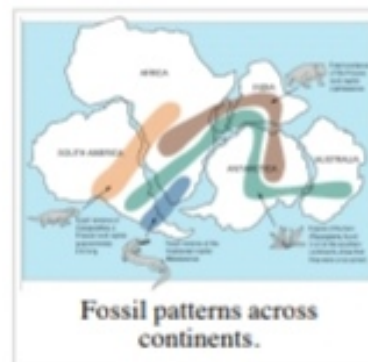
For more details on this topic, see Plate tectonics.

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.^[13] 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.^[14]

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.^[15] 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,^[16] 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.^[17]