Flipped from head to toe: 100 years of continental drift theory

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Exactly 100 years ago, on 6 January 1912, Alfred Wegener presented his theory of continental drift to the public for the first time. At a meeting of the Geological Association in Frankfurt's Senckenberg Museum, he revealed his thoughts on the supercontinent Pangaea, which broke apart and whose individual parts now drift across the earth as today's continents. In 1915, he published his book "The Origin of Continents and Oceans". Its third edition in 1922 was translated into the languages of the world and today is considered the foundation stone of plate tectonics.

Wegener's genius idea did not only find friends, because it had the main disadvantage that it lacked the engine to break apart the supercontinent and move huge continental masses over the Earth's surface. Indeed, only by the seismology of the 1950s and through scientific drilling in the oceans in the 1960s, the foundation for plate tectonics was laid – at the same time, however, Wegener's groundbreaking theory was turned upside down.

Seismological insights

Earthquakes are not only terrible natural disasters, they also offer a view inside the Earth. It was the geophysicists Wadati and Benioff, who in 1954 independently discovered the systematic arrangement of earthquakes in the places which we now know as plate boundaries. "More than 90% of the global seismic energy is released at the plate boundaries", says Professor Michael Weber, head seismologist at the German Research Centre for Geosciences GFZ. "We use these earthquakes for tomographic screening of the earth." With modern methods of scientific seismology it is even possible to reconstruct how quickly the continents moved. The speed record is held by India, which started to make its way from East Gondwana to Eurasia about 140 million years ago – at a speed of 20 centimeters per year.

Drilling into the ocean floor

The real breakthrough, however, came only when those findings were combined with the research results from the great ocean drilling programs of the sixties. Previously, using magnetic measurements of the ocean floor and topography of the seabed the mid-ocean ridges had been discovered, as well as a magnetic polarization of the rocks in parallel strips either side of mid-ocean ridges. Now, the obtained cores showed: No piece of the drilled ocean floor was older than 200 million years, and therefore decidedly younger than Wegener had assumed. Continental rocks, in contrast, can achieve an age of more than four billion years. Secondly, it could be shown that the ocean floor is very young in the immediate vicinity of the mid-ocean ridges. With increasing distance from these undersea mountains, the rocks exhibit an increase in age. Thirdly, the ocean floors below the top layer of sediment are entirely of magmatic origin. "These results could in fact only allow one interpretation. From the interior of the earth, hot, liquid rock rises to these ridges and pushes the ocean floor off to the side", explains Dr. Ulrich Harms, who at the GFZ directs the "Centre for Scientific Drilling". "Not the continents drift, but entire tectonic plates, which consist of continents , ocean floors, and parts of the upper mantle."

Ascending rocks and the engine of plate tectonics

All these findings in the second half of the sixties put Wegener's ingenious discoveries into a correct context, and also flipped his theory from the head to its feet: not only were his assumptions as to the age of oceans and continents completely reversed, the idea that the continents plow the ocean turns around so that continents and oceans move together as a common upper part of the lithospheric plates. The continents float on top as the lightest rocks, so to speak.

These tectonic plates move, collide, grind past each other or drift apart. All these processes are associated with earthquakes, which can thus be explained as part of the overall process. But what forces the heavy rock inside the earth to rise? The enormous heat inside the earth's core and mantle comes in one part from the formation of Earth, in another from the radioactive decay of elements in the mantle. The heated rock rises and induces the movement expressed on the surface as a displacement of the plates. We know this process today as plate tectonics, which the science magazine "New Scientist" places on an equal footing with the theory of evolution and the theory of relativity.

The quiet revolution in the theory of tectonics

The classical concept of tectonics as a quasi mechanical process of the movement and collision of rigid plates is now itself in disarray. "Recent findings show plate tectonics as a self-regulating system of interactions, in which all the subsystems of the planet earth are involved", explains Professor Onno Oncken. The Director of the Department "Geodynamics" at GFZ notes: "It is not a mechanical system, but rather complex feedback processes." The climate as example: high-altitude mountains have a decisive influence on the climate, of course. But that the climate in turn controls the tectonics, is a new discovery: the Andes, for example, are caused by the collision of the Nazca plate with South America. The humid climate of the South Andes leads to the erosion of material that ends up as sediment in the Pacific. The Nazca plate approaching from the west deposits this rock on the South American crust. The arid climate of the Northern and Central Andes, however, gives rise to no sediment, therefore the Nazca plate rasps off the continental crust here. The thus created great increase in friction in turn transmits a force that causes the Andean plateau to gain height and width. This in turn enhances the rain shadow on the west side of the Andes and additionally reduces erosion.

The classical notion of folded mountains as a result of a collision also had to be revised: "The Andes, for example, in their present form, exist for about 45 million years, the subduction of the Nazca plate beneath South America has been going on since the Paleozoic, so hundreds of millions of years longer," says Onno Oncken. Similarly, the interplay between the hot, rising rock masses and the Earth's crust is much more complex than originally thought. When a hot rock bubble rises, the poorly heat-conductive lithosphere acts as a boundary layer to the surface like a blanket, which in turn increases the temperature further below. This heat buildup can eventually soften whole continents like a welding torch until they dissolve, as it happened around 140 to 130 million years ago, when Gondwana fell apart first in the East, then in the West.

At that time Africa also separated from South America, but it was exactly the contours of these two continents that sparked Wegener's idea. Professor Oncken: "Wegener's approach was the starting point, the plate tectonics of the previous century was the revolution in geoscientific perception. Today we see an equally thorough, quiet revolution in the theory of [plate tectonics](), because we understand our planet increasingly as a complete system".

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