Wegener proposes idea of continental drift
1912

Ever since the continents were all mapped, people had noticed that many coastlines, like those of South America and Africa, looked as though they would fit together if they could be moved like puzzle pieces.

Alfred Wegener was one of those people. Though trained as an astronomer, he was a specialist on Greenland. He noticed that, based on nineteenth-century longitude determinations, it appeared that Greenland had moved a mile away from Europe in a hundred years. And Paris and Washington, D.C., seemed to be moving apart by about 15 feet each year while San Diego and Shanghai got about six feet closer. On top of that, Wegener learned that related species, too small to swim the oceans, were found on different continents, as were similar fossils.

In 1912 he proposed that the continents we know today were once all attached in a single landmass he called Pangaea (Greek for "all earth"). They were surrounded by one global ocean, but then broke apart and somehow "drifted" to their separate places on the globe. Although the calculations of Greenland's movement were found to be due to faulty determinations of longitude, the other evidence seemed to match up: the shape of the continents, fossil evidence, matching rock types and geologic structures, and evidence of ancient climate patterns. But Wegener could not come up with an acceptable way to explain how the continents moved.

Few people accepted Wegener's views in his day, but they became the center of heated debate. The year after Wegener died, Arthur Holmes published his idea that thermal convection in the earth's mantle could cause continents to move. Holmes also suggested that the continents didn't move but were "carried" by larger pieces of the earth's crust. The controversy quieted down and fell from prominence until the 1960s, when new evidence was brought to the fore. Discoveries of the Mid-Ocean Ridge and the work of Harry Hess and others led to the development of plate tectonics. Though not without problems, this theory has gained wide acceptance. It is the most complete theory of global dynamics yet, and its roots lie in the work of Alfred Wegener.

Arthur Holmes
1890 - 1965

Arthur Holmes began studying physics at the Imperial College of Science in London, but switched to geology before graduating in 1910. In 1913, before he even earned his doctoral degree, he proposed the first geological time scale, based on the fairly recently discovered phenomenon of radioactivity. Using his quantititive time scale and other factors, he made an estimate of Earth's age that was far older than anyone had suggested until then -- 4 billion years. His initial estimates of Earth's eras have held up remarkably well over time: For example, he placed the beginning of the Cambrian period at around 600 million years ago; today 590 million years is the time frame largely accepted.

Around 1930, Holmes suggested a mechanism that could explain Alfred Wegener's theory of continental drift: the power of convection. Currents of heat and thermal expansion in the Earth's mantle, he suggested, could force the continents toward or away from one another, creating new ocean floor and building mountain ranges (a theory later clarified by Harry Hess). Holmes was a widely respected geologist by then, but he was a few years too late to support Wegener (who died in 1930), and about 30 years too early to have hard data to back up his theory. He warned that his ideas were "purely speculative" and could "have no scientific value until they acquire support from independent evidence." Yet he had come very close to describing the modern view of Earth's plates and the dynamics between them.

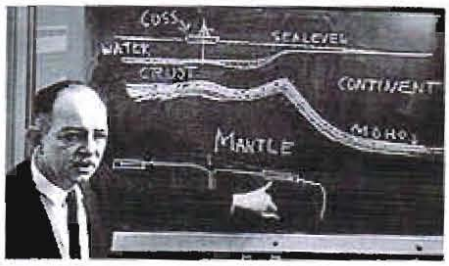
Holmes was professor of geology at the universities of Durham and Edinburgh until his death in 1965.

Great Global Rift is discovered
1953

After World War I, Germany was suffering from the weight of debt imposed by war reparations and a devastated economy. German chemist Fritz Haber had read reports of an analysis showing that 65 mg of gold could be extracted from a metric ton of sea water. Haber proposed extracting gold from international waters as a way to ease Germany's economic plight. This seemed like a good idea and it caught on, though another, more modern analysis showed that the gold concentration was far lower and changed the nature of the maritime venture. In 1925, Germany outfitted a boat and set out for two years to systematically and scientifically look at the oceans -- and to show the flag, since the Versailles Treaty had banned German navy boats from foreign ports. This expedition was the first use of closely spaced echo sounders to map deep sea topography and the first to reveal the extent of the sea floor's rugged terrain. The expedition also found that a continuous mountain-like ridge runs through the Atlantic to the southwest of Africa. Unfortunately it was not realized at the time that this finding supported Alfred Wegener's theory of continental drift.

That ridge, it was later discovered, extended through the major oceans of the world. It is now called the Mid-Ocean Ridge. In 1953, American physicists Maurice Ewing (1906-1974) and Bruce Heezen (1924-1977) discovered that through this underwater mountain range ran a deep canyon. In some places the canyon, called the Great Global Rift, came very close to land. The rift appeared to be breaks in the earth's crust, but perfectly fitted breaks, like joints made by a carpenter. The rift outlined chunks of the earth's crust, which were named tectonic (from a Greek word for "carpenter") plates. Six large and several smaller plates make up the surface of the globe. Most of the world's earthquakes and volcanoes occur at the plates' edges. The large plate containing most of the Pacific Rim accounts for 80 percent of the earthquake energy of the planet.

Ewing and Heezen's finding marked an explosion in data from newly advanced technology that revolutionized geology. Harry Hess was inspired by the findings to look back at soundings he'd made during the war on a U.S. submarine. His evidence and the work of Frederick Vine and Drummond Matthews brought the data together in the theory of sea-floor spreading.



Hess proposes sea-floor spreading
1960

Photo: Harry Hess argues that the continents had once been one, and have drifted apart.

With the discovery of plate tectonics and the mapping of the earth into about 12 plates, plus the understanding that plates' movement caused earthquakes, Alfred Wegener's idea of "continental drift" looked less ludicrous than his contemporaries had thought. There still seemed to be no way that continents could plow through the earth's surface on their own, but perhaps something else could explain how the land masses had once been joined.

Harry Hess was a geologist and Navy submarine commander during World War II. Part of his mission had been to study the deepest parts of the ocean floor. In 1946 he had discovered that hundreds of flat-topped mountains, perhaps sunken islands, shape the Pacific floor. The discovery of the Great Global Rift in the 1950s inspired him to look back at his data from years before. After much thought, he proposed in 1960 that the movement of the continents was a result of sea-floor spreading. In 1962, he added a geologic mechanism to account for Wegener's moving continents. It was possible, he said, that molten magma from beneath the earth's crust could ooze up between the plates in the Great Global Rift. As this hot magma cooled in the ocean water, it would expand and push the plates on either side of it -- North and South America to the west and Eurasia and Africa to the east. This way, the Atlantic Ocean would get wider but the coastlines of the landmasses would not change dramatically. (If, as Georges LeMaitre suggested for visualizing the early universe, you play the "film" of this phenomenon backwards, the continents come closer together until Brazil fits right into the Gulf of Guinea.)

Hess proved Wegener's basic idea right and clarifed the mechanism that broke the once-joined continents into the seven with which we are familiar. The continents are attached to the plates and do not move independently of them. But the plates themselves shift and change shape, carrying the continents along.

Magnetic bands provide evidence of sea-floor spreading
1963

In 1963, Fred Vine, Drummond Matthews, and others found that the crust surrounding the midocean ridges showed alternating bands -- each band magnetized with a polarity opposite the surrounding bands. They suggested that as new sea-floor crust was formed around the rift in the midocean ridge, it magnetized differently, depending upon the polarity of the planet at that time. This supported the theory that Harry Hess had put forth, that the ocean progressivley widens as new sea floor is created along a crack that follows the crest of midocean ridges.

In 1966, earth scientists first identified the Jaramillo Event, the wholesale reversal of Earth's magnetic fields some 900,000 years ago. This confirmed the theory that Earth's magnetic field had flip-flopped through the planet's life, and it made Matthews and Vine's 1963 finding quite clear. They realized that the pattern of reversals matched perfectly the magnetic profile they had compiled of the sea floor. This discovery, together with data from a 1964 research vessel, transformed the field of geology. It confirmed sea-floor spreading as hypothesized by Hess, and thus "continental drift," originally proposed by Alfred Wegener back in 1912. It convinced many that plate tectonics was the best theory to unify nearly all the previously accumulated, but disjoint geological data.
