THE GREAT EARTH DEBATE

An implausible theory evolves into a new view of earth history

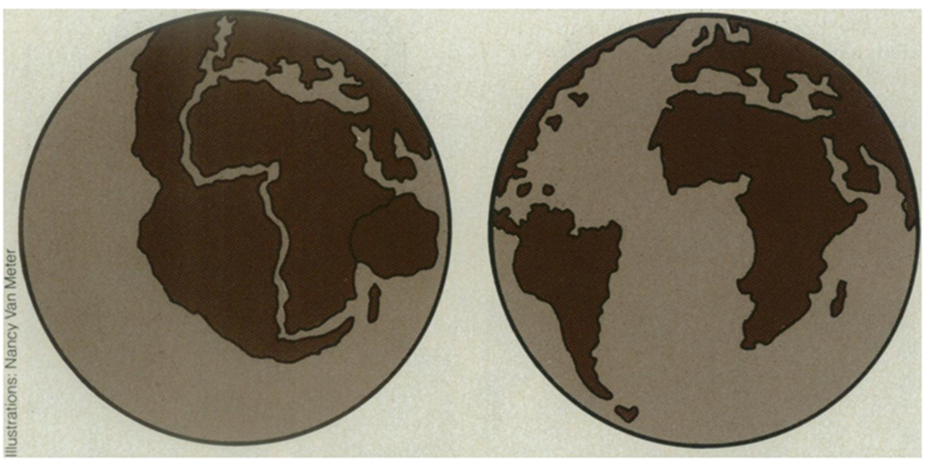
BY CHERYL SIMON

A session on biology of the southern oceans was of only passing interest to many geologists attending a meeting in Chile in 1966. But tacked onto its end was a late addition, a paper on magnetic reversals recorded in the oceanic crust. As James Heirtzler, then of Lamont Geological Observatory, flashed a slide up onto the screen, the black and white stripes of the magnetic profile sent waves of recognition coursing through the crowd.

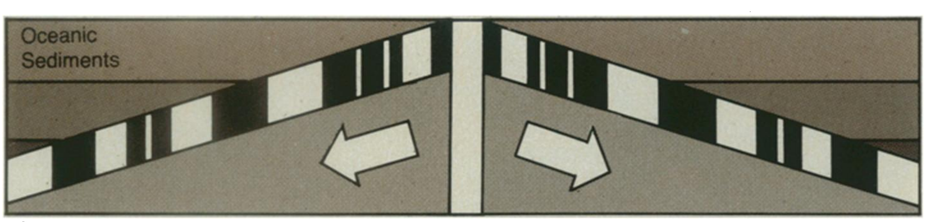
"I went crazy. The magnetic anomalies were so amazing, so powerful," recalls Tanya Atwater, now a professor at the University of California at Santa Barbara. "It's so symmetrical, and it has the magnetic time scale in it so perfectly, it turns you into a believer."

It was the first time that Atwater had seen compelling evidence that the seafloor is spreading. When the same data were presented at similar scientific gatherings near that time, scientists all over the world echoed her excitement.

It was more than fifty years since a German meteorologist named Alfred Wegener argued that the continents are in motion, plowing horizontally through the denser basaltic material that forms the seafloor.



About 200 million years ago, the continents may have been fused into a universal land mass called Pangea. For centuries, observers had noted the conspicuous fit of the contours of the continents, especially those in the Southern Hemisphere. It was not proved until the 1960s, however, that the continents move. About 180 million years ago the northern continent, named Laurasia, split off from the southern land mass, known as Gondwana. The world as it looks today was produced in the last 65 million years.



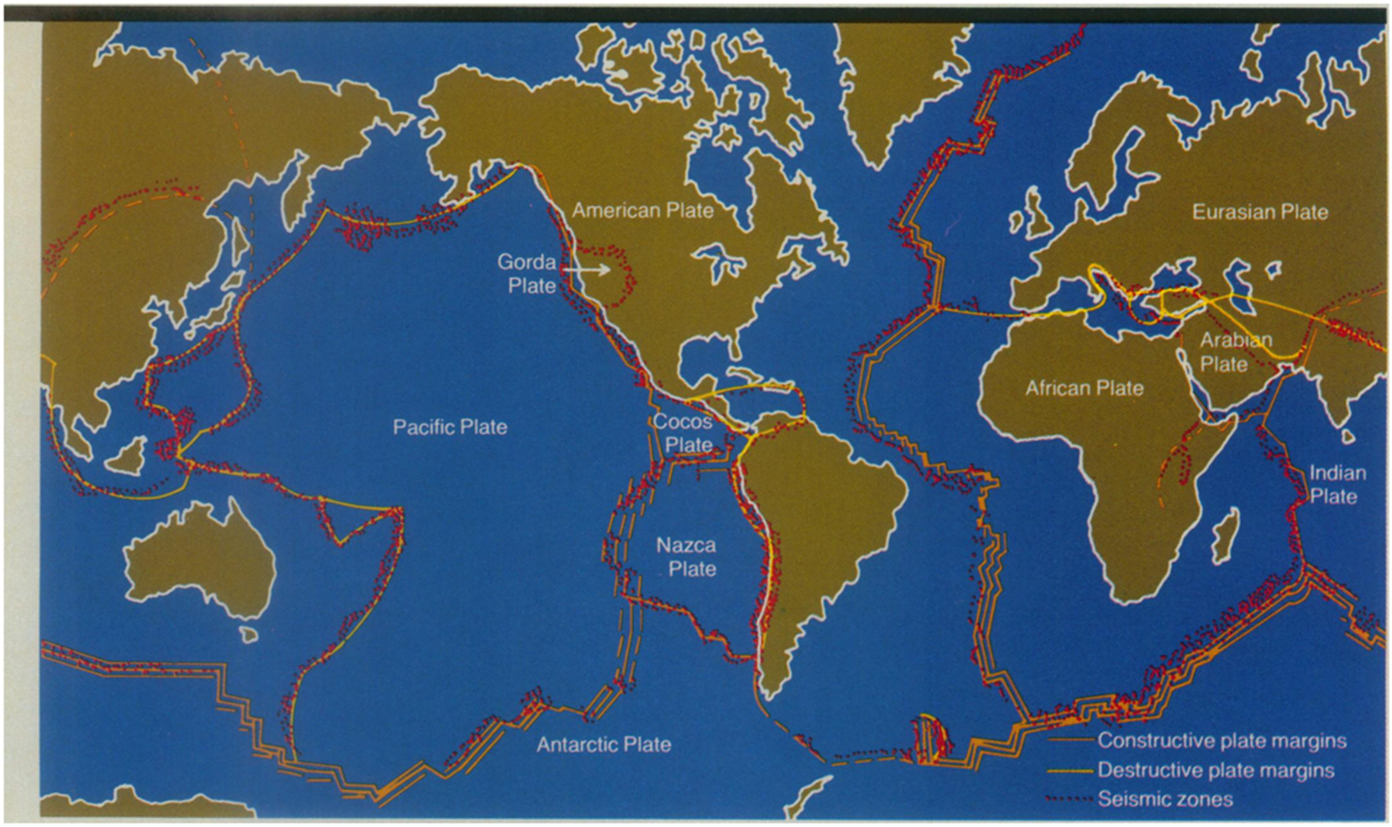
Symmetrical patterns of magnetized strips on either side of deep sea ridges were a critical factor in confirming the theory that new crustal material forms as the ridges spread apart. Magnetic particles in molten rock, oriented parallel to the earth's magnetic field, record changes in the earth's polarity over time. The significance of the magnetic patterns was proposed in 1963 by two Englishmen, Fred Vine and Drummond Matthews. A time scale of magnetic reversals shows that the seafloor spreads at a rate of 2 to 18 centimeters per year.

Over the years scientists had debated the theory, most treating it with scorn, many with indifference, few with respect. The idea that the continents move was appealing because it explained phenomena that had puzzled geologists for years. Why did the contours of the eastern coast of South America and the western coast of Africa fit together so well? Why did continents have geological features with strikingly similar composition and configuration if they were separated by oceans? Why did the fossil record show that many animal and plant species had lived in both South America and Africa before the Paleozoic era? If at one time the continents had been one mass, a supercontinent Wegener called Pangea, the answers were clear.

The main problem with Wegener's comprehensive version of continental drift—a theory that had been expressed in various less persuasive forms by previous observers — was that there was no apparent mechanism strong enough to propel the continents through the ocean floor. Then, in the 1960s new evidence began to emerge that over the next decade would explain and engulf the theory of continental drift.

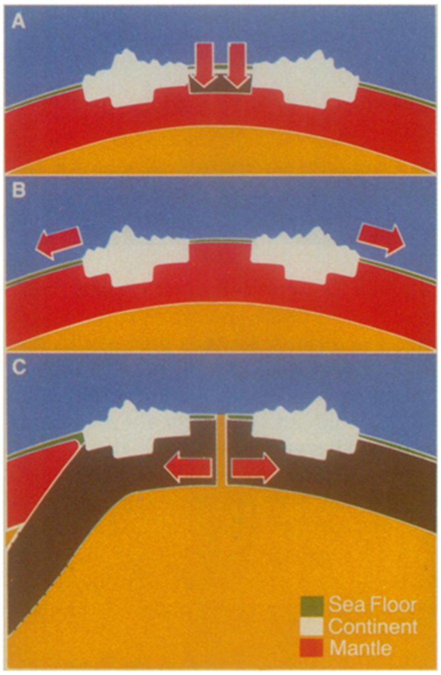
The capability to study the seafloor, negligible in Wegener's day, allowed scientists to see that unlike the continents, oceans are ephemeral features. As the late Harry Hess of Princeton suggested in the early 1960s, new ocean floor is created along ridges in the deep sea where crustal plates spread apart, and is destroyed along trenches near the continental margins in a process now known as subduction. His contention was verified in part by the finding that no part of the ocean floor is older than 200 million years, less than five percent or so of the earth's estimated age. The age difference could be explained if the seafloor was recycled continually.

The famous magnetic profile, known as Eltanin-19, persuaded many skeptics that the old continental drift theory might have some validity. For years oceanographic research vessels had been collecting data on the magnetism of the earth's crust. But not until this profile, taken in the South Pacific in 1966 from the vessel *Eltanin,* was it clear that the seafloor was spreading apart. The striped pattern of magnetic reversals showed the kind of mirror image created when one paints parallel lines on a sheet of



paper and folds it before the ink is dry. As a ridge spreads, molten material wells up from the mantle. As the magma cools into rock, the record of the earth's magnetic orientation is frozen into place. Though spreading rates vary, the widths of the magnetic bands on the ocean floor are proportional to the time intervals during which the earth had a given polarity. And, as other profiles showed, the pattern of reversals is the same all over the world.

Not every scientist was convinced that the magnetic patterns proved that the seafloor spreads. Many, however, began to re-evaluate existing data in light of new evidence. The distribution of earthquakes and volcanic eruptions, when marked on a world map, was found to delineate six major plates and a number of minor ones on the earth's surface. Samples of crust extracted by the drilling ship the *Glomar Challenger* beginning in 1968 revealed that the age of the seafloor increases with distance from deep sea ridges. Wegener's idea that the continents are adrift gave way to the belief that entire plates of the earth's crust are in motion. The continents, composed of lighter crustal material, are simply along for the ride. After fifty years, the old theory had metamorphosed into a bold, dynamic framework for reconstructing earth history: plate tectonics. □



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Earthquakes and volcanos delineate the six major plates that cover the earth's surface. Such tectonic events occur at plate boundaries where crustal material is either destroyed beneath trenches or created when molten material wells up at ridges in the ocean floor where plates spread apart (above). While gradual processes such as erosion are important in shaping earth features, the tectonic model solves some long-standing geological puzzles, such as island arcs, evolution of some mountain chains, volcanism, and the relative youth of the ocean basins compared to the ancient continental shields. Far left: The traditional view of the earth's structure held that the continents were fixed in place and that lateral movement was impossible. The continents could move vertically, however. The principle of isostasy supported the idea that the continents rose or subsided until their mass was supported or compensated by the thickness of the underlying crust (top). Wegener reasoned that if the continents could move vertically through a viscous substratum, they could move horizontally as well (middle). He credited the earth's rotation as the mechanism for this motion, an idea rejected by his peers. In the modern theory of plate tectonics, the continents are carried aboard rigid crustal plates that are forced apart at mid-ocean ridges (bottom). The precise mechanism for plate motion is still debated. Left: At Thingvelli, Iceland, the Mid-Atlantic Ridge rises above sea level.