



# Data Do Not Speak

## The Development of a Mechanism for Continental Drift



Harry Hess

While many scientists criticized Wegener's proposed theory, a few respected geologists supported it. In 1929, Arthur Holmes suggested a more plausible mechanism for how continents could move. He proposed that convection currents in a fluid layer beneath the crust, caused by heat released from radioactivity within the Earth, allowed the continents to move. In 1937, Alexander Du Toit proposed that Pangea had originally broken into a northern supercontinent, which he called Laurasia, and a southern supercontinent called Gondwanaland. These ideas were based on his work in Africa and much evidence from South America and South Africa. Many European and American geologists were unaware of this work.

However, despite the plausibility of these new ideas and the support of some well-known geologists, Wegener's theory languished. Bailey Willis stated in 1943:

I confess that my reason refuses to consider 'continental drift' possible. This position is not assumed on impulse. It is one established by 20 years of study of the problem of former continental connections as presented by Wegener, Taylor, Schuchert, du Toit, and others with a definite purpose of giving due consideration to every hypothesis which may explain the proven facts. But when conclusive negative evidence regarding any hypothesis is available, that hypothesis should, in my judgement, be placed in the discard, since further discussion of it merely incumbers the literature and befogs the mind of fellow students.

**1. The scientist's perspective above raises one of the most interesting aspects of doing science. Note that while some scientists have discarded Wegener's theory, others support the idea or some variation of it. Decisions regarding the acceptance or rejection of scientific ideas are a very complex process. How does this example illustrate the importance of consensus building in the scientific community versus the views of individual scientists?**

Because so little was known about the ocean floor, determining if and how continents move was very difficult. One scientist noted that trying to understand the Earth without knowing about the ocean floors "was like trying to describe a football after being given a look at a piece of the lacing." For centuries, most people thought that the ocean floor was flat and featureless. However, beginning in the 1600s, deep-sea line readings by naval explorers provided evidence that the ocean floor was not flat. By the

1850s, evidence supported the existence of underwater mountains in the middle of the Atlantic Ocean. Survey ships laying the trans-Atlantic telegraph cable in the early 1900s confirmed these ideas.

Technological development over several centuries had helped scientists better understand what the ocean floor looked like. During the 1940s and 1950s, technologies initially developed for the military were adapted by geologists and used to provide a much better idea of the ocean bottom. For example, sonar devices that had been developed to track warships on and under the ocean surface provided confirming evidence of ocean floor ridges and trenches. By the 1950s, sonar data supported the idea that a global mid-ocean ridge system existed.

A very important piece of data was collected using magnetometers. These devices, adapted from airborne equipment used to detect submarines, indicated variation in the magnetic field of the rocks that make up the ocean floor. This variation consisted of areas with normal polarity (a compass points in the direction we know as the North Pole) and reversed polarity (imagine a compass pointing in the direction we know as the South Pole). An interesting feature was that this variation was not random, but rather was found in alternating stripes (Figure 1). Developing an explanation for this occurrence would play a crucial role in explaining how the continents move.

**FIGURE 1**

*Adjacent stretches of ocean floor rock were observed to have reversed magnetic orientations.*



To understand these phenomena, scientists needed an accurate age of the rocks found in the ocean. They were able to do this using techniques developed by nuclear scientists during the development of the atomic bomb. By using the ages of rock samples from around the globe, scientists determined when the magnetic reversals had occurred. The idea of dating rocks based on the amount of radioactive material in them had been around since early in the twentieth century. However the technology to

accomplish this was not available until after World War II.

The data collected from the magnetic study and radioactive dating of rocks were interpreted to mean that the geomagnetic pole had moved – a phenomenon called polar wandering. S.K. Runcorn studied ancient rocks from Europe. He interpreted the data as indicating that the “North” pole had moved from a location near Hawaii about 600 million years ago to its present position. Two possible explanations existed for how this could have occurred. Scientists who maintained a “fixist” view of the Earth thought the pole was what had moved. Scientists who maintained a “mobilist” view of the Earth maintained that the continents had moved in their relation to the pole.

**2. Note the different interpretations depending on the framework and ideas one uses to make sense of the same data. People often think that good scientists are objective (i.e. open-minded/not letting other ideas influence their thinking). What does this story imply about the possibility of scientists being objective?**

To resolve this problem, Runcorn studied rocks in North America. The data he collected could be interpreted to mean that the pole had moved. However, the path of the pole based on rocks from North America was different than the path derived from rocks in Europe. The 'mobilist' view that the continents had moved (not the pole) made sense of both North American and European rocks. The apparently different polar paths could be explained as the pole remaining still and the continents moving in different directions in relation to the pole. Runcorn, who had been a critic of continental drift, became a supporter based on this new evidence.

Moreover, the sediment layer on the ocean bottom was much thinner than would be expected if the oceans had existed since the formation of the Earth approximately 4.5 billion years ago. The oldest portions of the ocean floor appeared to be less than 200 million years old. According to the 'fixists' view, the ocean floor would have a very thick layer of sediment consistent with at least a 3.8 billion year old Earth. The “fixist” view of continents could not account for the relatively young age of the ocean bottom sediment layer compared to the age of the Earth.

Another piece in the puzzle came from scientists who recognized a pattern in the location of earthquakes and volcanoes around the Earth. Using seismographs, scientists determined that earthquakes tend to occur near the ridges and trenches in the Earth's oceans. It was also determined that a significant amount of volcanism on Earth occurs near the ridges.

An explanation accounting for these observations was proposed by Harry Hess in 1960. Hess studied oceanic ridges and was a critic of continental drift in the 1940s and 1950s. However, he was open to examining many ideas when attempting to solve the mysteries of nature and

favoured the use of what has been described as “multiple working hypotheses”. He argued that, “Without hypotheses to test or disprove, exploration tends to be haphazard and ill-directed. Even completely incorrect hypotheses may be very useful in directing investigation toward critical details”.

Hess proposed a mechanism for continental drift that accounted for much of the new evidence available to scientists. He argued that new seafloor was created at the mid-ocean ridges and then spread out toward the trenches where it descends into the mantle. Another scientist, R.S. Dietz, independently developed the same idea in 1961 and coined the term “sea-floor spreading” to describe it. The following are Hess's words describing sea floor spreading:

A continent's leading edges are strongly deformed when they impinge upon the downward moving limbs of convecting mantle... Rising limbs coming up under continental areas move the fragmented parts away from one another at a uniform rate so a truly median ridge forms as in the Atlantic Ocean... The cover of oceanic sediments and the volcanic sea mounts also ride down into the jaw crusher of the descending limb, are metamorphosed, and eventually probably are welded on to the continents.

**! Wegener had used the analogy of the torn newspaper. Here Hess speaks of rising limbs and jaws. Scientists use analogies, even when speaking to other scientists, because new thinking is always connected in some way to prior thinking, and making reference to well understood ideas helps others understand new thinking.**

Hess's idea explained how continents drift around the Earth. Two types of boundaries existed between the plates. The first, divergent boundaries, such as the Mid-Atlantic Ridge, are where new crust is formed. The second, convergent boundaries, are where two plates collide and crust is 'recycled' into the mantle. Thus as the plates grew from the creation of new seafloor, the continents would move with the plate. Yet he noted that there was a difference between Wegener's yet unsubstantiated theory and his idea:

This [my view] is not exactly the same as continental drift. The continents do not plow through oceanic crust impelled by some unknown forces, rather they ride passively in mantle material as it comes to the surface at the crest of the ridge and then moves laterally away from it.

Hess's mechanism provided explanations for why:

- the oceanic ridges are found in the middle of the oceans and have a high temperature;
- fracture zones widen;
- volcanoes tend to occur near the oceanic ridges; and
- ocean floor is not older than 180 million years and predicted to never exceed 200 million years in age.

Hess's mechanism explained many things about the ocean floor, but scientists who held to a 'fixist' and 'contractionist' view of the Earth still largely rejected it. However, over the next few years several groups of scientists provided additional evidence that convinced most scientists to accept the 'mobilist' view of plate tectonics.



**Again, notice that scientists do not vote on what nature is like. Often, long periods of time and much evidence from many sources are required to persuade scientists, and some are never convinced.**

Remember that the idea of magnetic reversals had already been developed. Fred Vine and Drummond Matthews suggested that, if seafloor spreading occurs, then strips of seafloor material having reversed and normal polarity spreading out symmetrically and parallel to the ridges should exist. Having no data to determine the rate at which the sea floor spread each year, they assumed the rate to be several centimeters per year. This correlated strongly with the known pattern and age of magnetic reversals. Yet as Vine noted, 'it created more problems than it solved,' because the idea of sea floor spreading was still not widely accepted. Whether magnetic reversals had occurred was still being debated, and no empirical data supported the prediction of symmetrical and parallel ridges. In fact, some scientists interpreted the initial data as inconsistent with predicted results. The disagreements in making sense of data are illustrated in the following passage:

I remember in 1966 Bill Menard came up here and spent the whole day looking at profiles – he never said a word. Joe Worzel, who was one of the chief opponents ... came up and said, "Bill, what do you think? Do you see this silly correlation; this lousy correlation [between magnetic profiles]? Menard looked up and said, "@\*#!, how good do you want them to be?"

Yet, by 1966 some key magnetic profiles, especially one known as Elantin-19, provided evidence to support Vine and Matthews' hypothesis. Walter Pitman, who put together this profile, noted its importance:

It hit me like a hammer.... In retrospect, we were lucky to strike a place where there are no hindrances to sea-floor spreading. We don't get profiles quite that perfect from any other place. There were no irregularities to distract or deceive us. That was good, because by then people had shot down an awful lot of sea-floor spreading. I had thought Vine and Matthews was a fairly dubious hypothesis at the time, and Fred Vine had told me he was not wholly convinced of his own theory until he saw Elantin-19. It does grab you. It looks very much like the way a profile ought to look and never does.

Following the publication of the Elantin-19 profile, other data that had initially been interpreted as inconsistent with sea floor spreading were reinterpreted as supporting Vine

and Matthews' hypothesis.

**3. Given that data must be interpreted, how do statements like "The data shows . . ." inaccurately convey how scientific ideas are developed?**

Interestingly, another scientist, Lawrence Morley, independently developed this idea at the same time. However, his paper presenting this was rejected by the prestigious scientific journal *Nature* in February of 1963. This was the same journal which then published Vine and Matthews' idea in September of 1963. Morley's paper was also rejected by the *Journal of Geophysical Research* with the comment, "This is the sort of thing you would talk about at a cocktail party, but you would not write a letter on it." Morley did not make further efforts to publish his idea and never worked in this field again.

J. Tuzo Wilson provided two other pieces of evidence to support sea floor spreading and plate tectonics. In 1963, he proposed that volcanic island chains, such as Hawaii, which are not located near an oceanic ridge, are actually formed due to the movement of a plate over a stationary 'hotspot' in the mantle. This explained an apparent contradiction in the plate tectonic theory that some volcanoes occur thousands of miles from a plate boundary. This idea was not accepted at first and Hess's paper presenting it was rejected by all of the major scientific journals. It was eventually published in the *Canadian Journal of Physics*, a relatively obscure journal.

Then in 1965, Hess put forth an idea based on the observation that oceanic ridges and trenches can end abruptly. He proposed that if the continents are drifting, there must be a third type of fault to connect two ridges or trenches and 'transform' the movement of the plates horizontally. This would result in shallow earthquakes. Wilson, who had written papers on supporting a 'contractionist' view of the Earth in the 1950s, noted that transform faults cannot exist unless the continents are indeed moving:

Transform faults cannot exist unless there is crustal displacement and their existence would provide a powerful argument in favor of continental drift and a guide to the nature of the displacement involved.

Based on the work of Vine, Matthews, and Wilson and other supporting evidence, the majority of scientists who had been critics of continental drift and plate tectonics became supporters of this 'mobilist' view of the Earth. The following is Sir Edwards Bullard's comment about a conference he attended in America in 1966 where much new data was presented supporting sea-floor spreading and drift:

The effect was striking. As we assembled on the first day, Maurice Ewing came up to me and said, I thought with some anxiety, 'You don't believe all this rubbish do you, Teddy?' At

the end of the meeting I was to sum up in favor of continental movement and Gordon Macdonald against; on the last day Macdonald was unable to attend and no one else volunteered to take his place.

The following passage illustrates how scientists accepted sea-floor spreading once they could see the relevance it held to their own research:

Reidel came up to me at some time in 1967 or so and said, "Look, my data can't be compatible with sea floor spreading." He collects cores and dates radiolaria [microfossils] and he knew the stratigraphy of the sea floor before JOIDES [ocean drilling] stuff. He said that his data don't agree with this, but he didn't know how to run a decent test. Since he knew I had the magnetics data that existed, he asked if we could work together and I would tell him how old the sea floor is from the magnetics and he would tell me how old it really was... I got out the maps and did the best I could to give him the ages, and he plotted this with his samples. He didn't destroy the idea; they were in perfect agreement. So he says "Ye Gods!" and writes a paper about the confirmation of sea floor spreading.

And like all good scientific theories, plate tectonics helped *make sense of phenomena* and *made accurate predictions* regarding natural phenomena:

I found that...I could read a lot of papers in geological journals and start to see something important and significant in them. Before I just read the ones in my specialty, I didn't even understand what the others were about. But suddenly—really almost overnight—I could see significance in these things that I had never paid any attention to before. (Oliver)

Sea floor spreading was a wonderful concept because it could explain so much of what we knew, but plate tectonics really set us free and flying. It gave us some firm rules so that we could predict what we should find in unknown places. (Atwater)

The following quotation illustrates how good theories also *unify a scientific discipline* bringing together what at the surface appear to be disparate fields.

Earth science is no longer a compartmentalized science, it is a unified science that is glued together by the theory of plate tectonics. This is most vividly displayed on the deepsea drillship Glomar Challenger where paleontologists, geochemists, sedimentologists, petrologists, and geophysicists all work together on sediments and rocks recovered from beneath the deep sea floor. Without the theory of plate tectonics as a background framework, this interaction would be almost impossible. (Larson)



**The general public often wrongly dismisses theories as being mere speculations. However, rather than conveying the certainty of an idea, the terms "law" and "theory" refer to what particular science ideas do. Scientific laws convey relationships between phenomena. Scientific theories make sense of laws by providing an explanation for those relationships. When first conceived, all scientific knowledge (including both laws and theories) has a speculative character. As this story illustrates, much time usually passes before ideas are rejected or accepted by the scientific community. Continental drift is a theory that is now so well supported by evidence that scientists accept it as accurately accounting for how nature works. It is called a theory because of the role the knowledge plays in science. Continental drift, like all good scientific theories, explains several scientific laws, brings coherence to a field of study, and suggests research questions worth pursuing, how to go about answering those questions, and how to interpret data derived from research.**

While plate tectonics provides a robust explanation for the major geological processes on Earth, the following passages demonstrate the caution that scientists profess until theories have withstood the test of time:

I think that we should work the theory of the new global tectonics for all that it is worth—just as we should do with any theory or model, for it is through such intensive studies that we obtain large quantities of valuable information. We should reexamine the geologic data within this new conceptual framework, but we must not assume that we have arrived at the final solution—because geology just is not that simple. (Wylie, 1974)

If the plate tectonics model is false, it will nevertheless be difficult to refute or replace, for the plate model is so widely believed to be correct that it is difficult to publish alternative interpretations. Lacking well-known alternatives, a dominant model will not be rejected... (Saul, 1986)

**4. Scientific theories make sense of the natural world. Why are scientists likely to hold onto and use a dominant theory (even if it doesn't work as well as desired) unless a very plausible alternative theory exists?**

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written by Mark Williams, Michael P. Clough, Jane Pedrick Dawson & Cinzia Cervato

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