Continents

A Jigsaw Puzzle with No Mechanism

Alfred Wegener

Place your feet on the ground and describe the motion beneath you. Our senses give us the impression the Earth's surface is not moving. But overwhelming evidence supports the idea that it is in constant motion. The Earth's surface is composed of a series of plates that move towards or away from each other producing earthquakes, volcanoes, and mountains. Over long periods of time the movement of these plates changes the position of entire continents. How did scientists develop this idea when common sense indicates the Earth's surface to be still? The following story will help you better understand how scientists came to this conclusion. It also provides an interesting glimpse into how science operates to create new knowledge.

Our story begins in the 15th and 16th centuries, as explorers' travels resulted in increasingly accurate maps of the world. Looking at these maps, some people noticed similarities in the edges of continents. For example, the Atlantic coasts of Africa and South America, although separated by thousands of miles, seem as though they could fit together (Figure 1). Francis Bacon suggested that some reason must exist to explain the way continents appear to fit together. In 1620 he noted, “The very configuration of the world itself in its greater parts presents conformable instances which are not to be neglected.”

FIGURE 1

Early explorers noticed the apparent fit of coastlines shared between continents separated by great distances.

The accepted view at this time was that except for rare occurrences, the Earth's continents and oceans are 'fixed' in their positions and do not move. Reflecting this view, for the next several centuries the similarities in continents' borders were explained as the result of a sudden change in the Earth caused by catastrophic events. In 1596, Dutch mapmaker Abraham Ortelius suggested that the Americas were “torn away from Europe and Africa…by earthquakes and floods”.

In 1666, Father Francis Placet claimed that America did not exist before Noah's flood. He maintained that the American land mass was created “either by the conjugation of many floating islands…; or by the destruction of the island of Atlantis which after sinking down into the deep could have caused the uncovering of a new Earth.” While not referring to the flood of Noah, in 1801 Friedrich Humboldt argued that a giant current had dug out the landmass that connected Europe with America. He claimed “What we call the Atlantic Ocean is nothing else than a valley scooped out by the sea.”

In 1858 Antonio Snider-Pellegrini was the first to note that similar fossils and rock formations are found on adjacent continents. He suggested that the continents we see today were created from an original single land mass. He thought that multiple catastrophes caused the separation of the single land mass. Those catastrophes included Noah's flood and outbursts of material from the Earth's interior along cracks in that original land mass.

1. Note how several of these explanations use catastrophes appearing in religious texts to explain natural events. How does this illustrate the influence of the wider culture and prevailing ideas on people investigating the natural world?

Destructive events such as earthquakes and volcanoes were known to occur regularly. However, some questioned whether such events, no matter how severe, could separate continents. In 1758 James Hutton proposed a Uniformitarian Principle. He claimed that the forces acting on Earth today are the same as they have always been. Thus, since we do not see extreme catastrophes today, they must not have occurred in the past. Hutton's “uniformitarianism” influenced the thinking of many 19th century scientists as they studied the Earth's history.

Uniformitarianism is the name given to an important geological idea that the natural processes acting today act in much the same way as they have in the distant past.

For instance, in the late 1800s Edward Suess noted flows of lava from volcanoes and suggested that the Earth is cooling from a molten state. A cooling Earth would grow smaller and this would distort the Earth's surface much like the skin of a shrinking apple. This was thought to be how mountains and ocean basins were formed. Yet this 'contractionist' view could not account for the observation that mountains are formed only in certain locations, and that earthquakes and volcanoes tend to occur only in certain areas. Nor could it account for the observation that similar fossils and rock formations are found on different continents.

Suess also developed an explanation for the fossil evidence that did not rely on any catastrophic event. He suggested that land passageways once connected continents. These land “bridges” were thought to have permitted organisms to travel between continents. To explain why these land “bridges” are not seen today, he claimed they had sunk into the oceanic crust at some point in the past. While this would violate accepted knowledge that continental crust should float on more dense oceanic crust (this idea is known as the law of isostasy), many scientists supported this “landbridge” explanation.

2. These scientists, just like scientists today, are devoting much time, thought and effort to developing and substantiating ideas that will account for the available evidence. However, whenever a new idea is proposed, it almost always requires further work and modification. Note that each idea proposed thus far regarding the continents has some explanatory power, but also has significant problems. How does the time required to develop and substantiate science ideas as illustrated in this story compare to what science textbooks convey about the time required to develop and substantiate science ideas?

In the early 1900s several scientists proposed that the continents separated by moving over the Earth's surface over a long span of time. This 'mobilist' view could provide an explanation for the fossil evidence, and much more. In 1910 Frank Taylor suggested that a “mighty creeping movement” of the crust formed mountains, and speculated that the continents were “pushed” as a result of tidal forces caused by the gravitational attraction between Earth and the moon. However, this explanation wasn’t deemed plausible. Thus, the scientific community paid little attention to his work.

Alfred Wegener in 1912 put forth a detailed explanation involving a slow “continental displacement” over vast periods of time. He proposed that around 200 million years ago one giant supercontintent, which he called Pangea, existed. Over time the continents had been pulled apart, and they were still moving. This idea was referred to as “drift,” a derogatory term that critics of Wegener used when referring to the idea. Wegener's idea of continental displacement provided a plausible explanation for many geological phenomena, including:

- Why the contours of many continents seem to fit together so well,
- Why there were numerous geological similarities between Africa and South America, and between North America and Europe,
- Why many similar fossils exist in Africa and South America before the Paleozoic (when Pangea existed), and very few afterwards (when the continents would be separate),
- Why mountain regions are formed along coastlines, and are narrow and long (from the compression and folding of the leading edges of colliding continents), and
- Why there were glacial deposits in what are now warm regions

In explaining his unsubstantiated theory to other scientists, Wegener noted his firm belief in the idea:

> Even though the theory in certain individual cases may still be uncertain, the totality of these points of correspondence constitutes an almost incontrovertible proof of the correctness of our belief that the Atlantic is to be regarded as an expanded rift. Of crucial importance here is the fact that although the blocks must be rejoined on the basis of other features their outlines especially the conjunction brings the continuation of each formation on the farther side into perfect contact with the end of the formation on the near side. It is just as if we were to refit the torn pieces of a newspaper by matching their edges and the check whether the lines of print run smoothly across. If they do, there is nothing left but to conclude that the pieces were in fact joined in this way.

3. Note that Wegener and other scientists are creating ideas to *account for* what they observe. That is, nature and extracted data does NOT *tell* scientists what to think. Data doesn't speak—it must be noticed, valued, and interpreted. What does this imply about the way in which scientists construct new ideas?

In a letter to a friend, Wegener argued that his proposed theory provided a more plausible explanation for the fossil evidence than that provided by proponents of land bridges.

> You consider my primordial continent to be a figment of my imagination, but it is only a question of the interpretation of observations. I came to the idea on the grounds of the matching coastlines, but the proof must come from the geological observations. These compel us to infer, for example, a land connection between South America and Africa. This can be explained in two ways: the sinking of a connecting continent or separation. Previously, because of the unproved concept of permanence, people have considered only the former and have ignored the latter possibility. But the modern teaching of isostasy and more generally our current geophysical ideas oppose the sinking of a continent because it is lighter than the material on which it rests. Thus we are forced to consider the alternative interpretation. And if we now find many surprising simplifications and can begin at last to make real sense of an entire mass of geological data, why should we delay in throwing the old concept overboard?

In 1921 Wegener noted that he knew of no geophysicist who opposed his theory. However, his writings on this subject were not translated into other languages until 1922. Thus, his work was not well known outside of Germany. Beginning in 1922 most scientists, especially those in America, began criticizing Wegener's ideas. C.T. Chamberlin, a well-respected geologist, said during the 1922 meeting of the Geological Society of America “If we are to believe Wegener's hypothesis we must forget everything which has been learned in the past 70 years and start all over again.” In 1928, nearly all of the participants of the American Association of Petroleum Geologists were critical of Wegener's ideas. They argued that Wegener was misinterpreting the data. They questioned the supposed jigsaw puzzle fit of the Atlantic continents, and denied that rock formations on opposite sides of the ocean are closely related.

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These scientists are looking at the same data as Wegener, but are interpreting it differently. That is, nature and extracted data are not *telling* scientists what to think. Wegener and other scientists are creating ideas to *account for* what they observe.

This intense opposition to Wegener's ideas by well-respected scientists affected other scientists. Years later, the geologist R.D. Oldham noted that scientists who accepted Wegener's proposed theory would not say so publicly:

> But also I remember very well that in those days it was unsafe for anyone to advocate an idea of that sort…. Those ideas (solid Earth and contraction) held the ground so strongly that it was more than any man who valued his reputation for scientific sanity ought to venture on to advocate anything like this theory that Wegener has nowadays been able to put forward…

Yet, while most scientists rejected Wegener's ideas, even critics found his idea intriguing:

> In examining the ideas so novel as those of Wegener it is not easy to avoid bias. A moving continent is as strange to us as moving Earth was to our ancestors, and we may be as prejudiced as they were. On the other hand, if continents have moved many former difficulties disappear, and we may be tempted to forget the difficulties of the theory itself and the imperfection of the evidence. (Lake, 1923)

Wegener did not originally attempt to describe what kind of forces moved the continents. He knew his theory would be much stronger if he could propose a plausible physical mechanism for how the continents moved. He later proposed that the continents moved northward through the oceanic crust. He argued that the forces generated as the Earth rotated on its axis propelled the continents' movement. However, Harold Jeffreys, a highly respected English geophysicist, demonstrated that Wegener's proposed mechanism was “geophysically impossible.” He argued that if the softer continental crust moved through the harder ocean floor the continents would break up. Additionally, Wegener had proposed that tidal forces moved the continents westward. Jeffreys noted that if the tidal force was this strong, it would halt the Earth's rotation in one year. Jeffereys demonstrated that Wegener's mechanism was implausible, but Wegener's confidence in the theory of continental drift remained steadfast:

> The Newton of drift theory has not yet appeared. His absence need cause no anxiety; the theory is still young and still often treated with suspicion. In the long run, one cannot blame a theoretician for hesitating to spend time and trouble explaining a law whose validity no unanimity prevails. It is probable, at any rate, that the complete solution to the problem of the driving forces will still be a long time coming, for it means the unraveling of a whole tangle of interdependent phenomena, where it is often hard to distinguish what is cause and what is effect.

Wegener was clearly aware that the history of science is filled with ideas that accurately account for phenomena, but with no underlying mechanism. For instance, Isaac Newton derived the universal law of gravity. However, even today no consensus exists on a theory that explains how bodies at a distance exert a force on one another.

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Note how this story illustrates that (1) scientific ideas develop over time, and (2) scientists do not vote on what the natural world is like. They do sometimes vote on what to call something or how to categorize it, but not how the natural world works. Much time (often decades) passes as scientific ideas emerge, develop and are eventually accepted or discarded.

The lack of a mechanism for continental drift may not have been the only reason scientists disputed Wegener's idea. World War I had ended just a few years earlier, and negative sentiment toward his German heritage widely existed. Moreover, Wegener was a meteorologist by training, spent most of his time studying meteorology, and was professionally employed in this field. Thus he may have been seen as an outsider who did not have the specific training in the Earth sciences needed to work in this field of science. However, this may have been beneficial as Wegener could tie interdisciplinary knowledge together because he had no stake in preserving the status quo in any one field. Louis Frank in 1990 wrote of two deadly sins in science: advocating an idea that (1) is at odds with what everyone else is thinking and doing so while (2) not affecting their own field of study.

4. Currently accepted scientific knowledge influences scientists' interpretation of data. Many times someone who is new to a field of study begins revolutions in scientific thinking. Why might this often be the case? In this particular story, why might Wegener not be so committed to prior explanations of the Earth?

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