Tracing Michael Strevens' Iron Rule of Enlightenment Through the Continental Drift/Plate Tectonics History.

By Jon Thoreau Scott (April 5, 2022)

The manner in which this theory has gained acceptance underscores the fallibility of scientists and the fact that fashions prevail in science as they do in clothing and hair styles. Walter Sullivan (Continents in Motion)

The book *The Knowledge Machine* by Michael Strevens has altered how I view the history of ideas on continental drift and the theory of plate tectonics. He proposes that science proceeds by the iron rule of enlightenment, that progress in understanding how science works proceeds only through empirical evidence (observations) followed by high plausibility rankings by scientists working in the same field. That leads to what he terms Baconian convergence and to new theories or truths. Strevens argues that the use of specific methods in scientific research does not work well and that only observational evidence leads to a theory.

The most recognized ideas on how science works are based on concepts that Thomas Kuhn discusses in his 1964 book *Structure of Scientific Revolutions* and on Karl Popper's ideas of falsification in science in his 1959 book *The Logic of Scientific Discovery*. Kuhn proposes that scientists tend to follow a paradigm (a set of precepts) in a given research area of science until too many anomalies are found that lead to the rejection of the paradigm leading to a new scientific revolution. Popper's falsification is similar to what I call the scientific method originally proposed by Francis Bacon in his 1620 book *The New Organum*. J.R. Platt provides details on Bacon's view of the scientific method in his 1964 paper in *Science* entitled *Strong Inference.* Platt's interpretation of Bacon's viewpoint is that researchers find as many hypotheses and measurements as possible in a given research area and attempt to eliminate hypotheses using Baconian exclusion until only one remains. Baconian exclusion does not disprove ideas; it does suggest that the excluded ideas be set aside for the time being and to look for other ideas that satisfy the appropriate empirical evidence. The problem is that it is difficult to reveal all of the possible new hypotheses and to come up with the observations needed to exclude them. Platt also points out that exclusion of a hypothesis often leads to disputation in the peer review process. I found that to be oh so true!

The view in the early 1900s among those in the geosciences is that Earth is shrinking and rigid with continents fixed in place. This paradigm is based on the speculations of Isaac Newton and Lord Kelvin that the Earth is cooling and fairly young and thus it is probably getting smaller (see Chapter 1 of Sullivan's book *Continents in motion)*. Strevans discusses Kelvin's arguments in his book where Kelvin thought that the Earth is too young for evolution to have taken place. The analogy of the shrinking Earth is that as an apple gets smaller as it dries the skin forms ripples in the skin analogous to mountains over its entire surface.   However, many Earth scientists of the time were puzzled as to why high mountains exist in specific regions such as along the western coasts of North and South America and in the Alps and Himalayas.   To understand this conceptual difficulty there were many papers published at the time using arguments of the formation of geosynclines to form mountains and valleys, all within the shrinking Earth paradigm.

Many scientists and explorers noted that the coastlines of western Africa and eastern South America form a "jig-saw fit" as if they were at one time attached. Alfred Wegener, a German meteorologist, was one of those who marveled at this geography and while recovering from wartime wounds he decided to look into the matter. He collected a lot of empirical evidence from research papers to show that the continents must move. He wrote his first paper on the subject in 1912 and his first book*, The Origins of Continents and Oceans*, in 1915 with later editions of the book in 1924 and 1929. Wegener made no measurements himself, but summarized research by others to conclude that the continents must move.

In addition to the jig-saw fit, to which many agreed, Wegener also gathered climatic, fossil, geological and other kinds of empirical evidence. One of the most striking of the climatic evidence was that glaciers occurred about 400 million years ago (My) in Africa, in that part of the continent that is now equatorial. At about the same time (400 My) coal was being formed in regions such as Spitzbergen and Pennsylvania and other places that are now cool. There is no other conclusion than to infer that Africa and the northern regions must have moved! Fossils were found on either side of the oceans between Africa and South America and Antarctica with no means of getting across the oceans if the continents, at that time, were in their present locations. The geological landscapes on either side of the Atlantic Ocean were shown to be in many places almost identical. Why did this powerful evidence not convince geoscientists that the continents must have moved?

In 1926 a symposium was organized to discuss the concept of continental drift. Several leading geologists argued against the idea as Walter Sullivan discusses in the 1991 edition of his book *Continents in Motion.* Most American geologists at the meeting did not attack the arguments in favor of drift and the evidence summarized by Wegener but merely disputed the concept. In his 1986 book *The Ocean of Truth* Henry Menard discusses several ideas that made it difficult for the drift concept to be accepted by North American geoscientists. This included the disproof of Wegener's proposal on what causes the continents to move, that continents "plowed" through softer oceanic crust. Of course, disproof of a proposed mechanism to make the continents move does not prove that they don't.

In 1937 Alex du Toit a South African geologist published a book entitled O*ur Wandering Continents: A Hypothesis of Continental Drifting.* He had been involved in the observations of glacial striations in what is now tropical Africa, and was convinced that they were produced when much of Africa was in a region of a polar climate about 400 My. Several prominent geologists at the time, including Scottish born Arthur Holmes, were also convinced that the continents move.

Wegener's father-in-law, Vladimir Köppen, a respected climatologist, at first discouraged him from pursuing the idea of drift because it involved study in many disciplines and that would make it difficult for Wegener to find a position in a discipline-oriented university department. Wegener convinced Köppen that drift is indeed correct and together they later wrote a book entitled *Climates of the Past* that summarizes much of the climatic evidence in favor of drift. However, most mainstream earth scientists of the time, especially in North America, were unconvinced and were even hotly opposed to the idea. Why?

Fortunately, for the concept of continental drift, the U. S. Government began to sponsor oceanic research following WW II. In the 1950s the Office of Naval Research (founded in 1946) and other research sponsoring agencies, such as the National Science Foundation (1950), were concerned that we didn't have sufficient knowledge of the oceans to understand how to keep the U.S. safe in wars. This stimulated a determined effort, starting about 1948, to understand the oceans and the geology of the crust beneath the sea. It was not directed toward proving the correctness of either the shrinking earth paradigm or of continental drift.

The leading organizations in ocean research of the time were the Woods Hole Oceanographic Institution, Scripps Institution of Oceanography and Lamont Geophysical Observatory. This part of the history is covered thoroughly by Henry Menard in his 1986 book *The Ocean of Truth* and by Walter Sullivan in his 1991 book *Continents in Motion.* Menard was one of the leading marine geologists of the time and participated in much of the marine geology research.

From about 1950 to 1965 the ocean bottom was mapped, showing that there is a continuous mountain range under the world ocean that is termed the mid ocean ridge. At the top of the ridges a rift valley was found. On either side, near the ridges, the sediments were found to be thin, but they were much thicker in the abyssal plains far from the ridges and near the continents. This showed that the crust at the tops of the ridges is probably much younger than the ocean crust away from the ridges and that new crust is produced at ridge tops. The ridges between continents were about midway between the continents such as between Africa and the Americas, but the ocean ridge in the Pacific, usually termed a rise, was found to be mostly near the eastern edge of that ocean near the Americas. There were earthquakes found near the tops of these ridges and deeper in the regions where the Pacific crust collides with continents or island archipelagos. It was shown that all around the outer border of the Pacific Ocean the crust was being subducted under continents or island arcs and that deep earthquakes were formed in the "ring of fire" around the Pacific. There was no evidence found of subduction at the outer edges of plates associated only with continents.

In 1962 Robert Dietz of Lamont Geophysical Observatory (now Lamont Doherty Earth Observatory) and Harry Hess of Princeton published papers proposing that there is “sea-floor spreading” at the ocean ridges producing new crust at the ridge tops. Not all of the marine geologists gave this a high plausibility ranking.

In the late 1950s and mid 1960s a group in England were working on the magnetism of the crust at the ocean bottom. When magma solidifies, forming new rock, its iron crystals align with Earth’s magnetic field. The magnetic field undergoes non-periodic reversals (averaging about every 3 million years). Mapping of the magnetic alignment on either side of the ridges led to a classic paper in 1963 by graduate student F. J. Vine working with his advisor D. H. Matthews. They found that the magnetic profiles on either side of the ocean ridges form a bilateral symmetry of magnetic direction in lines parallel to the ridges. This was additional strong evidence of sea-floor spreading at the ridges where new crust is produced. Vine and Tuzo Wilson of the University of Toronto repeated the observations two years later on crusts near a Pacific ridge with similar results. Wilson was a highly respected marine geologist of the time, and this work convinced many of the sea-floor spreading hypothesis. This work by marine geologists also confirms that continental drift is correct although the concept changed to the plate tectonics model.

It is possible that the lack of acceptance of the hypothesis of continental drift by most North American geoscientists, before sea-floor spreading was proven, was due to their failure to examine thoroughly the multidisciplinary studies that Alfred Wegener collected in his books on the subject. However, geoscientists working in marine geology in the 1950s and 1960s did converse to exchange ideas and research papers on sea-floor spreading that was within their area of expertise. That exchange of ideas led to what Strevens calls high plausibility rankings and agreement that show that sea-floor was an important finding. This led to Baconian convergence on the sea-floor spreading hypothesis and soon after to the concept of plate tectonics.

The theory of plate tectonics was first presented by Jason Morgan of Princeton in a paper at an American Geophysical Union meeting in 1967. He proposed that the Earth’s crust is broken into rigid plates where new crust is formed at the ridges or rises, and that some crust is subducted into the upper mantle at convergent margins where the outer edges of the Pacific crust collide with continents. To most geoscientists the plate tectonics model also showed that the continents must move. Was this very much different from Wegener's drift proposal? I say that it was not much different, but most geologists would disagree with my contention.

Did the oceanic research leading to the concept of sea-floor spreading, in the mid-1960s, follow the iron rule? I believe it did. The development of the idea of sea-floor spreading and the concept of plate tectonics from the late 1940s to the 1970s may be a classic example of how the iron rule applies to the development of a scientific theory. It is fortunate that the marine geology of that period was not influenced strongly by the adherence to a previously held paradigm. A reading of Menards book, *The Ocean of Truth* shows this convincingly. Menard lists many examples of the discussions between scientists in letters and meetings that illustrated that there was a positive search for plausibility rankings leading eventually to what Strevans terms Baconian convergence on the concept of sea-floor spreading as a mechanism that caused the ocean plates to "drift" as continents.

In Menard's Chapter15, that he entitles "1961-1962 The Revolution Begins," his first sentence reads: "Half a century after Wegener's opening salvo the second phase of the revolution in the earth sciences began quietly in1961." Because a large number of geoscientists of that era did not agree with Wegener's continental drift idea, by itself, it did not get to the point of Baconian convergence. Sea-floor spreading and the plate tectonics model did. I'm heartened that Menard included Wegener in the idea of a revolution. Many geologists did not. My own view is that the revolution started with Wegener and should have ended there, but the shrinking Earth paradigm together with peer review that disputed, but did not disprove, that the continents move slowed the acceptance of Wegener' continental drift idea. This may be an example of how "doing and not thinking" works in Strevens' iron rule arguments or on what Menard says several times in his *Ocean of Truth* book that "ideas are cheap."

Although the theory of plate tectonics is on solid ground, I note that we still do not have a satisfactory explanation of the forces that make Earth's plates move. In the following I discuss several of highly reported mechanisms that propose a cause for plate movement. For a detailed discussion see my paper "*Using T. C. Chamberlin's Approach for Determining the Forces that Move the Earth's Tectonic Plates"* on the website tectonicforces.org. It may be listed there as: "On the forces of plate tectonics: A view from science philosophy."

The proposals I discuss are: (1) convection in the mantle (2) mantle plumes, (3) trench suction, (4) the plate model, (5) the supercontinental hypothesis, (6) polarized plate tectonics (7) lunar tectonics and (8) far above tectonics (expansion and contraction of the crust at the ridges).

I compare the mechanisms using the following robust observations of the geography of the ocean crust: (a) ridges are elevated about two Km higher than the abyssal plains on either side of the ridges; (b) ridges move away ("migrate") from the continent to which they were originally attached (from Africa and South America, for example to the middle of the Atlantic) and (c) ridges are approximately midway between continents (they are often called "mid-ocean ridges"). These are well-known observations that need no extra information or *ad hoc* assumptions

Arthur Holmes, a Scottish born, and highly respected geologist, speculated in 1929 (later modified in his 1944 book *Principles of Physical Geology*) that (1) heat-driven mantle convection moves the plates. He suggested that there are two large mantle convection rolls that meet in the center of what would be considered a plate like the present Pacific plate. This ridge does not move in his speculation. This bears no resemblance to the geographical pattern I discuss above (a-c) as to what exists on Earth. Ridges associated with continental plates move (migrate).

Convection is still the most quoted idea on what makes the plates move. It is often discussed in textbooks and on the internet. However, there is no direct observations that show that mantle convection drives the plates. The evidence is all circumstantial. Strevens mentions mantle convection on p 78 as a reason why Lord Kelvin's auxiliary assumption of the age of the Earth was probably wrong. However, I show below that it would require unrealistic auxiliary assumptions to prove that that convection can be the cause of plate movement.

Harold Hess of Princeton bought into the convection idea in 1962. He proposed that ridge elevation is due to warming from the upwelling and that the plates are either dragged by friction or they float on the asthenosphere that moves away from the center of ridges. The reality is that the ridges between continental plates are nothing like Holmes proposed. They are not stationary, but move systematically away from the continents to which they were originally attached. I call this "ridge migration." This problem was discussed in the 1960s by H. Menard (see p 184 in his *The Ocean of Truth*). He pointed out that the upward flow would have to follow the moving ridge and this is physically untenable. For example, the ridges surrounding three sides of Africa and those surrounding most of Antarctica are at the coasts of those continents when Pangaea started to break up. They now are about half way (mid-ocean) between those continents. The convection cells would have to move or change size in a very precise way for the upwelling between cells to stay directly under the ridges. This problem of ridge migration would require impossible *ad hoc* assumptions for the convection model to produce plate movement.

My other main objection to the convection mechanism is that mantle convection would not produce enough force to cause mountains such as the Himalayas to rise well above sea level. There would not be enough friction between the mantle and the lithosphere to drive the plates. I think that a "push" force is needed with compression in the plates. Don Anderson, a well-known geologist, formally at the California Institute of Technology proposed in 2006 that ocean crusts are like church domes or igloos. They are held together by compression, but break under extension. This counters the idea that ocean plates are "rigid' and this concept makes sense physically.

The idea that plate movement is driven by mantle plumes (2) was suggested in 1971 by Jason Morgan, also a Princeton geologist. There is evidence that plumes exist, but as suggested by many that they originate at the core-mantle boundary has not been demonstrated convincingly. In 1972, Morgan himself, points out that the plume mechanism has the same explanatory problem as convection in that the plumes must move to remain under the ridges that are between continental plates so that ridges are always about halfway between the continents. He then suggests that the ridges of the Atlantic remained fixed while others move.

This also amounts to another unreasonable *ad hoc* assumption because plumes between the other continental plates must also move to be directly under ridges. This goes against physics as in the case for mantle convection.

The plate model (3) originated with ideas of Don Anderson of the California Institute of Technology whose definition is that plate tectonics "is a self-organizing dissipative system that takes matter and energy from the mantle and converts it to mechanical forces (ridge push, slab pull)." Anderson rejects the idea that convection or plumes drive the plates. In this model the mantle is cooled from above and not heated from below. The shallow upper mantle is not homogeneous as it would be if it were mixed by convection or plumes. The plate model assumes that plates are driven by subduction at trenches with sliding away from ridges. The model has a lot of followers as Anderson's logic is always convincing and the idea of self-organization is attractive. However, it has no obvious explanation as to why the ridges are elevated to produce a ridge push force, why ridges between continental plates are midway between continents (near the middle of the ocean), and why they migrate. Without heating below ridges there is no cause for a ridge push force.

Trench rollback (4) is a gravity mechanism that is discussed by Warren Hamilton in a 2007 paper. He suggests that the slabs of the Pacific plate are not pushed to slide under nearby continental plates, but they roll back so as to pull the nearby continental plate by what has been called "trench suction" in earlier studies. For example, he proposed that the sinking of the Pacific plate downward in the Tonga Trench would leave a void which pulls the Australian plate to the east toward the middle of the Pacific plate making the latter smaller. This mechanism has no cause for the ridges between continental plates to be elevated and therefore it has no ridge push force. Hamilton states that there is a "requirement" that ridges between continental plates must be midway between the continents, but gives no reason for such a requirement. I note that in this model a continental plate must be pulled away from the ridges on the other side of the subduction zone (South America pulled to the west away from the Mid Atlantic Ridge). In 2006 Don Anderson suggested above that the pulling of a plate (extension) would cause it to break apart and that it takes compression to hold plates together.

The supercontinental cycle (5) is based upon an idea that heat build-up under a large land mass such as Pangaea causes it to rise as much as 400m and to break up by the sliding away from the geoid high that is formed. It is also based upon a speculation by Tuzo Wilson that there could be many supercontinents that form and reform. A group at the University of Ohio led by Thomas Worseley sketched out the details of how this might work. It involves two processes called extroversion and introversion. The former is similar to the present situation where the African, North American, Antarctic, and Eurasian plates gain in area and separate while the Pacific plate shrinks due to the subduction in the "ring of fire" that surrounds that ocean. With introversion the situation is the opposite where the crusts on the passive margins of the internal oceans sink to form subduction so the process reverses eventually to form another supercontinent.

There is no evidence presented by the Ohio group that during extroversion there is a cause for ridge elevation, ridge migration and why the ridges between continental plates are about midway between continents. A more serious concern I think is that an explanation is not given for what causes the margins to sink around the present internal oceans (presently the Atlantic, Indian etc.) at about the same time to produce the reversal into introversion. This would have to happen all around Antarctica, most of Africa, South America and North America, probably at nearly the same time.

The Polarized Plate Tectonics (6) is a mechanism of plate motion that would be caused by the attractive forces of the moon and sun on Earth's lithosphere. It is discussed by a group led by Carlos Dogliani of Sapienzo University, Rome. They posit that there is a westward drift of the lithosphere due the gravitational attraction of the moon assuming that the lithosphere is decoupled from the mantle (low friction). They show that this westward drift of the lithosphere causes the subduction in the trenches on the west side of the Pacific to be about twice the amount of subduction in the trenches on the east side of that ocean. To balance the extra downflow there is a passive upward flow in the mantle. This passive upward flow provides the Mid Ocean Ridge Basalt (MORB) that increases the area of the crust.

Because the polarized plate tectonics model assumes that most of the drift of the lithosphere is along the equatorial latitudes there is no explanation as to why the ridges, such as those in the Atlantic and around Antarctica are elevated, why they are midway between continental plates and why they migrate. This seems to be a standard problem of many of the models.

Another mechanism that proposes that forces of attraction of the sun and moon cause plate motion is called Luna Tectonics (7). It was discussed over several e-mails and phone calls with me by Peter Haney in 2016 (his e-mail address is lunatectonics21@gmail.com). Haney's statement is: "Every day lunar and solar forces lift the lithosphere and mantle below. As the tide passes through the divergent zones or faults of the Earth, that divergent faults are expanded by one meter for each kilometer of width of a fault. With this expansion molten material intrudes into the gap and some of it cools enough to change phase and solidify. As the Earth tide passes, the surface displacement returns to normal and even negatively six hours later, compressing what was molten before. The previously intruded molten mantle is now part of the lithosphere. As the process repeats day after day a pressure gradient is built up."

I note that this pressure gradient would produce compression away from the ridges and against the continents to cause the continental plates to grow. This would be a one-way process like a winch or, as Haney puts it, "the toothpaste coming out of a tube and not going back." If the increase in crust at the mid ocean ridges, especially for those around Antarctica, is possible by this mechanism, then it satisfies all of the observations I have been discussing for the other models.

The "far above tectonics" mechanism (8) was first proposed by me as a term project in 1965 to a senior graduate level course in oceanography and in other courses later on. The project was to determine if the mechanism that produces increase in area in lake ice in cold climates also applies to the movement of Earth's plates. In 1987 I presented the idea to a group of students that met every two weeks to discuss the problem and do library research. Together with this group in 1989 I submitted a paper to the journal *Global and Planetary Change*. We called it *Crustal Expansion and Contraction of Ocean Crust in Response to Climatic Change as a*

Mechanism for Driving the Earths Tectonic Plates. It was disputed, but not proven to be wrong by the peer reviewers. I now use the term Far Above to refer to this mechanism, because the driving force of climatic variation originates at the top of the ocean, far above the ocean crust. I do not provide details of the mechanism here, because it is described in the paper *On the Forces of Plate Tectonics* located on the website tectonicforces.org.

The Far Above hypothesis of plate motion is analogous to the manner in which the area of ice on lakes in cold climates increases due to diurnal air temperature variations. As applied to the Earth the trigger for temperature variations comes from the long-term variations in climate such as those due to the Milankovitch periodicities in Earth's orbit around the sun (about 22Ky, 41Ky and 96 Ky). The relatively small changes in climate due to these periodicities are amplified by positive feedbacks and this change in climate causes changes in the seawater temperature above the ocean ridges by warming or cooling the crust at the ridge tops. This is accomplished either by changes in the deep ocean circulation or in the vertical displacement of the thermocline.

During a time of cold seawater at the top of the ridges the crust contracts producing a crack. At this time mid ocean ridge basalt (MORB) flows up into the crack that is formed producing new crust when it solidifies. During warm climates (downward heat movement) the ridge-top crust expands and causes seafloor spreading. This produces compression in the crust on either side of the ridges that pushes and moves the continents. This expansion at the ridges causes the plates on either side to get larger and thus a ridge, such as the Mid Atlantic Ridge, is forced to move to the west with respect to Africa and Eurasia, and all other ridges associated with continental plates must move away from their original continents (they "migrate"). The continents, such as North and South America, must also move, relatively, to the west at the sea-floor spreading rate.

Ridge migration is **required** of the far above mechanism, as it is for the Luna Tectonics model, because the new crust at the ridges must move as the continental plates get larger. These two mechanisms also require that the ridges between continental plates are about half way between the continents because the distance from the continents to a ridge must increase and it is likely that new crust is formed about equally on each side of the ridges. They also explain that the ridges would be elevated similar to the manner in which pressure ridges buckle up on lake ice due to compression against the shores. See the Appendix of the article quoted above to see pictures of ice pressure ridges and lakeshore ramparts. The ramparts can be destructive to trees, docks and boathouses along the shores.

Do any of the plate moving hypotheses follow the iron rule? If my analysis above is correct the first six can be thought of as not passing what John R. Platt calls Baconian exclusion in his paper *Strong Inference.* Does this mean that the first six are wrong and the last two are correct? No. Although there is no direct empirical evidence to show that mechanisms like mantle convection or plumes follow the iron rule, evidence might be found to that effect so they remain suspect in my view at this time. The same may be true for all of the first six mechanisms.

The A key possibility for exclusion concerning Luna Tectonics may be that not enough MORB is pulled into the crack that is formed to solidify into new crust in only a short time between tides (half a day). Also, there is no direct evidence as to how wide the crack can become in each tidal cycle.

Regarding the Far Above mechanism, I discuss in my paper *On the Forces of Plate Tectonics* (see tectonicforces.org) that there are at least two observations that could produce Baconian exclusion. The first is that on ice-covered lakes the ice area grows in all directions due to random cracks in the ice. But in the Far Above mechanism the ocean crust at the ridges expands in area away from the ridges. I counter this difficulty by pointing out that that thickness of the crust grows rapidly with distance from the ridge and that there is no concrete evidence that MORB wells up into the transform fault cracks that form perpendicular to the ridges so that increase in area along the ridges is small or non-existent. In that paper I also I point to another difficulty of the Far Above model in that the crust near the top of ridges may not be strong enough to allow short climate variations (say less than 1000 years) to allow the crust to remain unbroken when it expands away from the ridges. Most geoscientists think that the crust is strong enough to push plates over the top of the mantle where there is low friction beneath the lithosphere and mantle.

I tried to publish the idea of Far Above tectonics in two journals, once with five students in1989, and once on a website mantleplumes.org. It was rejected by the journals and ignored by the manager of the website. In all three cases none of the reviewers commented on the idea that my students and I suggested in 1989 that ridge migration shows that that the convection mechanism fails the test of Baconian exclusion. The 1989 paper was accepted at that year's meeting of the American Geophysical Union, but only as a poster session

I mention above that in his book *The Ocean of Truth* Menard states in several places that "ideas are cheap." To me this shows that he believed in testing hypotheses by the iron rule, that empirical results are needed and as Strevans suggests that science progresses by "doing not thinking."

To summarize briefly, this history reveals that the iron rule did not apply to Wegener's continental drift proposal because most North American geoscientists at the time did not discuss the multidisciplinary scientific results that he gathered. But there was sufficiently high Plausibility rankings and Baconian convergence on the determination of sea-floor spreading which then led to the plate tectonics theory in the 1970s.

There has yet to be Baconian convergence on the forces that produce plate motion. I excluded six of eight ideas that have been proposed to cause plate motion by showing that they do not explain three robust geographical features of the oceanic crust. However, the two mechanisms that I did not eliminate by Baconian exclusion may not explain other key empirical data. So, as of this date none of the proposed plate motion mechanisns obey Strevens idea of Baconian convergence and the search for empirical evidence in favor of one or more of them will continue.