THE CONVECTION AND PLUME MODELS OF PLATE TECTONICS ARE GEOMYTHS

By Jon Thoreau Scott

Life is frittered away by detail…Simplify, simplify.
Henry David Thoreau, (Walden)

ABSTRACT

In this essay it is argued that the driving forces of plate tectonics are not well understood. In particular, it is posited that the mantle convection and mantle plume models are suspect primarily because these models cannot explain the very strong anomaly that oceanic ridges between continental plates migrate away from the continents. These two convective models also have difficulty explaining many other anomalies and thus this author terms them "geomyths." The major approach in this essay is the use of ideas that stem primarily from the philosophy of science to determine if the current ideas on the forces of plate tectonics are plausible.

INTRODUCTION

It took fifty years for the concept of continental drift to be recognized by many geoscientists, because most did not utilize simple philosophical ideas including Chamberlin's (1890, 1897) concept of examining multiple hypotheses, Bacon's (1620) scientific method that Platt (1964) calls *Strong Inference,* Popper's (1963) ideas on falsification and Kuhn's (1962) arguments on scientific revolutions. Instead of examining the evidence that Alfred Wegener (1966) presented to show that the continents must move most geoscientists adhered to a shrinking Earth concept that did not explain all of the geological features on Earth such as the preferred locations of mountain ranges, volcanoes and earthquakes. This concept of a shrinking Earth was wrong but was kept alive for fifty years. In their mantleplumes.org (hereafter mp. o) entry Anderson and Hamilton (2008) suggest that this paradigm of continents fixed in place became "zombie science" and a scientific myth. They state that the peer review system allowed this incorrect model to be the conventional wisdom by preferential rejection of research proposals and technical papers.

The characteristics of a good theory are used in this essay as a method of examining plate motion hypotheses. The most important characteristic is that a theory (paradigm, hypothesis, mechanism or model) must be consistent with all observations. If a theory cannot explain how any one of the most simply understood features of the Earth are formed the theory should probably be rejected. *Ad hoc* additions and complicated mathematical theory allow wrong ideas to continue on. Geosciences would evolve much faster than is usual if disproof and falsification were used in the testing of hypotheses. Unfortunately, this has not been the case in the geological disciplines.

HOW SHOULD SCIENCE WORK?

No amount of experimentation can ever prove me right;
a single experiment can prove me wrong.
From: "The Quotable Einstein" by Alice Calaprice (2005), Princeton Univ. Press.

Simple arguments should be applied when dealing with the testing of scientific hypotheses of plate motion. A good theory must explain all of the pertinent observations and these explanations (hypotheses, models or mechanisms) should be as simple as is possible, according to Occam's razor, but no simpler than needed. Many observations that are needed to examine the concept of plate motion are indeed quite easy to understand.

There are an impressive number of papers and books on mantle plumes and convection, where the researchers use tools such as tomography, sophisticated mathematics, computer models and isotopic analysis with many assumptions to prove that convection and plumes really exist on Earth. The question is: Why is proof of one's idea so rampant in the geosciences? T.C. Chamberlin (1890), who wrote the first version of *Studies for Students* when he was President of the University of Wisconsin, and the second after he organized the Journal of Geology (1897) asked why scientists use their "Ruling Theory" in their research instead of examining multiple hypotheses (Platt, 1964). Karl Popper (1963) asked the same question and argued that falsification, not proof, is the way science progresses.

Instead of taking the advice of Chamberlin on the evaluation of multiple hypotheses and that of Francis Bacon (1620, see Platt, 1964) on the scientific method, most scientists who support the convection mechanisms of plate tectonics fall into the trap of the "Ruling Theory" that Chamberlin warned against. He argued that one must avoid the temptation of considering an idea which a scientist has developed, or has studied, as one's "intellectual child." One should consider all of the possible hypotheses as one's children.

In his paper *Strong Inference* John R. Platt (1964) discusses how he thinks science could proceed rapidly by using the scientific method of Francis Bacon (1620). He states that strong inference is based upon the systematic application of:

(1) Devising alternative hypotheses.
(2) Devising a crucial experiment (or observation program), or several of them, with alternative possible outcomes, each of which will, as nearly as possible, exclude one or more of the hypotheses.
(3) Carrying out the experiment (observation) to get a clean result.
(4) Recycling the procedure, making sub-hypotheses to refine the possibilities that remain, and so on.

The procedure is called "Baconian exclusion." Platt (1964) quotes Bacon:

> *My way of discovering sciences goes far to level men's wit and leaves little to individual excellence because it performs everything by the surest rules and demonstration…Truth will sooner come from error than from confusion.*

Platt goes on to write:

> *The difficulty is that disproof is a hard doctrine. If you have one hypothesis and I have another, evidently one of them must be eliminated…Perhaps this is why so many scientists are disputatious"*

Perhaps this is also why Thomas Kuhn (1962) observed that "normal science" is what changes paradigms by the accumulation of anomalies to the existing conventional wisdom so that a scientific revolution takes place when the anomalies overwhelm the existing paradigm. The scientific method, or strong inference of Platt described above, is rarely employed in evaluating multiple hypotheses. Dickenson (2003) also discusses the use of multiple hypotheses and contends that strong inference suggested by Platt can prevent scientists from lapsing into the mythic mode of an idea.

As mentioned above, the idea that comes from the philosophy of science on what makes a good theory is used in this essay. One version comes from Aaron Ihde (pers. comm. 1962) when the author was a graduate assistant in his course "The Physical Universe." The course was part of an integrated liberal studies program, at the University of Wisconsin, Madison, that discussed the history and philosophy of science, in this case astronomy, physics and chemistry. Ihde suggested that good theories should:

(1) Explain all observations of phenomena or results of experiments.
(2) Be understandable, at least in a general way, to the interested layperson.
(3) Be reasonable so that they are testable (falsifiable or disprovable).
(4) Be economical or parsimonious (Occam's razor).
(5) Be predictive, or fruitful, leading to new observations or hypotheses.

The most important characteristic is that any theory or hypothesis must explain the relevant observations. The third characteristic is designed to eliminate "all encompassing" theories that can be changed with the addition of *ad hoc* devices that allow the theory to explain some observations that it otherwise could not. The fourth characteristic (Occam's razor) is best used when comparing two different hypotheses (Anderson, 2002). The most parsimonious should be accepted and those with complicated assumptions and *ad hoc* additions should most likely be excluded.

Several well understood observations of the Earth's crust and upper mantle that need to be explained by any proposed mechanism of plate motion are listed below. These observations include:

(1) The ocean ridges are elevated some 1 to 2.5 Km above the abyssal plains on either side.

(2) The ridges between continental plates migrate from 1 to 2 cm/y away from their original locations next to the continents of the supercontinent Pangaea (*i.e.* westward, eastward and southward from Africa, or away from Antarctica on nearly all sides).

(3) The ridges between continental plates are approximately mid-way between the continents.

(4) Seafloor spreading varies geographically.

(5) The East Pacific Rise is the fastest spreading ridge.

(6) Ridges in the Eastern Pacific are being covered over by continents and thus seem to be nearly stationary with respect to the mantle.

There are also a large number of observations that come from a variety of studies that are summarized in Anderson (2007, 2013), Hamilton (2007), Foulger *et al.* (2005), Foulger *et. al.* (2007) and Foulger (2010). These will be discussed later.

CONVENTIONAL WISDOM, DOGMA, MYTHS AND ZOMBIE SCIENCE

The great enemy of truth is not the lie – deliberate – continued and dishonest – but the myth – persistent, persuasive and unrealistic.

John F. Kennedy

In his paper on the cause of plate motion Anderson (2006) quotes Armstrong (1991) on why conventional wisdom is hard to change:

A myth is an invented tale, often to explain some natural phenomenon…which sometimes acquires the status of dogma…without a sound logical foundation.

Dickenson (2003) states that: "…geomyths have played a role in the evolution of our science and are still with us today." He considers the mantle plume idea to be one of those myths. Anderson and Hamilton (2008) and Charlton (2008) point out that it is the peer review system that helps to promulgate myths that they proclaim turn into zombie science.

As Charlton (2008) puts it zombie science is:

A sinister consequence of evaluating scientific theories purely on the basis of enlightened self-interest…In the real world it looks more like most scientists are quite willing to pursue wrong ideas so long as they are rewarded with a better chance of achieving more grants, publications and status.

Many scientists have found that this problem is true. It is much easier to get grant funding or publish if one stays within the paradigm. Peer review does three things as discussed by Foulger (2010) on p. 286 in her concluding remarks. First, it gets rid of some ideas that are probably wrong. But secondly, it also rejects some new and promising ideas that can change the thinking in a part of science, if considered fairly, and that is its biggest fault. The third thing that it does is maintain an existing paradigm through what Kuhn (1962) calls "normal science." The latter is both good and bad. Normal science, according to Kuhn, is good in that it produces anomalies to a current paradigm that eventually lead to a scientific revolution or a "paradigm shift." But it is bad when it allows the existing paradigm to hang around long after it should be changed, or after it becomes zombie science. In his usual concise manner Anderson states in his paper on incommensurability (mp. o/Philosophy/2):

Peer review and editorial and funding policies – the infrastructure of a paradigm – are effective in trimming both tails of the Gaussian that represents the allowable range of publishable wisdom.

The peer reviewers are the "gatekeepers" that protect the conventional wisdom. How much research money is spent on zombie science to protect the reputations of scientists who support the current dogma and as Charlton (2008) suggests for political or financial reasons?

The role of eminence in science is discussed by Glen (2005) in his essay on the early history of the plume hypothesis, He discusses the role of magisters in science as does Foulger (2010 p. 6). The idea that the Earth shrinks and that mountains were formed like the ripples on a drying apple goes back at least to Isaac Newton (1681) who proposed:

… ye breaking out of vapours from below before the Earth was well hardened, the settling & shrinking of ye whole globe after ye upper regions or surface began to hard.

Also, around 1862 William Thompson (Lord Kelvin) proposed the idea of a short lived Earth that is cooling and perhaps shrinking. Thus the shrinking Earth with continents fixed in place was supported by most geoscientists before the 1960s. Because Newton and Lord Kelvin were highly respected scientists (magisters), as were many well-known proponents of the shrinking Earth paradigm like the geophysicist Sir Harold Jeffreys, the idea had lasting power.

However, Alfred Wegener's first paper on the origins of continents and oceans was published in 1912 and his first book was published in 1915 (later editions were in 1920, 1922 and 1929). He showed conclusive evidence (climatic, fossil locations, geographic, geologic etc.) that supported the concept that continents must move. But the shrinking Earth and the continental "fixity" concepts lasted for another 50 years and became "zombie science" as discussed by Anderson and Hamilton (2008). In the introduction to his book *"Continents in Motion"* Walter Sullivan (1974, 1991) expressed it in a different way:

> *The manner in which this theory* (continental drift and plate tectonics) *has gained acceptance underscores the fallibility of scientists and the fact that fashions prevail in science as they do in clothing or hair styles.*

On pages 14 and 15 Sullivan describes the disputation by leading geologists of Wegener's continental drift hypothesis during a Symposium in 1926. The Symposium was organized by W. A. J. M. van der Waterschoot van der Gracht, a petroleum geologist who was in favor of the drift concept, but he failed to persuade most of the leading American geologists at the Symposium who disputed the concept so the continental movement idea was set aside for several more decades

After the geomyth of fixed continents and a shrinking Earth was finally set aside in the 1960s, when sea-floor spreading was discovered and the plate tectonics model was introduced, new ideas emerged that either mantle convection or mantle plumes produced plate motion. These convection mechanisms were supported by several highly respected scientists; mantle convection was proposed by Arthur Holmes (1931, 1944, 1965), and plumes by J. Tuzo Wilson (1963) although the convection idea was introduced much earlier (Glen, 2005, p. 94). The idea of convection currents was re-introduced by Harry Hess (1962) to explain seafloor spreading in his famous "Essay on Geopoetry" paper.

Perhaps another reason that the convection and plume models were introduced and have hung on for so long (about fifty years) is that they seem logical to the casual observer. The idea of an Earth-centered planetary system, another long-lasting geomyth, was believed for centuries because it seems obvious that the sun goes around the Earth. It rises in the morning and sets in the evening. Copernicus had to look at another possibility (heliocentricity) to explain some of the obvious observations of planets and the Earth-centered system could be removed by Occam's razor as being too complicated.

Similarly, it seems logical that hot material must come from far below in the Earth where it must be very hot, because volcanoes are seen with hot lava and explosions and some islands are in chains (Hawaii). Because of these observations it was thought that convection or plumes must exist. One has to look beyond the obvious and often that requires a difficult thought process. The inability to explain the migration of ridges between continental plates is an anomaly that amounts to disproof of the bottom-up (convection and plume) models, but it is easy to overlook when scientists defend their own "Ruling Theory."

The mantle plume concept was developed by W. Jason Morgan (1971, 1972). Hess and Morgan, who proposed convection and plume ideas, were highly respected in the geosciences and that helped lead geologists to the spread of these models for explaining plate motion. They are incomplete or incorrect, because they fail to explain some of the well-known observations of the Earth's crust as is discussed later on, but they persist despite this problem. Dickenson (1963) calls the plume hypothesis a "geomyth" as does Anderson (2013).

It is possible that Morgan suggested plumes as a mechanism to explain plate motions to replace the convection current model. He omits discussion of ridge migration in his original paper (Morgan 1971), but does discuss the problem in Morgan (1972). Some geologists were suspicious of the geographic pattern of convection as early as 1966, but there were only a very few. For example, Menard (1986, p. 184) states:

> *If the spreading rate was a fact, the spreading center had to drift and the problem shifted to how the convection cells drifted with it, or, a startling thought, whether the cells really existed.*

On the same page Menard also states that Bruce Heezen, also as early as 1966, suspected that the geography of convection was not plausible and he was in favor of an expanding Earth concept to explain continental drift. It is interesting that in a later paper Menard (1973) does not discuss this problem that he seemed to recognize around 1966.

Despite some disagreement in the literature the convection and plume models have enjoyed nearly universal support in the geosciences, such as in textbooks and in the popular literature found on the internet. Dickenson (2003) discusses the problem of the dominance of geoscience myths in the literature and poses the question:

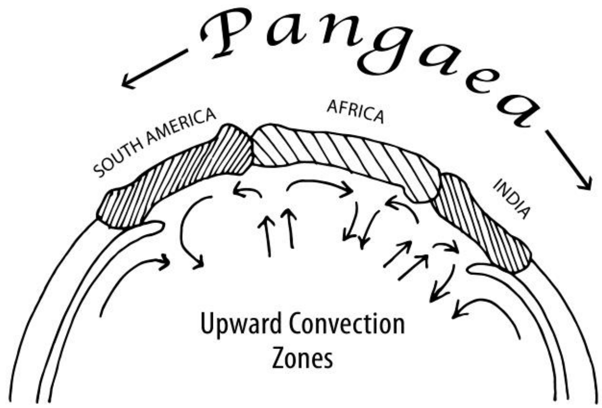
> *Why, in order to gain a sympathetic hearing, should the opponent of a geomyth have to assemble evidence against it more conclusive than the original evidence in favor of it?*

It is the peer review system that maintains the dominance of a paradigm whether it is a geomyth or not and this review process slows down the progress in science by squelching contradictory ideas even if some of them might be plausible.

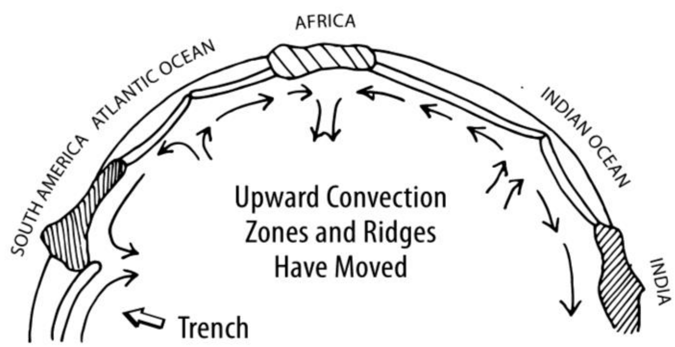
Figure 1 is introduced to illustrate the problem created by the observation that ridges between continental plates migrate. As shown in the figure the convection cells of Holmes (1944) and Hess (1962), which would really be lines of "rolls" on either side of ridges, would have to get larger in size as time goes on for the ridges to migrate so that the upward flow of the rolls is always directly under a ridge. This is physically impossible and is not supported by any model of convection or plumes.

If one follows a line on a map of the Earth (or a great circle on a globe) from west to east the line crosses three ridges at the latitude near the Equator. These ridges are the East Pacific Rise, the Mid Atlantic Ridge and the Carlsberg Ridge. Thus, in the convection model, there must be three sets of "rolls" producing upward flow. The rolls would be on either side of the ridges. The analogy often used to support convection is a pot of boiling water on a stove. This is completely inadequate to explain the rolls of convection on either side of a ridge. What force would cause the ridges to move both to the west and to the east of Africa or what would cause the rolls to change in size as shown in Figure 1b?

The problem is nearly the same for plumes to explain ridge migration. Courtillot et. al (2003) show that some of the proposed mantle plumes (" hot spots") are near ocean ridges, as Morgan (1971) proposed, but only in a few places. If plumes are always stationary and near mid-ocean ridges it is more likely that the manifestation of the plumes (igneous provinces, ocean island basalts etc.) are caused by what causes the ridges in the first place than by heated mantle that starts at the core mantle boundary (CMB). For example, examine Figure 5.9 in the textbook by Kearey, et. al. (2009). This figure clearly shows that "hotspot tracks" start out at the continents when Pangaea broke up and "moved" with the ridges toward their present locations. For example, the spot on the Walvis Ridge started out at the coast of Africa 113 Ma (million years before the present) and that on the Rio Grand Ridge started out at the coast of South America at about the same time and both have moved to be near their present locations of the Mid Atlantic Ridge. But the ridge has moved. So the "spots" have also moved. It is likely that the "spots" are caused by whatever causes the ridge. It is, therefore, impossible that the spots are the cause of seafloor spreading. Some form of shearing, extension, or "leaky transform faults" near the ridge, would cause the magma of the asthenosphere to move to the surface, perhaps by thermal contraction of the crust (Turcotte, 1974).



(a)



(b)

Figure 1: (a) Position of proposed convection currents at the time of the break-up of Pangaea and (b) showing that the "rolls" of convection would have to get larger after some time following the break-up of Pangaea. Plumes would also have to move under the ridges.

Morgan (1971) proposed that plumes were fixed with respect to the mantle and that they drive plate tectonics. Morgan (1972, p.208), however, does consider the problem of ridge migration:

> *Why are the mid-ocean rises "mid-ocean" and why is the magnetic pattern symmetrical about the rise crest? It would be easy to imagine that a rise creates new*

sea floor on one side only, analogous to the one-sided consumption of crust in the trench system.

And here he explains the crux of the issue:

As a consequence, rise crests cannot be fixed with respect to the mantle; they must migrate over the mantle to maintain their position midway between continents. An example of such ridge migration is seen for the rise boundaries that enclose Africa on three sides. As the Mid-Atlantic Rise spreads symmetrically, there is ever more sea floor between the rise crest and the African coastline. With a similar increase in the distance from Africa to the crest of the Mid-Indian Rise, the distance from the crest of the Mid-Atlantic Rise to the Mid-Indian Rise must be increasing.

Refer to Figure 1 or any globe or map of ridges on the Earth, to see how this works. And then Morgan (1972) changes the idea of fixed mantle plumes that was proposed in Morgan (1971).

Thus both rises cannot be fixed with respect to the mantle – one or both must be migrating over the mantle. The Mid-Atlantic Rise apparently is fixed to the mantle, as all the Atlantic plumes are near the present crest. Thus it is the Mid-Indian Rise that is migrating east at a rate faster than the African plate is moving northeastward.

This is where Morgan is trapped by his Ruling Hypothesis (Chamberlin, 1890, 1897) and has not taken Chamberlin's warning seriously. As Chamberlin puts it:

The moment one has offered an original explanation for a phenomenon which seems satisfactory, that moment affection for his intellectual child springs into existence; and as the explanation grows into a definite theory his parental affections cluster about his intellectual offspring, and it grows more and more dear to him, so that, while he holds it seemingly tentative, it is still lovingly tentative, and not partially tentative.

And later:

Instinctively, there is a special searching out of phenomena that support it, for the mind is led by its desires. There springs up, also, an unconscious pressing of the theory to make it fit the facts, and a pressing of the facts to make them fit the theory.

And a bit later:

The theory then rapidly rises to the ruling position and investigation, observation and interpretation are controlled and directed by it. From an unduly favored child, it readily becomes the master, and leads its author withersoever it will.

This is what happened to Morgan. His plume idea became his master, and this idea also became the master of many geoscientists who search for measurements, usually through tomography, that attempt to show that deep mantle plumes exist. Only two of these are discussed in this essay, but there are many.

Morgan should have asked why the rises (ridges) east of Africa undergo seafloor spreading even if they are moving very fast. If plumes cause the ridges they would have to move eastward very fast to stay underneath the ridges for them to produce seafloor spreading. He should also have asked how the "plumes" in the Mid-Atlantic Rise cause Africa, and Eurasia to move rapidly to the east? The Eurasian continent is the largest and should be the hardest to move.

On a plaque near the Lincoln statue in front of Bascom Hall at the University of Wisconsin (one of the original buildings) there is a declaration that states the core of the University's mission. It reads:

> *Whatever may be the limitations which trammel inquiry elsewhere, we believe that the great state University of Wisconsin should ever encourage that continual and fearless sifting and winnowing by which alone the truth can be found.*

Chamberlin (1890) who was President of the University of Wisconsin at the time refers to this plaque and he states: "Dust and chaff are mingled with the grain in what should be a winnowing process." Morgan and other enthusiasts of convection and plume mechanisms should have adhered to this advice.

Many papers in the current journals keep the plume myth in the forefront on the discussion on plate motion. A recent example is by Kerr (2013) who reported that the plume hypothesis is supported by much recent work including the study by Brandon Schmandt and his colleagues that a deep plume may exist beneath Yellowstone Park. Using an extensive seismic network, they claim that this "plume" is at least 900 Km deep "below which even their dense data set would not show a plume even if it were there." So they concluded that the "plume" (probably a low seismic velocity zone) comes from the core-mantle boundary! The supposed reason that they cannot see it is that the bottom of the plume is thought to be very narrow. They say that "thermodynamics requires an origin near the core." It seems that this "requirement" is not based upon a clean observation and is mostly speculation based upon many assumptions. Evidently, this study convinced many geologists that many plumes exist. But can a deep plume in the middle of a continent (Yellowstone) support the idea *that plumes cause the plates to move*?

There are many other examples of this type of thinking, but just one more is discussed here. French and Romanowicz (2015 - hereafter FR), using whole seismic waveform tomography and sophisticated computer diagnosis, found what they call broad plumes at the base of the mantle. Their Figure 2 shows thick red zones that seem to extend from the CMB upward to (usually) a depth of about 1000 Km below the Earth's surface. Only one, below Pitcairn Island, passes upwards through the 1000 Km depth line shown in their diagram. Six others (beneath Samoa, Tahiti, Marquesas, MacDonald, Cape Verde and Canary) appear to stop at that depth. The results for below Iceland, Jan Mayen and Guadalupe do not have red zones that extend *below* 1000 Km to the CMB. Rudolph *et. al.* (2015) find evidence that a viscosity jump at 1000 Km may be the cause of "plumes" not penetrating this level or slabs not passing down to the deeper mantle. Note that the plume idea, as discussed by Kerr (2013) above, is that they start out at the CMB as *narrow* upwellings less than 100 Km wide and broaden out at the top of the mantle presumably causing plate motion. The "plumes" of FR start out as *broad*, not narrow, zones in the lower mantle! Which is it? The very many tomographic results examined by this author are often confusing.

Hand (2015) takes the results of FR and produces a diagram that shows three plumes passing through the 1000 Km depth with two subducting slabs also passing downward through this depth. The latter is also not at all shown in the FR Figure 2. The Hand diagram is clearly a "cartoon" based on an interpretation that desires to show that mantle plumes exist. Hand also shows that the plumes bend in small-scale convection in the upper 1000 Km of the mantle. This is also not at all shown in the FR paper. The Hand interpretation seems to be nothing more than an exaggerated opinion that plumes and deep slabs exist. Chamberlin's ruling hypothesis is the problem. But even if there are some plumes it is unconvincing that they can produce plate motion and this is not clearly shown in the nearly all tomography results including those of FR. The "plumes" in Figure 2 of FR are all beneath islands and not ridges so they are not in any position to produce the plate motion by seafloor spreading. It is time to find another set of forces that might work to move the plates (Anderson, 2006).

DISCUSSION

A mind is like a parachute. It only works when it is open.
Don Anderson (Foulger, *et. al.* 2016)

In 1989 the author, together with a seminar group of students, attempted to publish a paper in that was disputed and rejected by two reviewers (see ACKNOWLEDGEMENTS). The reviewers did not respond to the conclusion that the convection model should be falsified because it could not explain ridge migration as discussed regarding Figure 1. Both reviewers did not disprove the mechanism that had been proposed by the authors, but both stated that we would have rejected our own mechanism had we quoted and understood the papers that had been written on the subject. One reviewer mentioned several "critical contributors" that we did not quote. These were "McKenzie, Richter, Sclater, Parsons and others."

Although this author, and probably others in the seminar group, did read many papers by the authors mentioned that was some time ago (late 1980s) so in the past several months this author read or re-read many papers and books on mantle convection and plumes to see if the convection models proposed so far did, in fact, explain ridge migration. This included all of the 69 papers in Bird (1980) and many in other journals that dealt with convection. All of those in Bird (1980) were published by the American Geophysical Union. Papers were searched for (a) the mechanism of seafloor spreading that was assumed by the authors and (b) whether or not migration of ridges was discussed in their modeling.

Sclater (1972) and later Parsons and Sclater (1977) discuss the elevation changes away from mid ocean ridges in a paper that is widely quoted. In both cases the convection current mechanism is assumed to produce the elevation of ridges with heat coming from below but no mention is made of ridge migration (b). Richter (1973), and in later papers, models the cause of ridge elevation and finds small scale convection in the upper mantle, but these bear no resemblance to the pattern of ridges on Earth. These have been called "Richter rolls." He makes no mention of (b). Richter does conclude that it is the "…preeminence of the subducted lithosphere among the driving mechanisms considered…" in agreement with many authors on the importance of slab pull. He gives no discussion of how the convection rolls would cause the plates to move away from ridges. Parsons and McKenzie (1978) develop a model that shows small-scale convection in the upper mantle and conclude that it is driven largely by cooling from above. They provide no discussion of how ridge migration is explained in the model. A search for other papers in which ridge migration is discussed was unsuccessful except for Morgan (1972) that is discussed above.

This search included several books on the problems of convection and plate motion to see if there have been discussions of how and why the ridges migrate. This included Davies (1999), Schubert, et. al. (2001) and Kearey, et. al. (2009). All three of these books start out with the assumption that mantle convection of some kind causes plate tectonics although the idea of mantle plumes is also considered. All provide models of how convection might work both from deep in the mantle and forced by subduction at trenches.

In all there is no explanation of ridge migration. No doubt few of the advocates of convection (or plumes) consider this important anomaly.

The Schubert et.al. book (2001) has the title "Mantle Convection in the Earth and Planets" and they start out in the first sentence with the concept that mantle convection is an obvious phenomenon in the Earth's mantle. It is therefore difficult to see why they neglect to solve the problem of why the ridges between continents move. They provide exhaustive mathematical presentations to show that convection exists without explaining how the models produce most of the simple features of the Earth's crust discussed earlier. Shouldn't this be done first before developing the complicated models? They present arguments of models in two dimensions (Chapter 9) and three dimensions (Chapter 10) and show many diagrams of convection. Like many of these kinds of diagrams in the literature there does not seem to be a resemblance to the pattern of ridges and trenches on the real Earth. Since many diagrams, using different assumptions, are often shown the question is: Which one do we pick?

Some form of mantle convection may exist, but the model results should have a closer fit to the pattern of ridges and trenches than those in the countless number of tomographic results, simulations and mathematical treatments that appear in the literature. Forced convection of the kind that Anderson (2007) discusses is a form of "convection" driven from the top and not from deep in the mantle or even in the upper layers of the mantle by thermal instability.

Anderson (2007b) mentions that the speed of seismic waves, as shown by colors in tomographic studies, results from (a) phase differences, (b) anisotropy as well as (c) temperature so that to conclude that the red and blue colors always indicate hot or cold parts of the mantle may lead to some confusion. Anderson (2007b), Karason and van der Hilst (2000), Dziewonski (2005), several other papers in Foulger *et. al.* (2005) and Anderson (2013) suggest that there are often inconsistencies in the tomographic studies.

For more than three decades this author has examined papers and figures in books that conclude that the results of tomography studies show that convection and plumes exist. In some of these the patterns of red and blue that are deemed to indicate hot and cold regions seem reasonable enough, but on further inspection there are many difficulties with the notion that convection and plumes produce the movement of plates. It seems that there are too many other interpretations of the data and this author concluded that, at least in some cases, the researcher(s) did some selection of the data. It seems to this observer that the blue ("cold") patterns extending down from subduction zones are reasonable in many tomography studies, but when an attempt is made to see that deep plumes or deep convection of hot (red) regions rise to the top of the mantle it is not at all obvious that they show up beneath ocean ridges. There is a continued search for deep plumes and the two papers discussed earlier (Kerr, 2013 and Hand, 2015) were unconvincing in showing that deep plumes produce seafloor spreading.

CONCLUSIONS

Sit down before fact as a little child. Be prepared to give up every preconceived notion, follow humbly wherever nature leads you or you shall learn nothing.

Thomas Henry Huxley (quoted in Anderson, 1984)

Anderson (1984, 2001, 2002, 2005 2006, 2007, 2007c and 2013), Hamilton (2007), Foulger *et.al.* (2005), Foulger *et. al.* (2007, 2010) and Anderson and King (2014) discuss the problem of significant anomalies to the convection models of plate motion. These anomalies have not been adequately addressed.

A partial list of anomalies:

(1) The upper mantle is "lumpy" not homogeneous as would be expected if vigorous convection exists.

(2) The deep mantle is not isothermal or super-adiabatic (unstable).

(3) The core is not an infinite source of heat and most of the heat comes from the upper mantle and crust from radioactive decay of some elements.

(4) It is *not* hotter under ridges than under thick lithosphere and continents.

(5) Only a few subducted slabs sink into the mantle below 670 Km (Hamilton) or below 1000 Km (Anderson).

(6) The lower mantle is probably "sluggish" with a high viscosity.

(7) Plate "rigidity" is assumed and compression in the continental plates is not explained**.**

(8) Slab pull and/or hinge rollback as plate moving forces are often neglected**.**

(9) The Boussinesq approximation is assumed for the deep mantle in most models, but the high pressure near the CMB changes properties such as the coefficient of thermal expansion and viscosity.

(10) The migration of ridges associated with continental plates is not explained (Fig.1).

(11) Geographic variation of spreading rate at ridges is not explained.

(12) The convective forces needed to cause mountains at continental plate collisions are too small because there is little friction in the low velocity layer below the lithosphere.

(13) The fast spreading rate in the East Pacific Rise is usually not explained.

(14) To explain triple points by convection the convection pattern would have to change about 90 degrees in direction at the triple point.

As emphasized in this essay, authors supporting the bottom-up models have great difficulty, or make no attempt, to explain these observations and they amount to what Kuhn (1962) calls anomalies. Apparently, they are ignored nearly universally by proponents of the convection and plume mechanisms. A computer model to show that the bottom-up mechanisms can produce ridge migration would require a most imaginative set of assumptions and even then it probably cannot be done. Mathematical models can illustrate convection in the mantle using many assumptions but the results apply only in the model. Only observations of the real Earth can prove that the models are realistic. For this reason alone, and as implied by the discussion of Menard (1986) above, the convection models also became what Anderson and Hamilton (2008) term zombie science very early after the concept of plate tectonics was developed.

It has now been 100 years since Wegener published his first book on continental drift in 1915. It was shown early on that the forces he proposed for the continents to move were inadequate. But that does not mean that the concept was wrong. Obviously, he was correct that the continents do move. After these 100 years the geosciences still have no convincing mechanism on what causes plate motion. These forces will be revealed in the future, but it may take some time.

As Anderson (2007c) points out*:*

The scientific method does not apply when conventional wisdom starts to fall apart. Defenders of an existing paradigm use their own ground rules and assumptions to attack the new models.

But the scientific method, using the comparison of multiple hypotheses, really works to test hypotheses and if used properly it can make science move rapidly as Platt (1964) states. He points out that knowledge in the fields of molecular biology and atomic science advanced rapidly by the conscious use of Bacon's method. Only this approach will remove the zombie science of the plutonic mechanisms. This will probably not happen very soon, but if Anderson, Hamilton, Foulger and many of the authors in the mp. o quoted in this essay, are correct the "truth" will come out at some time in the future. It always does in the form of a paradigm shift.

The bottom-up models should be rejected by the sifting and winnowing processes advocated by those who support the plate models that are quoted above. In the case of the top-down (or plate models) of Anderson (2001, 2006) and Hamilton (2007) it is easy to add a mechanism driven by expansion and contraction (EC) of the Earth's crust to the top-down gravity ideas to give a complete and parsimonious explanation of the observations that are listed in this essay.

This essay is ended with a quote from the movie "The Wizard of Oz." This was the first movie that the author viewed and the first book he read. Anderson and Hamilton (2008) quote the Munchkins after Dorothy's house lands on the wicked witch of the East. It is the desire of this author to be part of this merciful process regarding the geomyths of convection and plumes discussed in this essay (see ACKNOWLEDGEMENTS) no matter how long it may take.

Ding dong the witch is dead. Let the joyous news be spread…She's not only merely dead…She's really most sincerely dead.
From the 1939 movie of Earl Frank Baum's "The Wizard of Oz."

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In my unpublished book (Scott, 2015) I give a lengthy section on acknowledging those who helped in the thinking process that led to an alternative mechanism of plate motion and why the existing conventional wisdom may be wrong. That will not be repeated here (*). Many of the ideas in this essay originated in discussions of a seminar group that met for two years, every other Saturday, after which we wrote a paper in1989 entitled *Crustal Expansion and Contraction in response to climatic change as a mechanism for driving the Earth's Tectonic Plates.* The participants were G. Hakim, C, Memrick-Hawks, A. Mainolfi, N.E. Rosenbach and A. Rutherford. That paper was disputed and rejected by two authors, but is revised in Scott (2015).

I especially acknowledge those colleagues who helped me to discover the many anomalies to the convection and plume hypothesis and who led me and my students to develop an alternative mechanism of plate motion. These include former professors at the University of Wisconsin, my colleagues and friends at the University at Albany, especially Duncan Blanchard, Ulrich Czapski, Eugene McLaren, Dave Fitzjarrald, Bernard Vonnegut, Chris Walcek and the student co-authors of the paper Scott (1989) mentioned above. I am also indebted to Peter Flaherty, Nina Scott Frisch and Eugene McLaren for many useful comments on the writing that was rather messy before they helped in that process.

*For a free, postage paid, copy of Scott (2015) *Top-down Tectonics: The Role of Oceanus and Gaia* contact jscott34@nycap.rr.com.

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