• IV •

Modelling the Earth: a brief history

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This introduction is summarised from a preface written for me by Stefan Cwojdziñski[1], included in my first book called *Terra Non Firma Earth* (Maxlow 1995), and it aptly describes the state of play in tectonics today.

> "When studying the history of the creation and formulation of Plate Tectonics one can come to the conclusion that it is, and was at best only a hypothesis. A hypothesis, which uses an assumption as its basis. This is the assumption that the Earth has retained a constant size during its geological evolution. This assumption however is not supported by facts. When Carey (1958) and Heezen (1960) formulated the concept of lithospheric plates and the spreading of oceanic lithosphere, for instance, they pointed out that oceanic spreading is a manifestation of an expansion of the Earth. Plate tectonics, presented as a 'new global tectonics' rejected this conclusion, based on the assumption of a constant size of the Earth. So Plate Tectonics is in fact the concept of a 'non-expanding Earth'.
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> As a generation of geologists active in the sixties and seventies of last century still remember, discussion amongst different geotectonic ideas was very active. This generation was witness to the formulation of Plate Tectonics and was of course conscious of its basic assumptions. Subsequent generations have since lost this consciousness. Now the picture of the dynamics and paleodynamics of our planet, shaped during university studies and professional work, leaves no place for questions or doubts.
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> The dominating paradigm of Plate Tectonics and its *ad hoc* models now makes it easy to interpret more and more data and account for this data according to simple ideas. Undoubtedly this is one of the

[1] *See also the chapter by Stefan Cwojdziñski.*

> reasons for the acceptance of Plate Tectonics – the first in the history of geology, a global theory trying to explain almost all geologic processes.
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> Simultaneously Plate Tectonics refers to the deeply rooted belief, held by many geologists, in the idea of geological actualism and so it satisfied them. It was much easier to accept a theory which assumed a constant Earth dimension during its geological evolution and a repeatability of contemporary processes, rather than look at it from the point of view of Earth expansion. Acceptance of Earth expansion would require acceptance of geological evolution, were the physical parameters of the Earth change and hence would influence such processes as sedimentation, tectonic deformation, metamorphism and magmatism.
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> These and other reasons have created a unique situation in the history of the Earth sciences. The big discussions between geotectonists have ceased. The competition of scientific programs has died. Plate Tectonics has become a unification of the notional apparatus of geotectonics. The qualitative development has been replaced by quantitative incrementation of information. The competition of ideas – the basis of any progress in science - has now ceased."

With these introductory insights of Cwojdziñski kept in mind the intent of this chapter is to present a brief history of physical modelling the Earth, in particular in relation to assemblage of continents on an ancient Earth in context with an increasing radius Earth concept. It is this modelling that provides the key to, and compelling visual evidence for, an increase in Earth radius over time which is vitally important for the continued promation of this tectonic process.

In the 7 September 1963 issue of the scientific journal *Nature* a modest contribution titled *"Magnetic anomalies over ocean ridges"* appeared which heralded a profound advance in our understanding of the Earth. The authors were Fred Vine and Drummond Matthews. In order to explain the shapes of anomalies observed from magnetic profiles measured across mid-ocean-ridges, they brought together ideas that the Earth's magnetic field occasionally reverses in polarity and proposed that the ocean basin's are created by a more-or-less continuous volcanic process referred to as "*sea-floor spreading*." From this they showed how the magnetic anomalies record not just the changing Earth polarity, but the *"entire history of each of the ocean basins."* They then concluded that continents and oceans must migrate constantly over the surface of the Earth. This research effectively quantified what was previously referred to as Continental Drift, as published in "*The Origin of Continents and Oceans*" by the German polar explorer Alfred Wegener in 1912. The Vine-Matthews Hypothesis, as it was referred to, then provided the catalyst for the replacement of this contentious Continental Drift theory with the now all-to-familiar theory of Plate Tectonics.

In researching and promoting the concept of Continental Drift during the 1950s, however, Professor Samuel Warren Carey, Emeritus Professor of geology at the University of Tasmania, made a scale model of the present-day Earth in order to investigate the potential fit of the continents during closure of each of the oceans. In addition to the Atlantic Ocean, his investigation was extended to also consider fitting the various continents together within the Indian and Pacific Oceans. It is important to mention that Carey made an early observation that the trans-Atlantic continental fit was not as good a fit as Wegener and others had previously claimed. His comments and conclusions from this research are reproduced in full as follows:

> "At an early stage in my investigations I went to some pains to ensure that I compared and transferred shapes and sizes of the continental blocks accurately. I have spent tedious years plotting large oblique stereographic projections about diverse centres not only for Africa and South America but for every piece of the Earth's surface. I combined this with spherical tracings from the globe, working on a spherical table. The reward for this zeal for accuracy was frustration. Again and again over the years I have assembled Pangaea but could never attain a whole Pangaea. I could make satisfactory sketches like Wegener's classic assembly, but I could never put it all together on the globe, or a rigorous projection. I could reconstruct satisfactorily any sector I might choose but never the whole. If I started from the assembly of South America…by the time I reached Indonesia there was a yawning gulf to Australia, although I felt sure from the oroclines that Indonesia and Australia belonged together...If I started from Australia and Indonesia I had no hope of closing the Arctic Sphenochasm [where the split occurred]…, which I was convinced was basically correct...I was painfully aware that there was a crucial link missing from the global synthesis. I was tempted to abandon the quantitative assembly and resort to sketches which would show every block related as I inferred they should be, even though I knew I could not bring them together that way with the rigour I sought.
>
> But in the end the rigorous approach has paid off. For it has revealed a discrepancy which had not been apparent. It was not my method that was at fault, but my assumption that the earth of

> Pangaea was the same size as the earth of today. The assembly of Pangaea is not possible on the earth of the present radius, but on a smaller globe, a globe such as is demanded by the orocline analysis, these difficulties vanish."

Unfortunately, with the subsequent acceptance and promotion of Plate Tectonic theory, these very important physical observations and conclusions of Carey continue to be neglected and totally ignored to this day. Even with these inherent limitations Continental Drift was adopted by plate theory in order to explain the formation and movement of the continental crusts on a static radius Earth model without any further consideration of alternative proposals. In other words, even though Plate Tectonics goes to great lengths to model the past history of the Earth, "*The assembly of Pangaea is* [still] *not possible on the earth of the present radius*" without "*abandon*[ing] *the quantitative assembly and resort*[ing] *to sketches*." Just look at any Plate Tectonic assemblage of the ancient continents and you will understand what this means, e.g. four difference plate-fit asemblages are shown for the Columbia supercontinent in Fig. 1 highlighting the difficulty in reconstructing Plate Tectonic assemblages with one plate fit option.

Prior to this quantitative modelling exercise of Carey during the 19th and 20th centuries there were a number of additional independent thinkers who considered opening of the oceans could be attributed to an increase in Earth radius. In 1859, Alfred W. Drayson published his book "*The Earth We Inhabit: Its past, present, and probable future*" in which

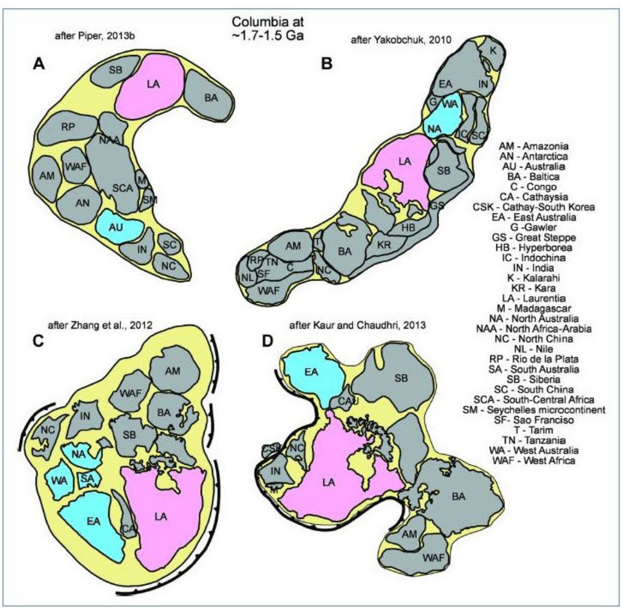


***Fig 1.** An example of four different Plate Tectonic reconstructions of the ancient Columbia Supercontinent at approximately 1.7-1.5 Ga. Note there is no geology and ancient continental outlines are simple sketches made on a flat map. [After Roberts 2013]*

he speculated that the Earth had undergone an *"expansion"* over time. In 1888, Yarkovski was the first to postulate a growth of the Earth mass. Similarly, Roberto Mantovani in 1889, and again in 1909, published a theory of *"...earth expansion and continental drift."* In this theory Mantovani considered that a closed continent covered the entire surface on a smaller radius Earth. He suggested that *"...thermal expansion led to volcanic activity, which broke the land mass into smaller continents."* These continents then drifted away from each other because of further *"expansion" at the "rip-zones,"* where the oceans currently lie. This work was followed later by the pioneering research and publications of Lindemann in 1927, small Earth modelling by Ott Christoph Hilgenberg during the 1930s, ongoing research by Samuel Warren Carey during the 1950s to late 1990s, crustal modelling by Jan Koziar[1] during the 1980s, and small Earth modelling by Klaus Vogel during the 1980s and 1990s.

Hilgenberg, stimulated by the pioneering work of Wegener on Continental Drift, has been attributed as being the first model maker to fit all of the present-day land masses together to completely enclose a small papier-mâché globe and in 1933 his work was published in his classic book *"Vom Wachsenden Erdball"* [About the growing Earth]. On each of his globes (Fig. 2) all oceans were progressively eliminated and

[1] *See also the chapter by Jan Koziar.*

Fig 2. *Reproductions of Hilgenberg's small Earth models, attributed to being the first small Earth models constructed. The size of the small globe to the left is approximately 60 percent of the present Earth shown on the right. [From Maxlow, 2018]*

the remaining continental crusts enclosed the entire Earth on a globe at about 60 percent of the diameter of the present Earth.

More specifically, Hilgenberg's reconstruction across the Atlantic was considered to be convincing, however difficulties were encountered in the Indian Ocean due to a greater dispersion of continents and an uncertain initial position of India and Madagascar. The Pacific region was the most difficult to reconstruct, as workers to follow also found. Unlike the Atlantic and Indian Oceans, where the borders of these oceans retained their shapes, the Pacific borders were considered by Hilgenberg to have opened much earlier and hence the shape of these borders remained tectonically active throughout the continental dispersal times.

To explain the expansion process Hilgenberg postulated that the mass of the Earth, as well as its volume, "*...waxed with time*." Because of this stance and the several problems inherent in his reconstructions, Hilgenberg's ideas were largely ignored and he has since received scant recognition for his efforts.

In 1983, Klaus Vogel published a comprehensive set of scaled small Earth models, or "*terrella*"—meaning small Earth—as he referred to them. These models were made at various diameters, including a representation of a 55 percent reassembled globe inside a transparent plastic sphere of the present-day Earth (Fig. 3). Each of Vogel's models is unique in that his work coincided with the first publication of sea-floor geological mapping, as promoted by Vine and Matthews in 1963. For the first time, this geological mapping enabled Vogel to accurately constrain both continental and sea-floor crustal plate assemblages back in time, without having to resort to arbitrary fragmentation of the continents or to visual fitting-together of the various crustal plates, as predecessors had done.

This visual fitting-together is a very important point to take note of because all previous small Earth model makers, while having enough foresight and courage to remove sea-floor crusts, were faced with the less than envious task of having to visually fit together the remaining continental crusts without any form of quantitative constraint. This visual fitting was done prior to publication of sea-floor geological mapping and hence did not have the benefit of being able to accurately constrain or position the crustal fragments relative to each other.

Vogels modelling is unique in that he was the first to accurately constrain plate-fit using the sea-floor geological mapping first published during the 1980s. Because of this, he was able to construct accurately constrained models with a high degree of precision using magnetic anaomally mapping within each of the ocean basins. Each of

Fig 3. *Vogel's 1983 "terrella" models at various stages of increase in radius commencing on the far left with a continental reconstruction, without continental shelves, at 40 percent of the present Earth radius. A 55 percent radius model is also shown within a transparent sphere of the present day Earth at the right, demonstrating a radial motion of increase in Earth radius. [From Maxlow, 2018]*

his models demonstrated a greater dispersion of the southern continents, compared to those in the northern hemisphere, and he also noted a marked westward movement of all the northern continents relative to the southern continents. His models demonstrated that, in general, the continents tend to move out radially from their ancient positions to reach their modern positions. Vogel commented that this demonstration is an "...*odd coincidence for any theory except that of expansion of the Earth*."

From his extensive modelling studies, Vogel published a number of articles and gave a comprehensive outline of the fit of continental fragments under the headings of the ancient supercontinents Gondwana and Laurasia. On Vogel's models, these ancient supercontinents represent an assemblage of the ancient continental crusts, which agree in principal with conventional tectonic theory, however, on Vogel's models the continents are more tightly assembled on a reduced radius Earth model.

Vogel considered that development of the oceans commenced during the early Mesozoic Era—starting around 200 million years ago—and breakup and dislocation of the continental fragments was considered to be due to a widening of the oceans, centred along the mid-oceanic crustal spreading zones. Vogel went further to consider the two hemispheres of the Earth as complementary counterparts, with no need for consideration of additional ancient oceans, or for arbitrary breakup or fragmentation of the continents, as is required on constant radius Earth Plate Tectonic models.

Vogel concluded from his modelling studies that:

- At a reduced Earth radius of between 55 to 60 percent of the present radius, the continental outlines can be neatly fitted together to form a closed crust.
- The positions of the different continents with respect to each other remain generally constant, with their separation caused by a radial *"expansion"* of the Earth.
- The cause of the movements of continents has resulted from an accelerating increase in Earth radius with time, in accordance with sea-floor spreading.

Vogel also made comment that "*...an accordance of these three phenomena cannot be accidental,*" but must be due to "*...processes operating from within the interior of the Earth resulting in Earth expansion.*" In addition to these observations, Vogel realized that it was theoretically possible for the continents, without their continental shelves, to fit together on an even smaller Earth globe calculated to be approximately 40 percent of the size of the present Earth. He based this observation on his comment that *"...the continental shelves must have formed only after the brittle upper crust had broken into pieces."*

What each of these researchers have shown is that, like Wegener and others had suggested for closure of the Atlantic Ocean, if each of the oceans are removed and the remaining continents are fitted together using sea-floor geological mapping they neatly envelope the Earth with continental crust on a small Earth globe some 50 to 55 percent of its present size during the early Mesozoic Era [around 200 million years ago]. This coincidence led both Hilgenberg and Vogel, and similarly Carey from his early Continental Drift studies and Koziar from his extensive mathematical and crustal modelling studies, to come to similar conclusions that *"terrestrial expansion has brought about the splitting and gradual dispersal of continents as they moved radially outwards during geological time."* And, in particular, that *"an ancient Pangaean crustal assemblage on a small Earth globe, at between 50 to 60 percent of the present Earth radius, can produce a tight and coherent fit of all continents."* So, are these empirical observations fact or mere coincidence?

Fact or Mere Coincidence

In the mid-1970's when all this research was going on I was working in the Pilbara region of Western Australia. As a recently graduated up and coming professional geologist working at one of Australia's premier iron ore mines I started thinking about the geology, and in particular the geological history of what is referred to as the Pilbara Craton. The Pilbara Craton is described as an old and stable part of the ancient continental crust located in the Pilbara region of Western Australia. The Pilbara Craton is one of only two pristine Archaean 3.6-2.7 billion year old crusts identified on the Earth, along with the Kaapvaal Craton in South Africa. Both locations are said to have once been part of the Vaalbara Supercontinent.

My thoughts at the time revolved around trying to understand the origin of the huge, essentially domal structure of the Pilbara Craton. This domal structure is of the order of 300 by 500 kilometres where up to 30 kilometres of rock has been eroded from the central parts of the dome leaving a rim of relatively younger rocks along the flanks. After much thought my conclusions came down to considering that the craton may have represented a fragmented remnant of an ancient, much smaller radius, Earth crust. This was radical thinking which led me to do a search on the expanding Earth theory at the local library. My search located the recently published book called *"The Expanding Earth"* written by Professor Sam Warren Carey, published in 1976. While I was elated to read this book I did feel as though I had been pipped at the post so to speak. While I was still convinced that my Pilbara observation was correct and that I had something useful to contribute, it took a further 15 years of working and raising a family to finally find the time to do formal research.

In the early 1990s my original geology degree was getting rather tattered and outdated so, thanks to a downturn in the mining industry and being made redundant from my role as mine geologist with a gold mining company based in Perth, Western Australia, I decided to return to university. My initial intent was to refresh my degree but my longer-term aim, pending family and finances, was to do post-graduate research into the expanding Earth theory. After completing a Bachelor of Science degree followed by a Bachelor of Science degree with honors in geology my opportunity came in 1993 when I commenced a Master's degree. By that time I had befriended a number of sympathetic staff at Curtin University of Technology, Perth, and they were keen to support me in my research.

My Master's research thesis, titled *"Global Expansion Tectonics: The Geological Implications of an Exponential Earth Expansion From the Archaean to the Present,"* set out to unify and quantify the concept of Earth expansion, as conceived and developed by such notable workers as Hilgenberg (1933), Carey (1958, 1976, 1988), Koziar (1980) and, Vogel (1983, 1984, 1990), and to establish a sound mathematical credence through extensive quantitative modelling of available modern databases. It should be noted that this is also where I first proposed the term *"Global Expansion Tectonics"* to replace the less popular terms Expanding Earth and, more recently, Growing Earth.

To present Earth expansion as a viable global tectonic concept and to present a mathematical expression for increase in Earth radius over time a series of eleven spherical scale models of the Earth (Fig. 4) were constructed (Maxlow, 1995) utilising the global geologic mapping data of Larson *et al.*, 1985. These models demonstrated that continents, when reconstructed on small Earth models, coincide fully with the sea-floor spreading and geological fit-data. This coincidence applied not only to the passive margin oceans such as the Atlantic, where conventional reconstructions agree in principle, but also to the Pacific Ocean where the necessity for subduction of all or part of the oceanic crust generated at spreading ridges was contested. From this, I was able to conclude that the mechanism of sea-floor spreading, as defined by sea-floor geological mapping, provides a definitive means to accurately constrain and quantify post-Triassic expansion of the Earth.

It was further concluded in Maxlow (1995) that post Triassic Earth expansion is a viable alternative global tectonic process which

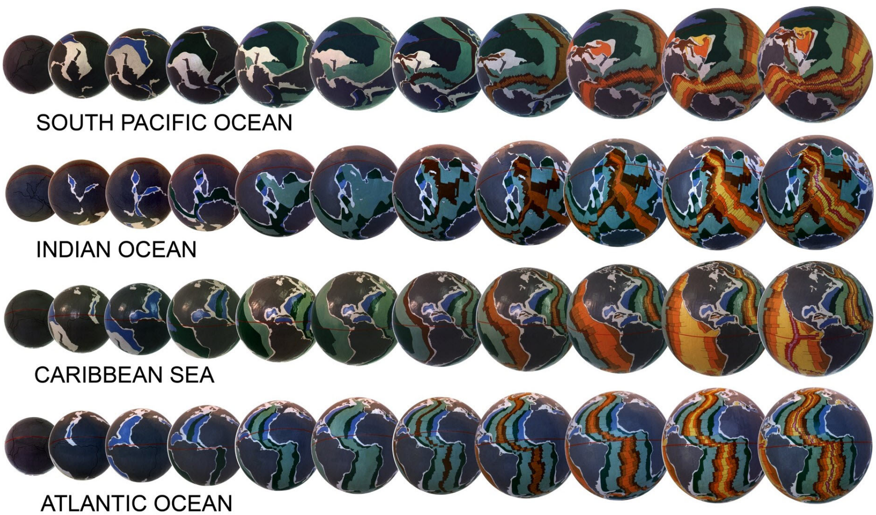


Fig 4. *Spherical small Earth models of the Jurassic to present-day increasing radius Earth. Each small Earth model demonstrates that the sea-floor crustal plate assemblage coincides fully with sea-floor spreading and geological data and accords with the derived ancient Earth radii. [From Maxlow, 1995]*

potentially enables the dynamic principles behind all geologic phenomena to be resolved and readily explained.

During this same time I was also introduced, via Professor Carey, to researchers in both Poland and Germany, including Jan Koziar, a geology lecturer from the Wrocław University, Poland, and Klaus Vogel, a Civil Engineer and small Earth modeller from East Germany. Both Jan and Klaus were kind enough to invite me on a two week lecture tour of Germany and Poland in 1995. While in Germany I stayed at Klaus' home in Werdau where we were able to compare and contrast our small Earth globes (Fig. 5). It came as no surprise that both sets of globes, created independently using much the same published mapping data, were virtually identical. While in Poland under the guidence of Jan Koziar my set of globes were purchased and after being on display at various locations in Poland now reside in the geological museum at the Wrocław University (Fig. 6).

The success of my post-Triassic modelling studies presented in my Master's theisis then prompted the need to extend research and modelling studies to the Archaean by incorporating continental

Fig 5 & 6. *The picture at left shows the author (right) with Klaus Vogel (left) comparing and contrasting each of our small Earth globes at Werdau, Germany, 1995. The picture at the bottom shows Stefan Cwojdziñski admiring my same globes on display at the geological museum of the Wrocław University, Poland.*

geology and applying the concept of Earth expansion to modern global geological and geophysical data. After a few years back in the work force I then made the decision in 1999 to return to Curtin University to complete a PhD by research. I was grateful for financial assistance received through the Australian Postgraduate Award Scheme to complete this research. The title of my research thesis was: *"Quantification of an Archaean to Recent Earth Expansion Process Using Global Geological and Geophysical Data Sets."* I graduated in 2002 where I was also awarded a "*Letter of Commendation*" from the Dean of the universiy for original and thought provocing research.

During the early stages of this research I was fortunate in locating the *"Geological Map of the World"* first published by the Commission de la Carte Geologique du Monda, Paris and UNESCO in 1990. I was also fortunate in having worked with a young geologist, Simon Brown, at my previous employment who, after we gained permission from the Commission de la Carte Geologique du Monda, proceded to digitise the entire Geological Map of the World at 1:25,000,000 M scale (Fig. 7). This digitised map then formed the basis of all my PhD and ongoing modelling and research.

The colours depicted on this geological map represent rocks that have been deposited, intruded, or extruded during set intervals of

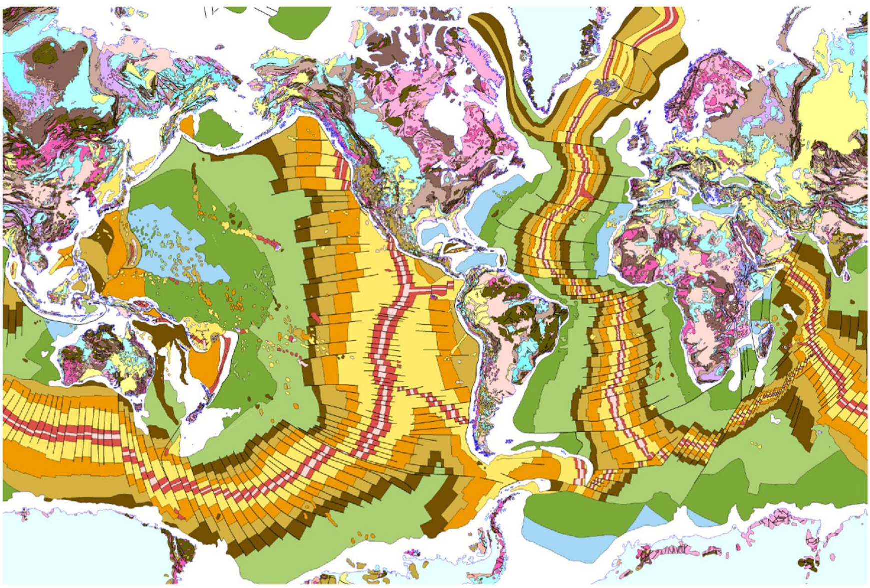


Fig 7. *Geological Map of the World, 1990. Digitized with permission from the Commission de la Carte Geologique du Monda, Paris and UNESCO.*

geological time. The colours do not represent specific rock types, although at the map scale used there is a broad correlation between the most ancient continental rocks shown as red and pink colours, belts of ancient deformed and folded rocks shown as khaki colour, younger sedimentary rocks shown as browns, blues and yellow colours, and the sea-floor crusts shown as various coloured stripes. In effect, this mapping records the *"entire* [growth] *history of each of the ocean basins"* as proposed by Vine and Matthews in 1963.

In Fig. 7, each ocean is shown to contain a mid-ocean-ridge and these ridges are centrally located within each ocean coinciding with the pink Pleistocene stripes. These observations are further substantiated by sea-floor bathymetric surveys which show that the ridges coincide with the distribution of an extensive, centrally located, network of submarine mountain ranges. As is known from modern Plate Tectonic studies these mid-ocean-ridges subdivide the entire Earth's crust into very large, convex, plate-like crustal fragments. Each plate generally includes both continental and sea-floor crust, and the plates are mainly centred on and around each of the continents.

On this map the coloured patterns of sea-floor crustal ages are shown to be symmetrical about the mid-ocean-ridges and their ages become progressively older when moving away from these ridges. This age distribution occurs because new volcanic lava is continually being added along the full length of the mid-ocean-ridge spreading centres—at a rate of centimetres per year. The oldest sea-floor crust in each ocean is early-Jurassic in age—pale blue coloured areas—and these rocks are mainly located along the present continental margins. From these observations, the symmetrical pattern of sea-floor stripes in each of the oceans demonstrates that all continents are moving away from each other as the surface area of each ocean increases over time.

The fundemental basis of my small Earth modelling studies was that, when moving back in time the sea-floor volcanic rocks must be returned to the mantle, from where they originally came from, the surface areas of each of the oceans must, by established protocol, be progressively reduced and each of the continents must move closer together. The uniqueness of adopting an increasing radius model of the Earth is that there is no need to consider where, or when, pre-existing crusts occurred or, similarly, where they must go to. All that is required is to let the configuration of the coloured sea-floor crustal mapping dictate the precise crustal plate assemblages at any moment in time. This published coloured *Geological Map of the World* map then provided me with a unique means to constrain the precise location of all crustal plates at any moment back in time to the early-Jurassic

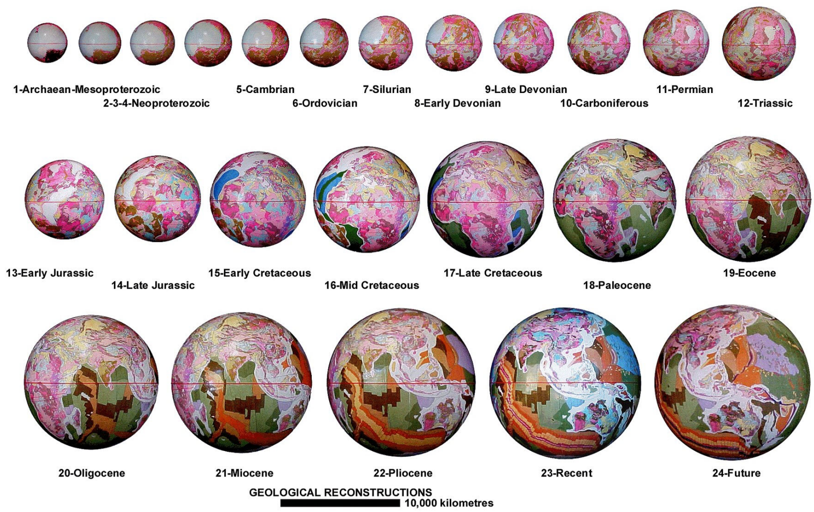


Fig 8. *Spherical Archaean to future small Earth geological models. Models range in age from the early-Archaean [4 billion years ago] to the present-day, plus one model projected 5 million years into the future. [From Maxlow, 2001]*

Period and, in addition, provided me with a means to measure ancient Earth surface areas and hence establish ancient Earth radii.

Utilising this *Geological Map of the World* map the primary objective of my PhD research thesis was to continue modelling the Earth back to the early Archaean and to investigate the concept of Earth expansion as an explanation for observed Archaean to present-day global physical data. To achieve this objective a series of 24 spherical models of the Earth were constructed using 300 millimetre diameter polystyrene foam spheres. These spheres were then digitally resized to the same scale to display and present global geological and geophysical data in an expanding Earth conceptual framework.

For the completed small Earth models (Fig. 8), it was observed that as the coloured sea-floor stripes were progressively removed the remaining coloured stripes neatly close together on each successive model. Each crustal plate assembled together in a unique, orderly, and predictable manner during systematic closure of all the oceans. By removing the coloured sea-floor stripes in succession and refitting the plates together on smaller radius Earth models, each plate was then shown to reunite precisely along their respective mid-ocean-ridge spreading axes, estimated to be at better than 99 percent fit-together for each model constructed. The remaining one percent misfit was simply a combination of map error, cartographic discrepancies, as well as the influence of unaccounted crustal distortion or graphical limitations inherited during model making.

In contrast to the relatively simple sea-floor crusts, continental crust is shown in Fig. 7 to be made up of a diverse range of present-day to ancient rocks dating back to the earliest Archaean times. These rocks include ancient granite and volcanic rocks—pink and red colours, deformed and physically altered sediments and magmatic rocks eroded from the more ancient lands—khaki coloured areas, as well as multiple layers of overlying younger sediments deposited in past low-lying regions—browns blues and yellows depending on age of the rocks. These younger rocks, in particular, often cover vast areas of older rocks. This continental geology is complicated still further by periods of metamorphism, folding, faulting, weathering, and erosion that may have occurred intermittently throughout Earth history.

Construction of pre-Triassic—older than 250 million years old—small Earth models on an increasing radius Earth, extending back to the early-Archaean, involved the progressive removal of all younger continental basin sediments and magmatic rocks and simply returning these rocks to the ancient lands or back to the mantle where they came from. Each continental basin and igneous complex was then restored to a pre-extension or pre-rift configuration on a smaller radius Earth model. By moving back in time the adjacent margins of each sedimentary basin or igneous complex was then progressively moved closer together while still preserving the spatial integrity of adjacent, more ancient, cratonic or orogenic crusts.

It is important to appreciate from this research that these constructed small Earth models are unique and represent the first time that the geology of the Earth has been accurately modelled back to the beginning of the Archaean. This research and modelling was then further substantiated by draping an extensive range of additional global tectonic data from the fields of geology, geophysics, geography, biogeography, palaeontology, metallogeny, space technology, petroleum geology, and palaeomagnetics.

A Paradigm Shift in Thinking

The essence of all my expanding Earth research (Maxlow, 1995, 2002, 2005, 2014, 2018) has been to move away from conventional Plate Tectonics in order to test and quantify the proposal that modern published geological mapping of the oceans and continents can be used to constrain crustal plate assemblages on models of an ancient

Earth. Heavy reliance has been made on using the published bedrock *Geological Map of the World* map (CGMW and UNESCO, 1990) to constrain assemblage of both the oceanic and continental plates. In order to achieve this aim, all preconceptions about Earth radius were simply ignored in order to measure potential changes to ancient radii of the Earth and to establish a formula for determining ancient Earth radii at any moment in time (see Maxlow, 2018).

The modelling studies presented in my research demonstrate conclusively that sea-floor crustal plates, when reconstructed on small Earth models, coincide fully with the sea-floor spreading and geological data and accord precisely with the derived ancient Earth radii for each model constructed, with only one plate-fit option. This coincidence applies not only to the more traditional oceans, such as the Atlantic Ocean where conventional reconstructions agree in principle, but also to the Pacific Ocean where the necessity for subduction of all or part of the sea-floor crusts generated at spreading

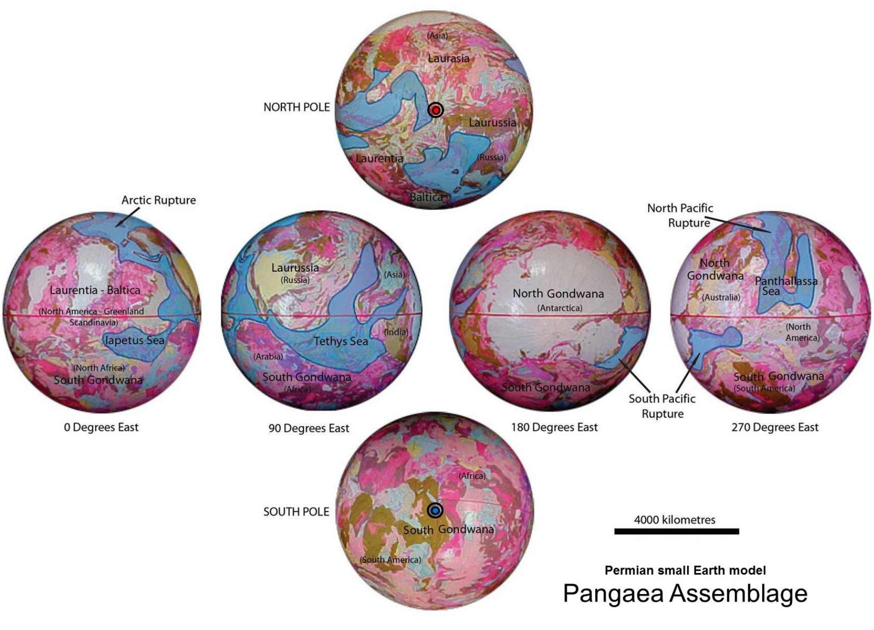


Fig 9. *Permian Pangaea small Earth crustal assemblage. The model shows the ancient coastline distribution (blue lines) as well as the ancient Tethys, Iapetus, and Panthalassa Seas (blue shaded areas) forming part of a global network of continental seas. The figure also shows the locations of continental rupture commencing in the north and south Pacific and Arctic Ocean regions to form the modern oceans. [Coastline data after Scotese, 1994, and Smith et al, 1994.]*

ridges is refuted. This research further demonstrated that all remaining continental crusts assemble as a complete Pangaean Earth at approximately 50 percent of the present Earth radius during the late-Permian—around 250 million years ago (Fig. 9).

Quantification of an increasing radius Earth back to the early-Archaean required an extension of the fundamental cumulative sea-floor volcanic crustal premise to include continental crusts. Continental crust was reconstructed on pre-Triassic small Earth models by considering the primary crustal elements cratons, orogens, and basins. In order to complete the pre-Triassic small Earth models, consideration was also given to an increase in Earth surface area occurring as a result of crustal stretching and extension within an established network of continental sedimentary basins. Moving back in time, this crustal extension was progressively restored to a pre-extension, pre-stretching, or pre-rift crustal configuration by simply

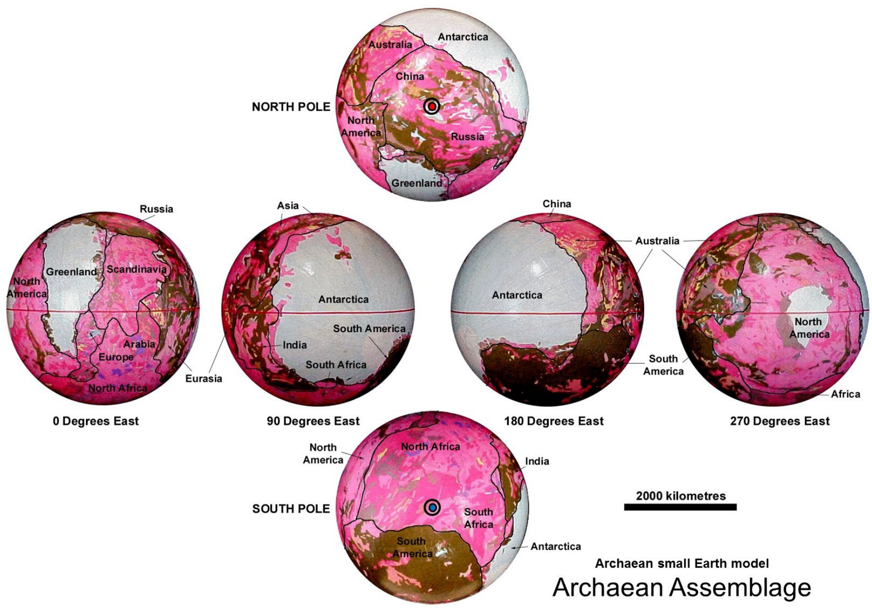


Fig 10. *Primordial Archaean small Earth model showing the assemblage of ancient early-Precambrian continental crusts. Cratons are shown as pink and red, Proterozoic orogenic rocks are shown as khaki and the location of the present-day Antarctic and Greenland ice-sheets (covering Precambrian crustal rocks) are shown as off white. The ancient equator is shown as a horizontal red line and the poles are shown as red and blue dots. Ancient remnants of each of the present-day continents are outlined in black. [Maxlow, 2001]*

removing a proportion of young sedimentary and intruded magmatic rocks and reducing the surface areas of each of the sedimentary basins in turn, consistent with the geological mapping shown on the *Geological Map of the World*.

During this modelling process, the spacial integrity of all existing ancient cratons and orogens was retained until restoration to a pre-orogenic configuration was required. By removing basin sediments and magmatic rocks, as well as progressively reducing the surface area of each sedimentary basin in turn, a potential ancient primordial small Earth with a radius of approximately 1,700 kilometres, representing 27 percent of the present Earth radius, was achieved during the early-Archaean (Fig. 10). This primordial Earth comprised an assemblage of the most ancient Archaean cratons and Proterozoic basement rocks, all other rocks were simply returned to their places of origin—albeit back to the mantle or back to the surface of the ancient lands.

From the outcomes of this empirical small Earth modelling exercise it was concluded that crustal modelling studies more than adequately quantify the validity of an increasing Earth radius global tectonic process. The unique assemblage of all continental and sea-floor crustal plates on small Earth models demonstrate that an increasing radius Earth, extending back 4,000 million years to the beginning of Earth's geological past, is indeed viable. What the full range of Archaean to present-day small Earth models also demonstrate is that, rather than being a random, arbitrary, amalgamation-dispersal-amalgamation cyclical crustal forming process as we are currently led to believe, crustal development on an increasing radius Earth model is instead shown to be a simple, evolving, and predictable crustal process.

It was further considered from this research that, if these small Earth crustal plate assemblages were mere coincidence, it would be expected that the sea-floor mapping, as well as geological and geographical evidence from adjoining continents, would not match across plate boundaries on any of the small Earth models constructed. The evidence instead shows that sea-floor bedrock mapping does indeed match across the plate boundaries, all continental sedimentary basins do merge to form a global network of ancient continental seas, orogenic and fold mountain belts coincide, and ancient crustal regions assemble together precisely.

As Shields astutely put it in 1997, *"Ultimately world reconstructions must be congruent not only with the data from geology and geophysics, but also with palaeobiogeography, palaeoclimatology, and palaeogeography."* The remainder of my research was then dedicated to using these small Earth models as a framework for draping modern global observational

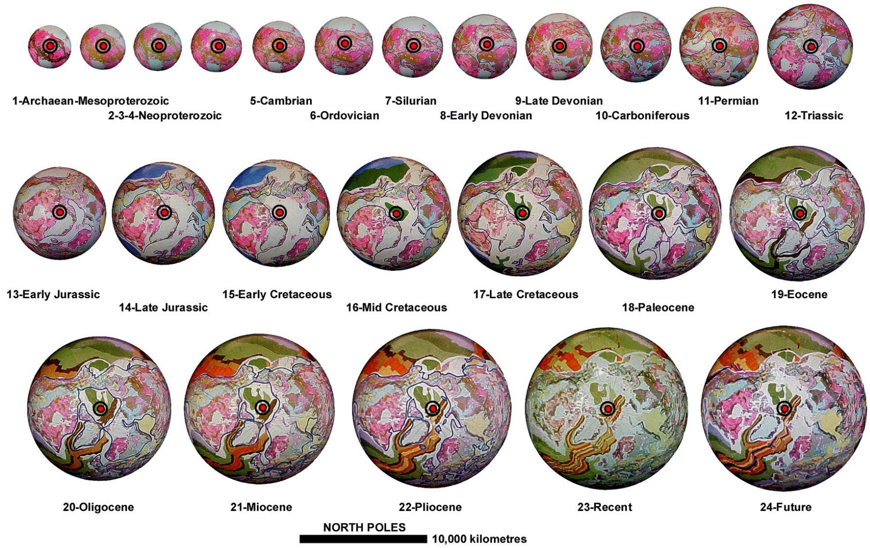


Fig 11. *Small Earth Archaean to Future magnetic North Poles (red dots). (Magnetic pole data after McElhinny & Lock, 1996)*

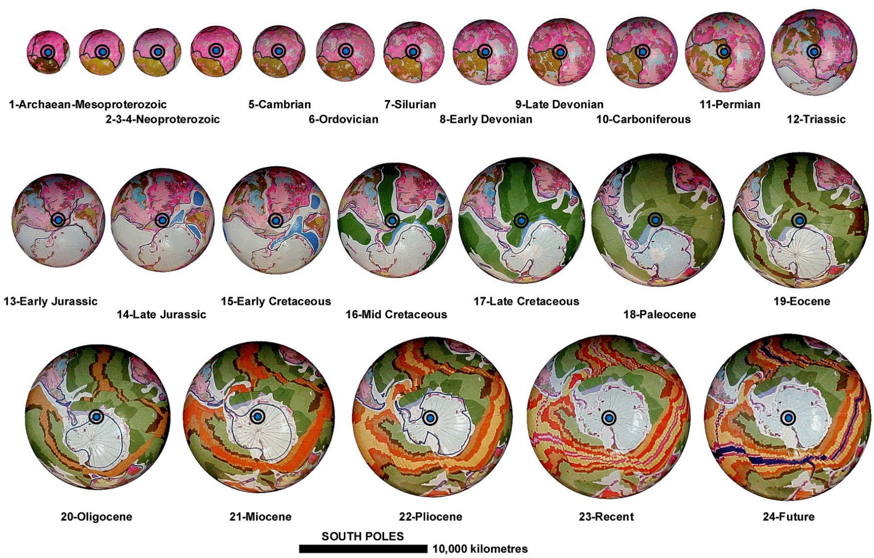


Fig 12. *Small Earth Archaean to Future magnetic South Poles (blue dots). (Magnetic pole data after McElhinny & Lock, 1996)*

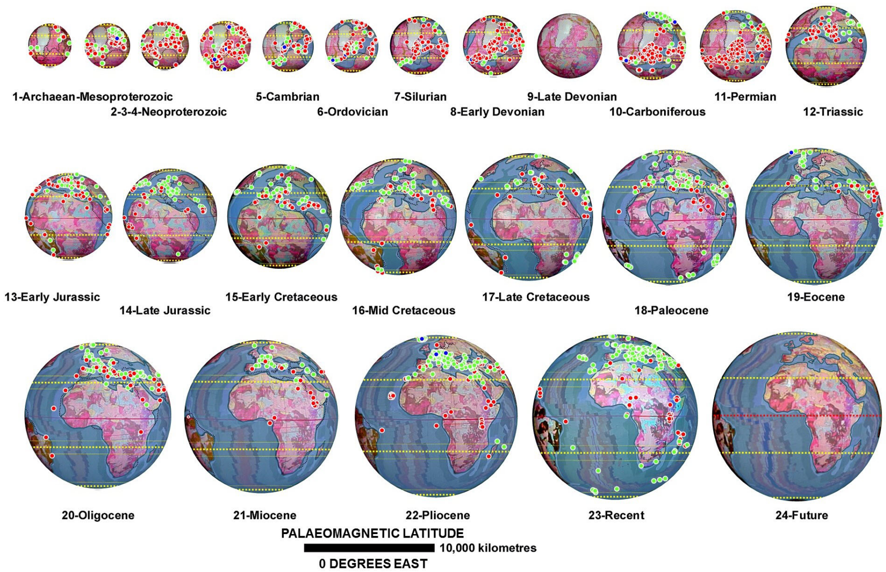


Fig 13. *Archaean to present-day palaeolatitude sample site data centred on zero degrees east longitude. Red dots represent calculated data located in the equatorial climate zones, green dots represent data located in the north and south temperate zones, and blue dots represent data located in the north and south Polar Regions. Heavy dashed yellow lines represent present day climate zone boundaries. Note: no data are shown for the late-Devonian model. (Data after International Global Palaeomagnetic Database, Pisarevsky, 2004)*

data from the fields of geology, geophysics, geography, biogeography, palaeontology, metallogeny, space technology, petroleum geology, and palaeomagnetics to test the distribution and significance of this data.

For example, applying the small Earth modelling to palaeomagnetics showed that all ancient magnetic poles cluster as unique, diametrically opposed, north (Fig. 11) and south poles (Fig. 12)—as they should—and similarly, plotted palaeolatitude data (Fig. 13) coincide with, and quantify, predicted climate zones on each small Earth model constructed. Additional geographical and biogeographical information aptly quantify the location of these ancient magnetic poles, equators, and climate zones as determined from unconstrained palaeomagnetic pole and latitudinal data.

When published coastal geography was plotted on each of the small Earth models it was shown that large, conventional, Panthalassa, Iapetus, and Tethys Oceans are not required on a smaller radius Earth. Instead, this same coastal geography defines the presence of

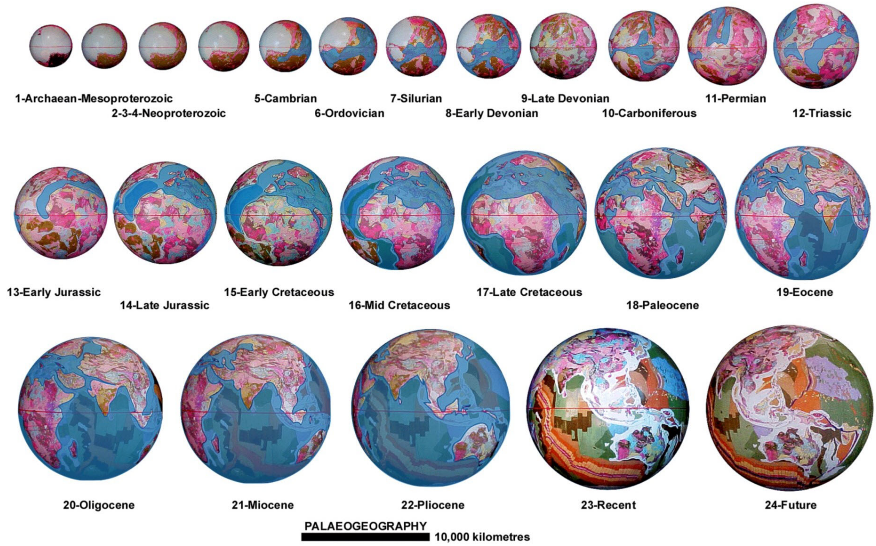


Fig 14. *Shoreline palaeogeography on Archaean to present-day small Earth models. The ancient shorelines are shown as blue lines and the ancient seas and modern oceans are shaded blue. Each image advances 15 degrees longitude throughout the sequence to show a broad coverage of palaeogeographic development. Note: there are no published data available for the late-Devonian model or models prior to the Cambrian Period. (Palaeogeographic data after Scotese, 1994, and Smith et al., 1994.)*

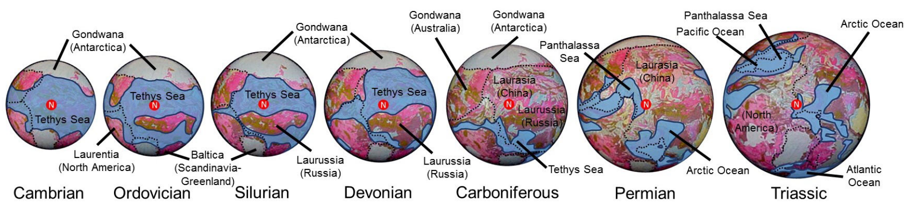


Fig 15. *The Tethys Sea and Laurentia, Baltica, Laurussia, Laurasia, and Gondwana supercontinental configurations centred over the ancient North Pole, extending from the Cambrian to Triassic Periods. (Palaeogeographic data after Scotese, 1994, and Smith et al., 1994)*

more restricted continental Panthalassa, Iapetus, and Tethys Seas (Fig. 14), which represent precursors to the modern Pacific and Atlantic Oceans and emergent Eurasian continents respectively. From this coastal geography the coastal outlines and emergent land surfaces on each small Earth model was then shown to define the ancient Rodinia, Gondwana, and Pangaea supercontinents and smaller sub-continents (Fig. 15). This coastal geography demonstrates an evolutionary progression and development of each of the ancient seas and supercontinents throughout Earth history which was shown to be intimately related to changes in sea-level, changes to the outlines of continental sedimentary basins, changes incurred during crustal mobility, and changes to sea-levels once the modern oceans opened to the present-day.

The timing and development of these ancient continental seas and supercontinents, along with formation of the modern continents and oceans, was then shown to be the prime cause for evolution of all life forms on Earth. On each of the small Earth models, warm sea waters during much of the Palaeozoic extended from equatorial regions through to the North Polar Region allowing newly evolved species to readily colonise and populate throughout each of the interconnected

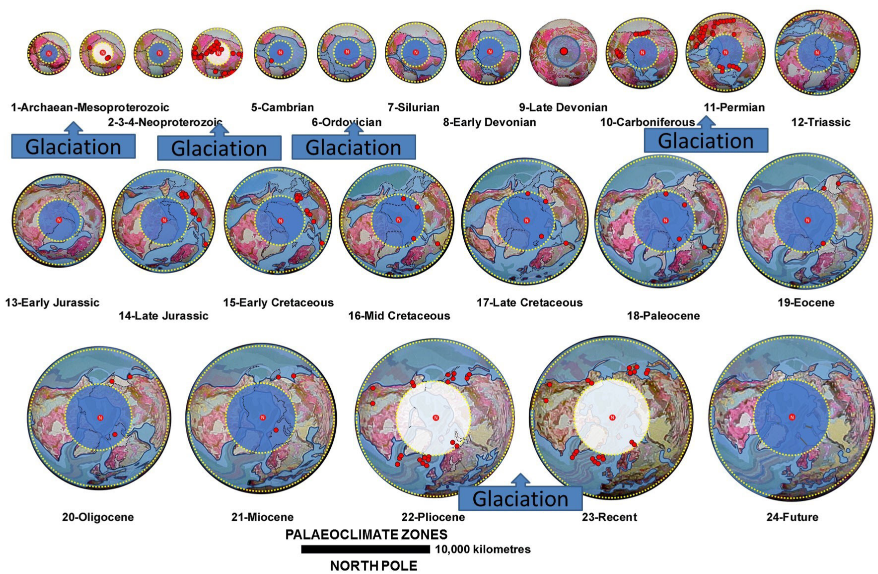


Fig 16. *Locations of ancient North Polar Regions shaded blue on small Earth models. Distribution of known glacial-related rocks are shown as red dots. Glacial events are highlighted, the presence of known ice-sheets are shaded white, and ancient seas and modern oceans are shaded pale blue. (Glacial data after Hambry and Harland, 1981)*

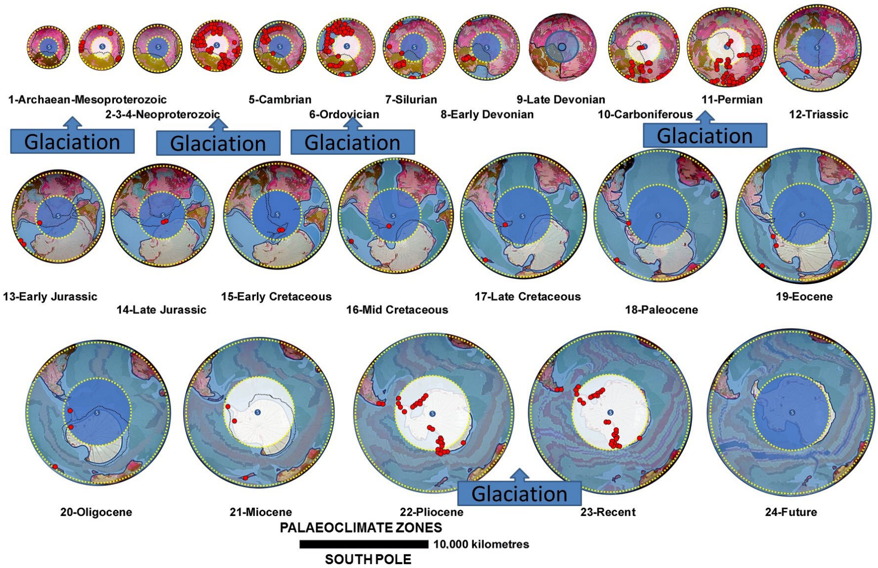


Fig 17. *Locations of ancient South Polar Region shaded in blue on small Earth models. Distribution of known glacial-related rocks are shown as red dots. Glacial events are highlighted, the presence of known ice-sheets are shaded white, and ancient seas and modern oceans are shaded pale blue. (Glacial data after Hambry and Harland, 1981)*

ancient Tethys, Iapetus, and Panthalassa seaways. This distribution of warm seas also limited the presence of a polar ice cap in the North Polar Region (Fig. 16) and instead restricted the presence of ice to the exposed Gondwanan South Polar Region throughout much of that time (Fig. 17).

On an increasing radius Earth the small Earth modelling studies also show that, during early-Palaeozoic to present-day times there have been a number of drastic and prolonged changes to sea-levels which coincide with known extinction events. On these models, major changes in sea-levels are shown to occur as a result of separation or merging of previous ancient continental seas, as well as onset of geosynclinal activity and orogenesis, breakup of the ancient supercontinents, opening of the modern oceans, and draining of the ancient continental seas. Depending on the severity of these events, it was considered that sea-level changes may have also adversely affected regional to global-scale climate, as well as ocean-water circulation patterns, species habitats, and the type and location of sedimentary deposition.

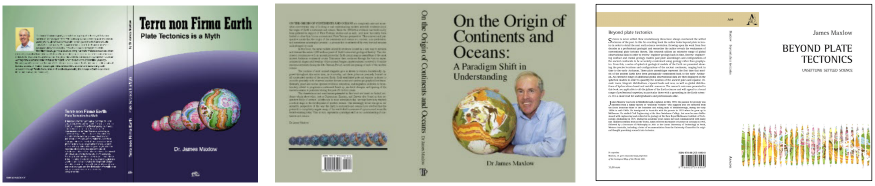


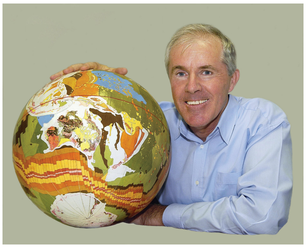
Fig 18. *Publications available: Terra non Firma Earth: Plate Tectonics is a Myth, published in 2005, On the Origins of Continents and Oceans: A Paradigm Shift in Understanding, published in 2014, and Beyond Plate Tectonics: Unsettling Settled Science, published in 2018.*

In summary: it was concluded from this research that the extensive global tectonic evidence and empirical modelling studies presented more than adequately demonstrate that an increasing radius Earth is indeed a viable and demonstrable tectonic process. From a geological perspective, at no point has any fundamental physical law been violated. The commonly held presumption that Earth radius has remained constant throughout time was simply removed and instead, the Earth was allowed to tell its own story.

By ignoring the overwhelming empirical evidence presented in this research and by continuing to accept any shortfalls conventional insistence imposes on the global tectonic observational data, it is considered that this will continue to slow geologic progress in science by maintaining narrow, rigid viewpoints. This ignorance will then continue to perpetuate scientific conundrum by discouraging alternative research and convincing students and scientists alike that the main global tectonic problems have all been resolved. In this context, I maintain that we should at least consider that modern global tectonic data may well be better suited to an increasing radius Earth scenario before continuing to unscientifically reject this proposal out of hand.

This ongoing doctorate and post-doctorate research has been published in three books: *Terra non Firma Earth: Plate Tectonics is a Myth*, published in 2005, *On the Origins of Continents and Oceans: A Paradigm Shift in Understanding*, published in 2014, and *Beyond Plate Tectonics: Unsettling Settled Science*, published in 2018 (Fig. 18).

About the Contributor



James Maxlow was born in Middlesbrough, England, in May 1949 and immigrated to Australia with his parents in 1953 where he grew up in Melbourne. He initially studied Civil Engineering at the then Swinburne College, before redirecting himself to geology at the then Royal Melbourne Institute of Technology, graduating in 1971. Before retiring in 2013 James spent in excess of 40 years working as an exploration and mine geologist throughout much of Australia, gaining valuable field experience and knowledge which he has since applied to research into his other passion—Expansion Tectonics. James gained his Master of Science in geology in 1995, followed by a Doctorate of Philosophy in 2001 at Curtin University of Technology, Perth, Western Australia, including a letter of commendation from the university Chancellor for original thought provoking research into Expansion Tectonics.

This essay was first published as a chapter in the 2020 book, *The Hidden History of Earth Expansion*, which is widely available from good bookshops in both Hardback and Paperback editions, as well as a Google eBook.

The *Hidden History of Earth Expansion* presents the personal histories of some of the most well-known researchers into Earth expansion in 14 original essays. In addition to furnishing us with their personal histories, as they strived to explore the seemingly overwhelming evidence for confirmation of Earth expansion, the authors' highlight areas where further research is required.

The chapters expressly written for the book are:

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