Expansion Tectonics:

A Complimentary Download

The intent of this complimentary download document is to both introduce you to the modern theory of **Expansion Tectonics** and, in particular, to introduce you to the many benefits that **Expansion Tectonics** provides via detailed small Earth models and data modelling studies. These small Earth models use the published Geological Map of the World (CGMW & UNESCO, 1990) to accurately constrain plate assemblages, extending from the early Archaean to the present-day. The methodology and benefits of this modelling study, in particular the Precambrian coverage, are unique to **Expansion Tectonics** and provides you with a modern viable alternative to conventional tectonic studies.

This document is a summary of the extensive research and data modelling studies presented on my website and in each of my publications: **On the Origin of Continents and Oceans** (2014), and **Terra non Firma Earth** (2005), both of which are available in hardcopy and eBook formats. See my website at: www.expansiontectonics.com for details of these publications and a newly released interactive data modelling facility.

"It is important you know the truth about global tectonics"

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Terrella Press

About the Author

James Maxlow was born in Middlesbrough, England in May 1949, exactly 23 years after the birth of his good friend and fellow expansionist Klaus Vogel. James' passion for geology was inherited from a family history of "ironstone workers" supplying ores mined from the Eston Ironstone Mine to the foundries and steel rolling mills of Middlesbrough during the 1800s to mid-1900s.

James immigrated to Australia with his parents in 1953, where he grew up in Melbourne. He studied Civil Engineering at the then Swinburne College, but soon became disillusioned with engineering and redirected himself to a degree in geology at the Royal Melbourne Institute of Technology, graduating in 1971. It was in Melbourne where he later met and married his lovely wife Anita and during their work and travels throughout Australia they had three children, Jason, Karena, and Jarred.

James' interest in the expanding Earth theory stems from working in the Pilbara region of Western Australia during the late 1970s where he first read the book "The Expanding Earth" written by Professor Samuel Warren Carey. The Pilbara region is a huge, Precambrian domal structure, several hundreds of kilometres across. It occurred to James that this relatively undisturbed domal structure may have been a fragment of a much smaller radius ancient Earth.

James gained his Master of Science in geology in 1995, followed by a Doctorate of Philosophy in 2002 at Curtin University of Technology, Perth, Western Australia, including a letter of commendation from the university Chancellor for thought provoking research into **Expansion Tectonics**.

During his academic years James met and communicated with many wonderful "expansionists" from around the world. Most notable of which was the late Professor Samuel Warren Carey from Tasmania, the father of modern Earth Expansion, Jan Koziar from Poland who was the first scientist to measure and calculate the ancient Earth radius, and Klaus Vogel from Germany, the father of modern Expanding Earth modelling studies. It was during James' academic studies that Professor Carey recognized the potential of his research into **Expansion Tectonics**. Carey then kindly *"passed on his Expanding Earth baton"* to James, an honour that James deeply cherishes to this day.

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Preface

"The main cause of intellectual stagnation [is] *the herd instinct which causes many scientists to stay with mainstream ideas and concepts rather than risk alienating their peers by investigating controversial new ideas. The peer review system thus tends to maintain the intellectual status quo by rejecting new ideas."* Gold, 2009

Few people realise that the now largely forgotten Expanding Earth theory was terminally rejected by mainstream science over half a century ago in favour of the fledgling new theory of Plate Tectonics. This rejection of the Expanding Earth theory, as we are still reminded by publications such as Sudiro (2014), was largely due to an inability to provide a convincing cause or mechanism for an increasing Earth radius, irrespective of the large amount of modern empirical geological evidence that has been amassed since then.

Today, thanks to well-meaning scientists, albeit with a vested interest in their academic careers or international reputations, you cannot publish anything if it remotely sounds like an Expanding Earth theory. Publishers will not take the risk—the theory is considered far too controversial. Similarly, if you try to publish anything on Wikipedia, for instance, all reference is removed within hours. So, what hope is there for so called advancements in modern science when you cannot challenge Plate Tectonics simply because you lost your chance half a century ago?

Irrespective of this rejection, the Expanding Earth theory has been kept alive by extensive research and modelling studies by, amongst many others, Professor S.W. Carey (1958, 1963, 1975, 1976, 1983a, 1983b, 1988, 1996), Klaus Vogel (1983, 1984, 1990), and **Expansion Tectonic** research by myself, James Maxlow (1995, 2001, 2005, 2014). However, damning palaeomagnetic evidence by McElhinny and Brock (1975) and more recently space geodetic research by Shen *et al* (2011, 2015) have continued to convince mainstream science that this theory should remain rejected.

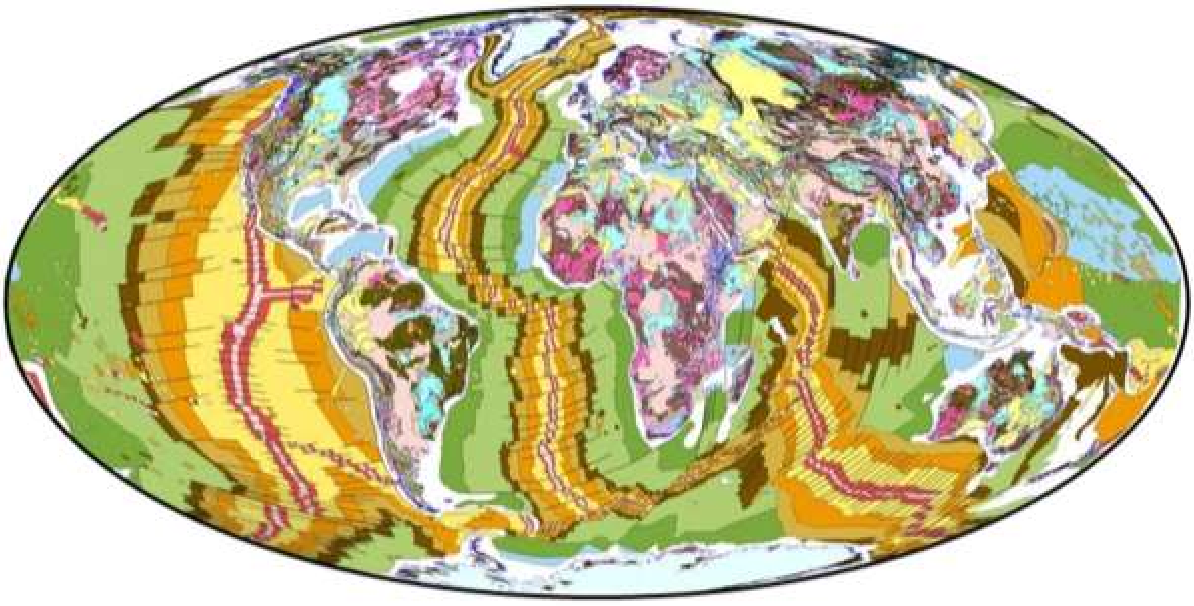
The purpose of this document is to let you know that modern science has come a long way since the relatively primitive 1960s when the Expanding Earth theory was first rejected. No longer can we justify rejection of any theory based on the outdated opinions or vested interests of a few well-intentioned scientists. Modern protocol now insists that acceptance of any scientific theory should be based on direct observation or direct measurement, in particular observation or measurement using modern data and modern technology, so it is time to at least reconsider the merits of this theory, renamed in this document as **Expansion Tectonics**.

It is important to appreciate that this document is not about rehashing the Expanding Earth theory, it is about informing you about modern **Expansion Tectonics**. Modern **Expansion Tectonics** uses the exact same global plate data collected in support of plate tectonics, it is only the interpretation of this data and primary assumptions that differ. More specifically, **Expansion Tectonics** uses global geological mapping to accurately constrain plate assemblages on geological models of the Earth extending back to the early Archaean, whereas Plate Tectonics does not. Plate Tectonics instead uses palaeomagnetics and struggles to constrain geophysical assemblages back to the early Palaeozoic.

***Expansion Tectonics** uses global geology to create geological models of the Earth, plate tectonics uses palaeomagnetics to create geophysical models. The difference is simple.*

Since the 1960s, two significant revelations to modern global data gathering have become available to all scientists that have the potential to change the course of global tectonics. Both of these revelations are acknowledged in science but their true relevance to tectonics remains largely unrecognised because their significance does not fit with perceived "normal" Plate Tectonic theory.

The first revelation came about in 1990 with the completion and publication of the "Geological Map of the World" (CGMW & UNESCO, 1990), in particular mapping of the seafloor crusts. This geological mapping has provided a unique insight into the growth history of each of the modern oceans and continents, a history which must be strictly adhered to in any tectonic theory of the Earth. This mapping was essentially completed during the late 1980s, and drilling and sampling of the ocean-floor, for age dating purposes and correlation studies, is ongoing.



A study of this geological map immediately shows a distinct, symmetric, stripe-like growth pattern of seafloor crusts centred over the pink-coloured mid-ocean-ridge spreading zones (MORs). Age dating of the crustal rocks shows that these patterns are youngest along the centrally located MORs and, in all cases, age away from the MORs towards the continents. These growth patterns, in effect, preserve the opening and growth history of each of the oceans, extending in time from the early Jurassic Period, around 200 million years ago, to the present-day.

What these growth patterns mean to tectonics is that, as we move forward in time, new basaltic lava is intruded and accumulates along the entire length of the MORs, which in turn spreads and enlarges each of the oceans. Logic dictates that if we then move back in time this same seafloor crustal process must be reversed. The youngest seafloor crust must be returned to the mantle, from where it came, each of the oceans must be reduced in surface area, and each of the continents must move closer together. By moving back in time, this crustal formation process must then strictly adhere to the seafloor growth patterns shown in the CMGW map, regardless of which tectonic theory is adhered to.

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*The fundamental difference between **Expansion Tectonic** and Plate Tectonic theory is that on an **Expansion Tectonic** Earth the increase in surface area of the oceans is a direct result of an increase in Earth radius.*

Logic dictates that this geological mapping should be a valuable aid in understanding and constraining plate assemblages back in time to at least the early Jurassic Period. This completed mapping though, has proved to be a disappointment for Plate Tectonics and has been less than successful in verifying the expected crustal plate motions on a static radius Earth.

In contrast, it has instead provided an extremely valuable and unique opportunity to constrain, and quantify, crustal motions and crustal plate assemblages on an **Expansion Tectonic** Earth. In addition, the mapping also provides us with a means to mathematically define a potential rate of change in Earth radius with time. This new data represents the first time in history that a potential Earth expansion process has been able to be both scientifically and mathematically investigated and quantified.

The second revelation came about in 2000 when four identical Cluster II satellites were launched to study the impact of the Sun's activity on the Earth's space environment by flying in formation around Earth. For the first time in space history, this mission was able to collect three-dimensional information on how the solar wind interacts with the magnetosphere and how it affects near-Earth space and its atmosphere, including the auroras. This study was undertaken by the European Space Agency and results have shown that it is much easier for the solar wind charged particles to penetrate the magnetosphere than had previously been thought.

A group of these scientists directly observed the existence of certain waves in the solar wind that were not expected. These waves enabled incoming charged particles of solar wind to breach the magnetopause, suggesting that the magnetosphere responds more as a filter rather than a continuous barrier. These discoveries were considered by the European Space Agency's project scientists to be of great importance because it showed how the Earth's magnetosphere can be penetrated by solar particles under specific interplanetary magnetic field circumstances. The study also suggested that these waves may be a lot more common and possibly represents a means for the constant penetration of solar wind into terrestrial magnetospheres, and hence a viable mechanism for an increase in Earth mass, and hence radius, over time.

Beyond the known observations about solar particle flow into the Earth, all else remains speculative once it enters the Earth. As Eichler stated, "*There is therefore no lack of component particles to create new matter deep within the body of the Earth. The exact process by which this occurs is complex in nature and, like the interior of the Earth itself, involves speculation as to its dynamics. It is argued that the avenue of approach proposed here is plausible and warrants further serious scientific investigation. If new matter has been added to the interior of the Earth, there must be an answer to the riddle of the dynamics of the process.*"

At this stage it is envisaged that solar particles, comprising electrons and protons, enter the Earth at the poles and recombine within the 200 to 300 kilometres thick D" region, located at the base of the mantle directly above the core-mantle boundary. Kremp concluded in 1992 that, *"…this thermal increase in the outer core may be a fairly recent process forcing a rapid expansion of the Earth."* New matter formation requires not only pure energy but the presence of both electrons and protons and space technology now knows that these are plentiful from the Sun. The recombination of charged electrons and protons within this D" region then provides a mechanism to form new matter. This matter in turn becomes the building blocks of all elements and mineral species present on and in the Earth including the new basaltic lava, water and gases now being expelled from the mid-ocean-ridge spreading centres in all of the ocean basins.

From an **Expansion Tectonic** perspective, new matter accumulates within the D" region, located at the core-mantle interface. This increase in new matter results in an increase in Earth mass and volume which manifests itself as a swelling of the mantle. The increase in Earth volume and associated mantle swell is then transferred to the outer crust where it results in crustal extension, which is currently occurring as extension along the full length of the mid-ocean-rift zones. Extension within the mid-ocean-rift zones is accompanied by intrusion of new basaltic mantle-derived lava, along with expulsion of new water and gases. These in turn increase the surface area of all of the modern oceans in strict accordance with the seafloor mapping shown in the Geological Map of the World.

1 Introduction

"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet in earlier times, and that the truth of the matter can only be reached by combing all this evidence. . . It is only by combing the information furnished by all the earth sciences that we can hope to determine 'truth' here, that is to say, to find the picture that sets out all the known facts in the best arrangement and that therefore has the highest degree of probability. Further, we have to be prepared always for the possibility that each new discovery, no matter what science furnishes it, may modify the conclusions we draw." Alfred Wegener. *The Origin of Continents and Oceans* (1915)

In 1915 Alfred Wegener, a PhD university professor, was making serious arguments for the idea of Continental Drift in the first edition of his book, *Die entstehung der kontinente und ozeane* [*The Origin of Continents and Oceans*]. In his book, as did mapmakers before him, he noted how the shape of the east coast of South America and the west coast of Africa looked as if they were once joined. When Wegener first presented his arguments for the idea of Continental Drift he became the first to gather significant fossil and geological evidence to support his simple observations for the break-up and subsequent movement of the continents through time. From these beginnings, Wegener went further to suggest that the present continents once formed a single land mass—later to be called *Pangaea*. This land mass was inferred by Wegener to have subsequently broken up and drifted apart, *"…thus releasing the continents from the Earth's mantle."* Wegener likened this too *"…icebergs of low density granite floating on a sea of denser basalt".*

At that time his ideas were not taken seriously and were rejected by most geologists. They rightly pointed out that there was no apparent mechanism for Continental Drift. Without detailed evidence, or a force sufficient to drive the movement, the theory was discounted: *…the Earth might have a solid crust and mantle and a liquid core, but there seemed to be no way that portions of the crust could move around the surface of the Earth.* Unfortunately Wegener could not explain the force that drove Continental Drift, and vindication for his efforts did not come until well after his untimely death. Other responses were less than sympathetic, including: "*Utter damned rot*" (the then President of the American Philosophical Society). "*If we are to believe this hypothesis we must forget everything we learned in the last seventy years and start all over again*" (Thomas Chamberlin). "*Anyone who valued his reputation or scientific sanity would never dare support such a theory*" (a British geologist).

Although rejected for nearly fifty years, when Wegener introduced his theory of Continental Drift he did in fact set in motion a completely new train of thinking and speculation about the origin of our continents and oceans. As Wegener correctly promoted, the fit of the Americas against Africa and Europe was real and had to be explained. Time has, of course, since shown that it was only the mechanism behind Continental Drift that was difficult to explain, not the actual fit of the continents. Since then, with changing ideas about the Earth and also a name change, Wegener's theory of Continental Drift is now credited with having given rise to the modern theory of Plate Tectonics.

All this evidence, including new evidence emerging from both the seafloor and the continental margins, made it clear during the early 1960s that Continental Drift was indeed feasible. From these early beginnings the theory of Plate Tectonics, which was defined in a series of papers published between 1965 and 1967, was born. This new theory of Plate Tectonics is now considered to have revolutionized the Earth sciences and is portrayed as explaining a diverse range of geological phenomena, with supporting implications from other studies such as ancient geography and ancient biogeography. Most people have now come to accept this Plate Tectonic theory without question and without prior concern for the considerable amount of initial and still relevant rejection.

1.1 It doesn't have to be Like That

The suggestion that continents have not always been at their present positions was introduced as early as 1596 by the Dutch map maker Abraham Ortelius. Ortelius suggested, based on the symmetric outlines of the Atlantic coastlines, that the Americas, Europe, Asia, and Africa were once joined and have since drifted apart *"...by earthquakes and floods"*, creating the modern Atlantic Ocean. For evidence he wrote: *"The vestiges of the rupture reveal themselves, if someone brings forward a map of the world and considers carefully the coasts of the three continents."* As mentioned above, in 1915 Alfred Wegener also noted how the east coast of South America and the west coast of Africa looked as if they were once joined. Wegener went further to suggest that the present continents once formed a single, what is now referred to as the *"Pangaean land mass"* that subsequently broke up and drifted apart.

So, did Wegener get it all wrong? No, he didn't get it wrong. In fact, he is justifiably credited with being one of the first scientists to apply correct geological observation to support and substantiate his claims. But, what he and others subsequently didn't do was to go far enough. What he and others failed to recognise was that, as well as fitting the South American and African coastlines together to come up with a reasonably approximate fit-together, the remaining Indian, Pacific, and Southern Ocean coastlines can just as easily be fitted together, with similar fossil and geological evidence to support these observations.

In researching the concept of Continental Drift during the 1950s, the late Professor S.W. Carey, formerly Emeritus Professor of geology at the University of Tasmania, made a scale model of the Earth to investigate the potential fit of the continents, as Wegener had proposed, 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 comment that the trans-Atlantic fit is not as good a fit as Wegener and others had claimed. His comments and conclusions from his 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 promotion of Plate Tectonics, these very important physical observations and conclusions of Carey continue to be neglected and totally ignored to this day. Reliance is instead heavily weighted towards using schematic sketches to portray plate assemblages.

During the 20th century there were also 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 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 was followed later by the pioneering work and publications of Lindemann in 1927, small Earth modelling by Ott Christoph Hilgenberg during the 1930s, S. Warren Carey during the 1950s to late 1990s, Jan Koziar 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 classical work *Vom Wachsenden Erdball* [*About the growing Earth*]. On each of his globes (Figure 1.1) all oceans were progressively eliminated and the remaining continental crusts eventually enclosed the entire Earth on a globe at about 60 percent of the diameter of the present Earth.

As can probably be seen in Figure 1.1 the main limitation to accepting Hilgenberg's globes was the purely visual fit-together of continents across each of the oceans? In 1990 Vogel commented that, "*…though fairly exact in several regions,* *the totality of Hilgenberg's result was not entirely convincing because, especially in the Indian, Pacific, and Arctic Ocean regions, numerous gaps and overlaps appeared between continental fragments*." Hilgenberg also gave no explanation for the subsequent creation of the oceans, nor an explanation as to what happens to the present-day volume of seawater on a much reduced radius Earth.

Figure 1.1 Reproductions of Hilgenberg's Expanding Earth models, attributed to being the first small Earth models constructed. Size of the small globe to the left is approximately 60 percent of the present Earth shown on the right.

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 on Earth expansion were largely ignored and he has since received scant recognition for his efforts.

In 1983 Vogel published a comprehensive set of scaled small Earth models, or *"terrella"*—meaning small Earth—as he referred to them, at various diameters, including a unique representation of a 55 percent reassembled globe inside a transparent plastic sphere of the present-day Earth (Figure 1.2). Each of Vogel's models is unique in that his work coincided with the first publication of seafloor mapping. For the first time, this mapping enabled Vogel to accurately constrain both continental and seafloor crustal assemblages back in time, without having to resort to arbitrary fragmentation of the continents or to visual fitting-together of the various crustal plates.

Figure 1.2 Vogel's 1983 *"terrella"* models at various stages of expansion 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 Earth expansion.

This is a very important point to take note of because all previous model makers, while having enough foresight and courage to remove seafloor crusts, were faced with the less than envious task of having to visually fit-together the remaining continental crusts. Their visual fitting was done without the benefit of being able to accurately constrain or reposition the remaining crustal fragments.

Also, the prevailing geological viewpoint during the 20th century, and to a lesser extent still remaining today, was that each of the continental crusts acted as rigid bodies. In other words, the crusts were considered to be solid, immovable rock incapable of any form of distortion other than fragmentation due to faulting and earthquake activity. The early small Earth model makers were then faced with the additional fixation that continental crusts were brittle and hence needed to be fragmented like an egg shell in order to be reassembled on a smaller size globe when moving back in time.

Vogel was an engineer, so he was not as fixated on geological protocol as most geologists at the time were. Because of this, he was able to construct stunning models with a high degree of precision. Each of 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 tended to move out radially from their ancient positions to reach their modern positions. Vogel commented that this is a *"...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 called *Gondwana* and *Laurasia*. On Vogel's models, these ancient supercontinents represent an assemblage of the ancient continental crusts, which agree in principal to conventional tectonic theory, however, on Vogel's models the continental fragments are more tightly assembled on a reduced radius Earth. Vogel considered that development of the oceans commenced during the early Mesozoic Era—starting around 200 million years ago—and break-up 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 on further to consider the two hemispheres of the Earth as complementary counterparts, with no need for consideration of additional ancient oceans, or to arbitrary break-up or fragment the continents, as is required in Plate Tectonic theory.

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 seafloor 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 the 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."* This simple observation therefore alludes to the further potential that expansion of the Earth has been operating throughout earlier Earth history and has been active long before the time that modelling of the seafloor crusts suggests.

What should be noted here is that these researchers all showed, as well as other small Earth model makers at the time, that, like Wegener and others had suggested for the Atlantic Ocean, if each of the oceans were removed and the remaining continents were physically fitted together they would neatly envelope the Earth with continental crust on a small Earth globe some 50 to 55 percent of its present size (Figures 1.1 and 1.2). 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, 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.

From this brief review of historical Earth expansion and small Earth modelling it must be noted that, although there is extensive literature on the subject of Earth expansion, the small Earth models briefly outlined above, as well as other lesser published models, represent essentially the sum-total from which Earth expansion has been judged in the past. These models were developed and the majority conceived prior to or during the early stages of investigation into seafloor spreading and prior to the complete and accurate geological mapping and age dating of the oceans. Most of these early reconstructions of continents on small Earth models suffered from a lack of precise cartographic methods, as well as quantitative constraint of both ancient Earth radius and crustal assemblage. Only Vogel was fortunate enough to have been able to use published seafloor mapping to constrain crustal assemblage on his models. All of these models have, however, since been totally ignored in mainstream science and tectonics.

Throughout the subsequent literature small Earth models, and hence Earth expansion, continue to be judged by the scientific community to be speculative and inconclusive. It is considered that one of the main reasons for this judgment is because, with early crustal assemblages based primarily on a visual fit-together of opposing continental margins, the small Earth models often gave rise to a wide variation of crustal fits, in particular the Pacific Ocean region. Similarly, a conclusive, quantifiable, *motor and mechanism* for Earth expansion was not able to be given.

The small Earth models of Hilgenberg and Vogel indicate, however, 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. Similarly, as will be shown here, remnant mountain belts from the various continents match consistently, geological boundaries are maintained and the ancient geographical and biological boundaries match precisely.

1.2 Important Contributions to Tectonic Theory

With the advent of modern geophysical and oceanographic studies it is now known that the seafloor crusts are, in fact, completely separate and distinct from the continental crusts. This will be elaborated on further at a later stage, sufficient to say that seafloor crusts are now known to comprise almost entirely of intruded volcanic basaltic lava which, in effect, represents cooled and solidified upper mantle rocks.

The seafloor crust can therefore just as easily be considered as exposed mantle rocks. In contrast, the continental crusts broadly consist of granite, as well as vast areas of sedimentary and metamorphic rocks originally derived from more ancient granite or volcanic rocks. In this context, the continental crustal rocks can be vaguely likened to the fragmented remains of more silica-rich rocks covering more extensive iron-rich upper mantle rocks.

This revelation in our knowledge about the seafloor crust is in stark contrast to past, pre-Plate Tectonic, thinking where seafloor crusts were originally thought to represent drowned and *oceanised* continental rocks covered by seawater. The outlines of the continents were then simply considered to be the result of periodic uplift of the crusts to form continents, followed by periodic down-warping and drowning of the crusts to form seas or oceans. The positions of all continents were then considered to be fixed and inter-continental land connections enabling species migration were the result of periodic land-bridges joining the various continents—which have now long since mysteriously disappeared.

At the human scale, the continental and seafloor crusts are also known to be very complex and are made up of a wide range of rock types formed at various times during the past 4,000 million years of recorded Earth's history—the age of the oldest known rocks on Earth. This relatively insignificant continental crustal and volcanic seafloor crustal skin is all that is available to measure and observe the unfolding geological history preserved on our Earth; all else is mere speculation or hypothetical guesswork.

1.2.1 Magnetic Seafloor Mapping

During the 1950s scientists, using sensitive instruments called magnetometers adapted from airborne devices developed during World War II to detect submarines, began to recognize strange magnetic patterns across the seafloor. This finding, though unexpected, was not entirely surprising because it was known that basalt—the iron-rich volcanic rock making up the seafloor crust—contains a strongly magnetic mineral called magnetite, which can locally distort compass readings. More importantly, because the presence of magnetite gives the basalt measurable magnetic properties, these newly discovered magnetic seafloor patterns provided an important means to study the distribution of intruded volcanic rocks throughout each of the oceans.

As more and more of the seafloors were mapped during the 1950s and 1960s, these magnetic patterns turned out to be not random or isolated occurrences but instead revealed a predictable zebra-stripe like pattern. These stripes were in turn found to be symmetrical about the centrally located mid-ocean-ridges (Figure 1.3). From this mapping, alternating stripes of magnetised basalt rock were shown to be laid out in parallel rows on either side of the mid-ocean-ridge, where one stripe showed a normal magnetic polarity and the adjoining stripe showed a reversed polarity. While the magnetic stripes were initially not linked to inversions of the Earth's magnetic field, this connection was later explained by Vine and Mathews in 1963. The overall magnetic pattern, as defined by these alternating bands of normally and reversely polarized rock, then became known as *magnetic striping.*

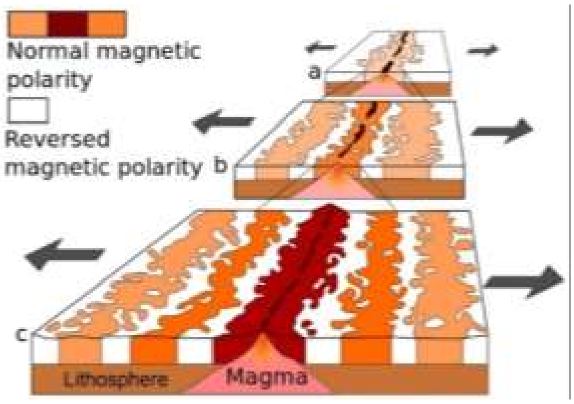

Figure 1.3 Symmetrical magnetic striping across a small part of the North Atlantic Ocean centred over the mid-ocean-ridge showing a progressive opening and increase in surface area of the seafloor crusts.
(http://en.wikipedia.org/wiki/File:Oceanic.Stripe.Magnetic.Anomalies.Scheme.svg)

The discovery of this symmetrical magnetic striping pattern suggested a close relationship between the mid-ocean-ridges, bathymetry, and the formation of the stripes. Seafloor spreading, as it later became known as, was first recognised by Carey in 1958 and again by Heezen in 1960. In 1961 scientists—most notably the American geologist Harry Hess—began to theorize that the mid-ocean-ridges mark structurally weak zones, where the seafloor was considered as being *"ripped apart"* lengthwise along the crest of the mid-ocean-ridges (Figure 1.4). From this, it was suggested that new volcanic lava from deep within the Earth must rise through these structurally weak zones to eventually erupt along the crest of the ridges and cool to form new basaltic seafloor crust.

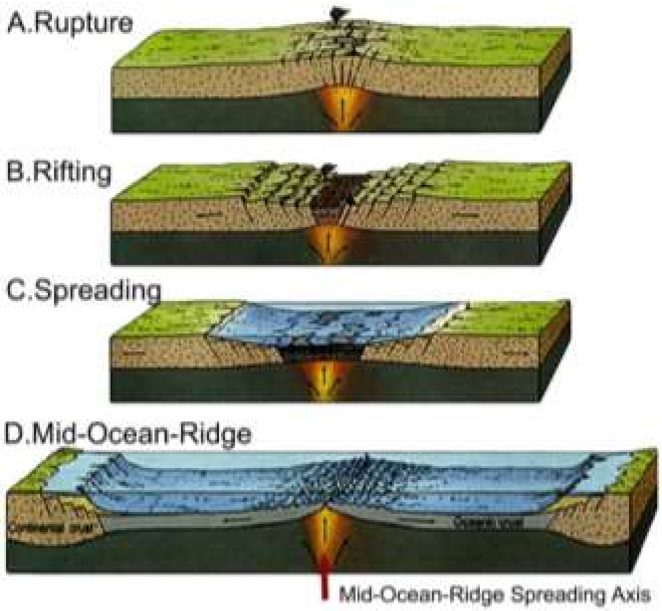

Figure 1.4 Schematic cross-sections showing structurally weak seafloor crustal zones opening along the crest of a mid-ocean-ridge to form a new ocean.

It was further appreciated from dating the ages of the various newly formed seafloor crustal rocks that this process has operated over many millions of years. Subsequent mapping has since shown that this process is continuing to form new seafloor crust along the entire 65,000 kilometre-long system of centrally located mid-ocean-ridges, now known to be present throughout each of the oceans.

This seafloor spreading hypothesis was based primarily on the magnetic mapping evidence. It was also supported by several additional lines of evidence available at the time including evidence from age dating and bathymetric surveys. At or near the crest of the mid-ocean-ridges, the seafloor crustal rocks were shown to be very young and these rocks become progressively older when moving away from the ridge crests. The youngest rocks at the ridge crests always have present-day normal magnetic polarity. Moving away from the ridge crests the stripes of rock parallel to the ridges were shown to have alternated in magnetic polarity from normal to reverse to normal and so on. This suggested that the Earth's magnetic field has reversed many times throughout its history. By explaining both the zebra-like magnetic striping and the construction of the mid-ocean-ridge system the seafloor spreading hypothesis quickly gained converts. Furthermore, this seafloor crustal mapping is now universally appreciated to be a *natural tape recording* of both the history of the reversals in the Earth's magnetic field and opening of each of the oceans.

A profound consequence of this observation of seafloor spreading is that new crust is being continually intruded along the full length of the seafloor spreading ridges. It is interesting to note that this observation was initially—and still is—considered to support the theory of Earth Expansion, where new crust was formed at the mid-ocean-ridges as a consequence of an increase in Earth radius. History now shows that subsequent work has favoured the Plate Tectonic theory, where excess crust generated at the mid-ocean-ridge spreading centres is presumed to eventually disappear along seafloor trenches located along the margins of some continents where *subduction* of the seafloor crustal rocks is inferred.

Subsequent oceanographic work by the Commission for the Geological Map of the World and UNESCO during the 1980s has since led to the publication of the *Geological Map of the World* in 1990 (Figure 1.5). Later versions of this map are now available but are not used here because the editors have since changed the colours to a more subdued pallet. A legend for each of the colours depicted in this map is shown in Figure 1.6. Similarly, an *Age of Oceanic Lithosphere* map was published in collaboration with the National Geophysical Data Centre (NGDC) and the National Oceanic and Atmospheric Administration (NOAA) in 2008 (Figure 1.7).

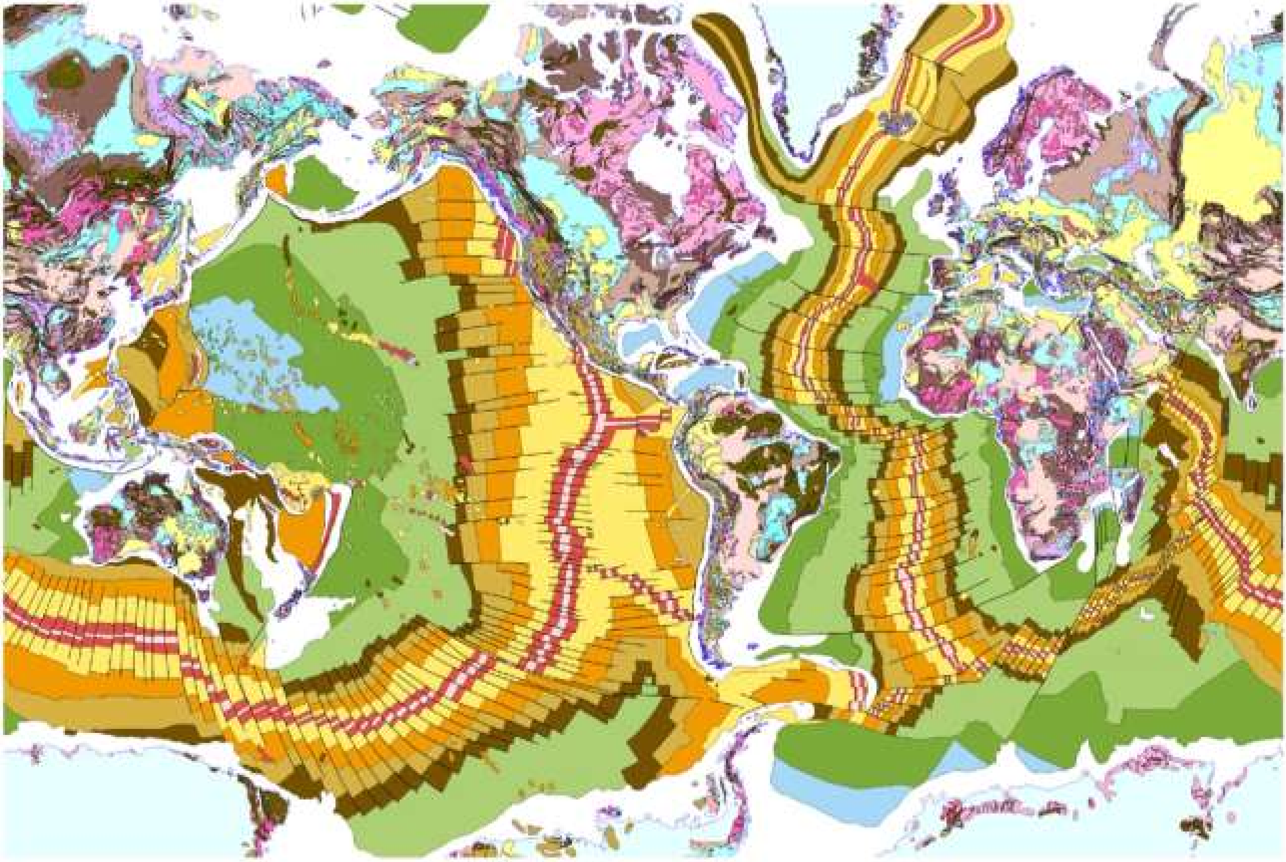

Figure 1.5 Geological Map of the World (digitized with permission from the Commission for the Geological Map of the World and UNESCO, 1990).

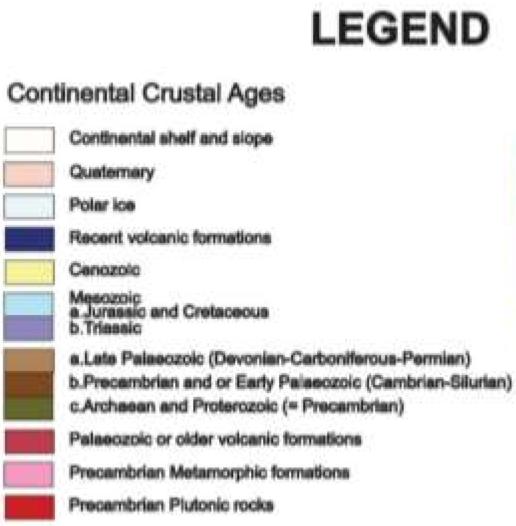

Figure 1.6 Geological timescale legend showing the various colours of the continental and seafloor crustal ages as shown in Figure 1.5. Seafloor crustal ages are in millions of years before the present-day.

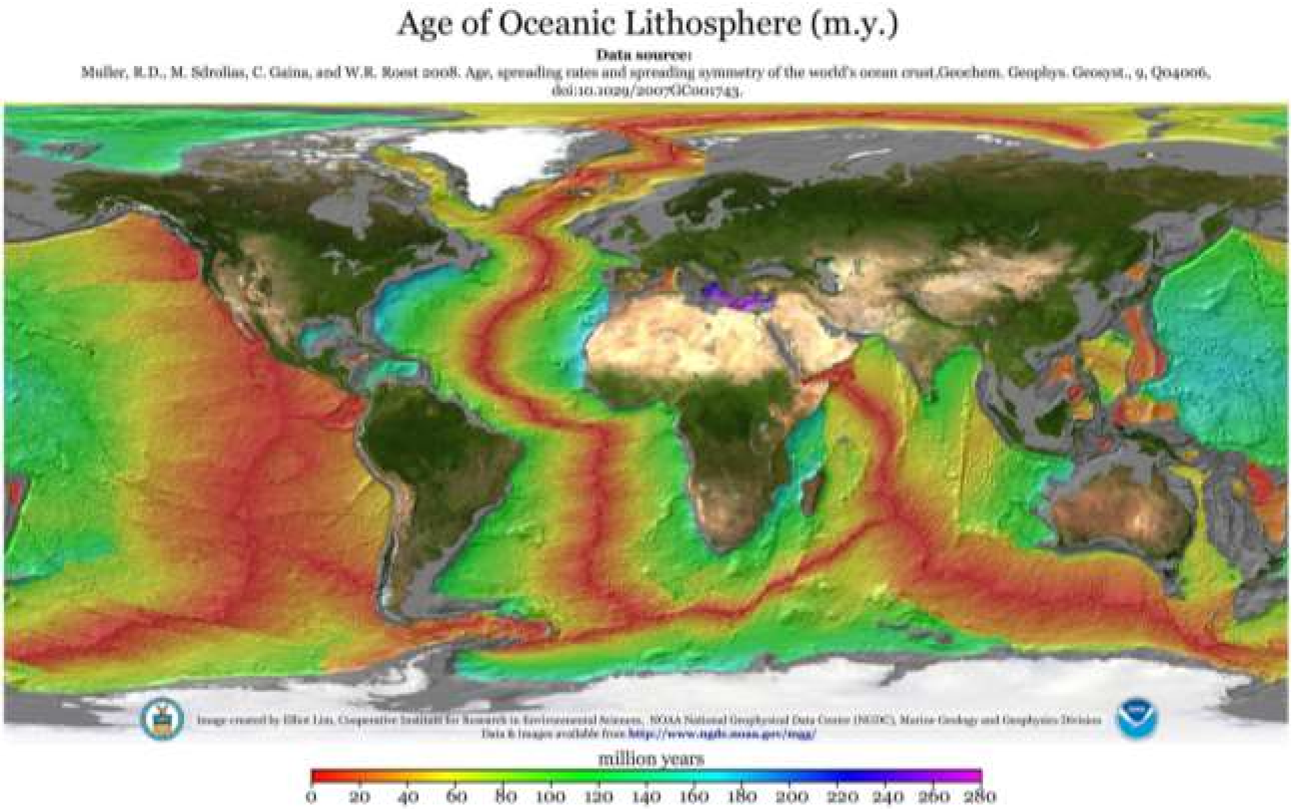

Figure 1.7 Age of Oceanic Lithosphere map (NOAA & NGDC, 2008).

In traditional geological usage the term *bedrock* refers to *the solid rock underlying unconsolidated surface materials,* such as soil or alluvium. In stratigraphy—a separate field of geology—bedrock is also regarded as *the native consolidated rock underlying the surface of a terrestrial planet.* In the context of geological mapping, however, this basic and somewhat historical definition is further extended to consider that; *a solid* [bedrock] *geologic map of an area will usually show the distribution of differing rock types, that is, rock that would be exposed at the surface if all soil or other superficial deposits were removed.*

What this simply means is that the bedrock geology depicted in the Geological Map of the World in Figure 1.5 shows the distribution of the various rocks occurring beneath the layer of surface soils. This mapping also includes bedrock located below other unconsolidated surface rocks, such as alluvial gravels in stream deposits, glacial debris, beach sands, recent volcanic eruptions, seafloor sediments, and so on. Removal of this surface material during mapping is necessary in order to give a truer depiction of the underlying distribution of more ancient rocks.

In each of the published maps shown in both Figures 1.5 and 1.7, the geophysical data gathering process introduced above has been extended to cover all of the oceans. In both maps the magnetic striping evidence has also been taken a step further. By dating the ages of samples of rock collected from the seafloor crust at regular intervals across the bottom of each of the oceans, and by comparing these ages with the magnetic striping, the seafloor crust in these maps is then depicted as geological time. The coloured striping shown in Figure 1.5 then represents age data displayed as set intervals of geological time, while in

Figure 1.7 the age data is displayed as a continuous rainbow time-spectrum of colour.

What this mapping evidence means is that the yellow stripes shown in Figure 1.5, for instance, located between the younger red stripes and the older orange stripes, represent volcanic rock—the volcanic lava called basalt—that was progressively intruded along the ancient mid-ocean-ridge spreading centres during the Miocene Epoch. The Miocene Epoch is the interval of time extending from 6 to 23 million years ago. During that time, the younger red and pink rocks respectively did not exist. It is easy to imagine that the two adjoining yellow Miocene stripes must have then been joined together and remained assembled along their common mid-ocean-ridges throughout this interval of time.

A good analogy for the seafloor stripes shown in Figure 1.5 is growth rings on a tree. For most trees, a new growth ring is added around the outside perimeter of a trunk or branch for each year of growth. By moving back in time and removing each growth ring in turn you can then measure the diameter of the ancient tree and by counting the remaining rings you also know how old the tree was. Similarly, the volcanic seafloor stripes shown in Figure 1.5 can be visualised as the growth pattern of each plate, where each stripe represents millions to tens of millions of year's crustal growth. By moving back in time and removing each growth stripe in turn the remaining surface area of each plate can be measured and from this an estimate of the ancient Earth radius can be made. This basic understanding is fundamental to further discussions on the origin of the oceans on an **Expansion Tectonic** Earth. It is also the fundamental process used here in the assemblage of crustal plates back in time to the Triassic Period—to about 200 million years ago.

At this stage there are a number of very important considerations relating to the bedrock geological mapping shown in Figure 1.5 that must be fully appreciated. As noted previously, this seafloor mapping represents a natural tape recording of the growth history based on reversals in the Earth's magnetic field and similarly represents the factual distribution and intrusive growth history of the volcanic rocks that make up the seafloor crusts. This preserved history must therefore be strictly adhered to during any theoretical crustal modelling study as well as during assemblage of the various crustal plates and continents back in time.

It should also be appreciated that none, or very little of this mapping, age dating, or bathymetric evidence was available when both **Expansion Tectonic** and Plate Tectonic theories were first proposed. The global distribution of this mapping, age dating, and bathymetry was, in fact, completed later in order to assist with, and substantiate assemblage of the various crustal plates and continents on a Plate Tectonic Earth model.

The bedrock geology map shown in Figure 1.5 will be discussed in more detail later. There are, however, a number of important observations that can be appreciated from an initial examination of this map. These observations are focussed on the seafloor striping, irrespective of preconceived assumptions about Earth radius, and include:

- The pattern of colours representing the ages of the crustal rocks shown in Figure 1.5 confirm that the seafloor rocks are vastly different from the continental crustal rocks. Similarly, the continental rocks, in general, are shown to be more ancient than the seafloor rocks.

- The intrusion of volcanic lava along each of the mid-ocean-ridge spreading centres represents quenched and cooled basaltic mantle rock; not oceanised continental rocks.

- The coloured striping shown in Figure 1.5 confirms that all of the oceans contain a mid-ocean-ridge—currently centred beneath the present day pink coloured stripes—and each ocean is increasing its surface area with time.

- This increase in surface area is symmetrical about the mid-ocean-ridges within each ocean. The maximum age of exposed seafloor volcanic crust, located along the continental margins, is early-Jurassic in age—about 170 million years old—which is shown as areas of pale blue striping.

- If it were possible to move back in time, each of the coloured stripes shown in Figure 1.5 must be progressively removed in turn. The corresponding edges of each coloured stripe must then be moved closer together. That is, the erupted volcanic rocks within each young coloured stripe must be progressively returned to the mantle where they originally came from.

- When moving back in time, each of the continents must move closer together in strict accordance with the coloured striping evidence. This phenomenon can then be used to accurately constrain the location of the various crustal plates during modelling of the ancient continents and oceans back in time.

- By measuring the surface area of each coloured stripe in turn, this information can also be used to investigate the change in seafloor surface area with time, and from this to investigate the change in Earth radius with time.

In summary, in Plate Tectonic theory the radius of the Earth is assumed to remain constant with time. As the ocean basins widen, new volcanic lava intrudes along the mid-ocean-ridge spreading centres, allowing new seafloor crust to solidify and form. To maintain a constant radius Earth, an equal amount of pre-existing crust must be disposed of elsewhere and returned to the mantle by a theorized process called subduction. This subduction process forms the basis of Plate Tectonic theory and, as a consequence, is essential in maintaining a static radius Earth premise.

Alternatively, for an **Expansion Tectonic** Earth the very same volcanic lava intruded along the mid-ocean-ridge spreading centres again widens the oceans and increases the surface area of seafloor crust. For an **Expansion Tectonic** Earth, this increase in surface area of all seafloors is a direct result of an increase in Earth radius and is cumulative with time. There is therefore no requirement for any net disposal of excess crust by subduction processes, nor is there a need to consider the existence of pre-existing crusts in order to maintain a static surface area.

What this simply means is that, for an **Expansion Tectonic** Earth, prior to about 250 million years ago—to be discussed in later chapters—none of the modern oceans existed. Instead, at that time all continental crust was assembled and united to form a single supercontinent called Pangaea enclosing the entire surface on a smaller radius Earth. As will also be elaborated on in later chapters, instead of the presence of modern oceans, a network of relatively shallow continental seas then covered low-lying parts of the ancient Pangaea supercontinent. At that time all of the relatively young seafloor volcanic crust, as well as much of the ocean water and atmosphere, were retained within the mantle where they originally came from.

While arguments exist for and against both theories, it is emphasized that small Earth model makers have consistently demonstrated, from a purely empirical perspective, that the continental crustal fragments making up both the ancient supercontinents and modern continents can indeed be fitted together precisely on a smaller radius Earth model. This assemblage process is somewhat like a spherical jigsaw puzzle, where continental crusts are assembled on a smaller radius Earth to form a single Pangaea supercontinent.

At this stage a fundamental question arises that must be seriously considered and further investigated:

Is this empirical phenomenon fact, or is it mere coincidence?

2 Geological Map of the World

As everyone knows the Earth is not flat, in particular not the way the Geological Map of the World is depicted in conventional Mercator projection previously shown in Figure 1.5; it is a sphere. The only reason why most people use flat maps is because of the ease and convenience in being able to display or fold a flat map as against carrying around a spherical globe. Of course, maps work extremely well at scales that are typically dealt with on a day to day basis, such as a street directory, an electronic navigational aid, or topographical map, but not when discussing or measuring the dimensions of the Earth. So, from now on I will be displaying and discussing the bedrock geological map in spherical format (Figure 2.1). The reason for this is because the information displayed on a spherical globe is realistic, true to scale, and distortion free, which then enables us to confidently view, measure, and model the data as required.

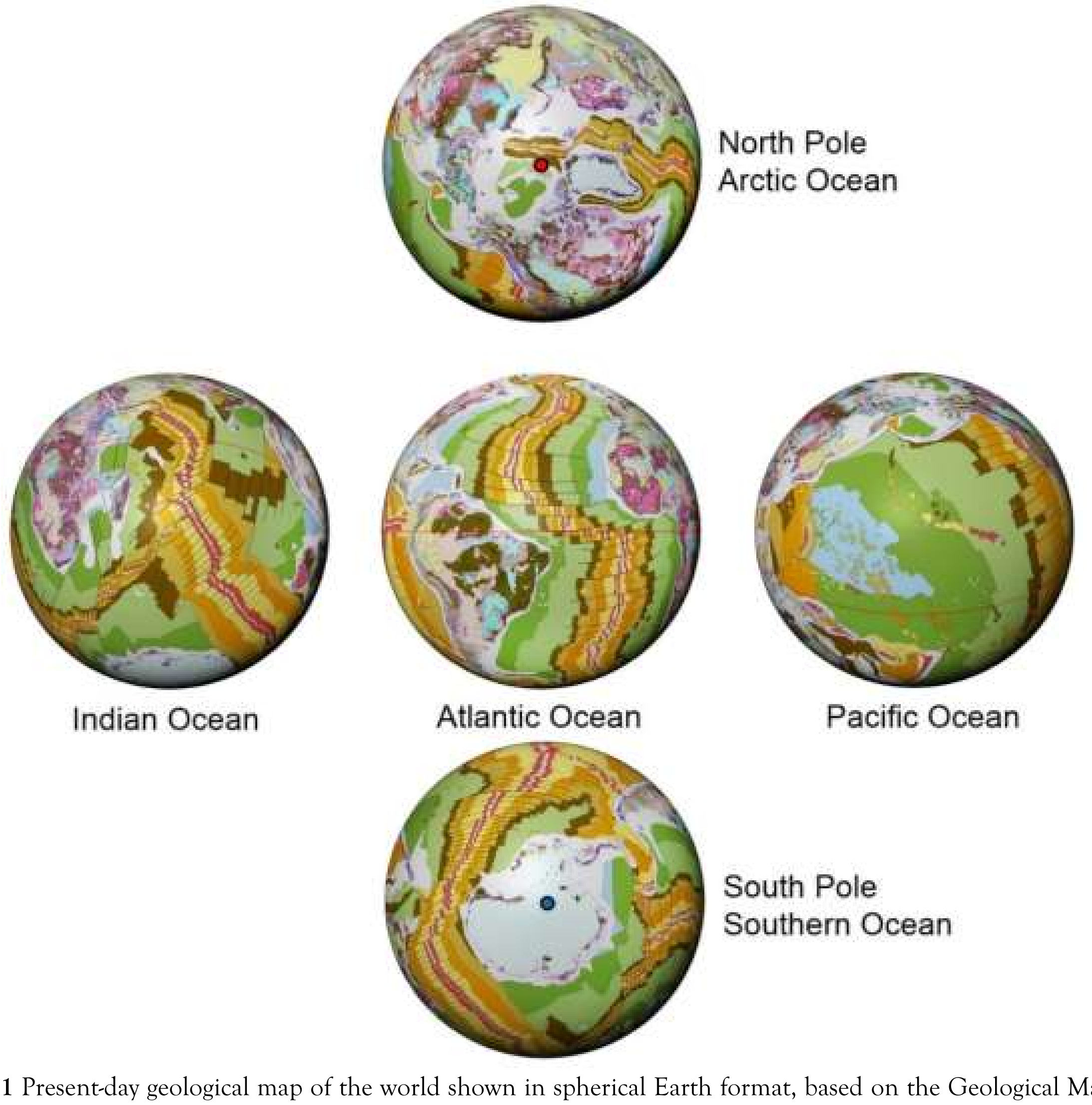

Figure 2.1 Present-day geological map of the world shown in spherical Earth format, based on the Geological Map of the World, 1990.

While appearing complicated, it should be appreciated that the various views of this globe show the actual continental and seafloor crustal geology of the Earth. The coloured geology shown in Figure 2.1 represents rocks that were formed during common intervals of geological time. These intervals of geological time have been studied and documented for many hundreds of years and form the basis of modern geology. The age relationships shown in this figure were originally established from the distribution of fossil plant and animal species in relation to major recognizable geologic events. These established age relationships are now further substantiated by modern age dating techniques.

The colours shown on this geological globe of the Earth simply mean that each colour represents rocks that have been deposited, intruded, or extruded during the same interval of 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 deformed and folded rocks shown as khaki colour, younger sedimentary rocks shown as browns, blues and yellow colours, and the seafloor crusts shown as various coloured stripes.

The colours depicting the continental crustal geology shown in Figure 2.1 represent rocks that were formed during the five major intervals of geological time, including the most ancient Archaean Eon—beginning around 4,000 million years ago—followed by the Proterozoic Eon and then the Palaeozoic, Mesozoic, and Cenozoic Eras. Similarly, the colours depicting the seafloor crustal geology represent rocks that were formed during the geological time periods and epochs, ranging from the Jurassic—beginning around 200 million years ago—through to present-day times. These periods and epochs also represent subdivisions of the Mesozoic and Cenozoic Eras. For the actual age relationships of these geological times refer to the legend previously shown in Figure 1.6 as well as the International Chronostratigraphic Chart shown in Figure 2.2.

While geological mapping of the continents commenced many centuries ago, geological and geophysical mapping of the oceans first began in the 1950s and complete coverage was essentially finished during the late 1980s. This completed seafloor mapping, as shown in the Geological Map of the World (Figure 1.5 and Figure 2.1), now provides a unique insight into what the seafloor crust is made of, when it was formed, and the age distribution of the various seafloor volcanic rocks that are present. It is emphasised that this seafloor mapping was not available to early researchers into global tectonics and it was originally commissioned to provide an important tool towards constraining reconstructions of past Plate Tectonic crustal assemblages.

As can be seen in Figure 2.1, each ocean contains a mid-ocean-ridge and these ridges are approximately centrally located within each ocean coinciding with the pink Pleistocene stripes. These observations are further substantiated by seafloor bathymetric surveys which show that the ridges also coincide with the distribution of an extensive, centrally located, network of submarine mountain ranges. As is known from modern tectonic studies these mid-ocean-ridges subdivide the entire Earth's crust into very large, convex, plate-like crustal fragments. Each plate includes both continental and seafloor crust, although some plates have seafloor crust only, and the plates are generally centred on and around each of the continents.

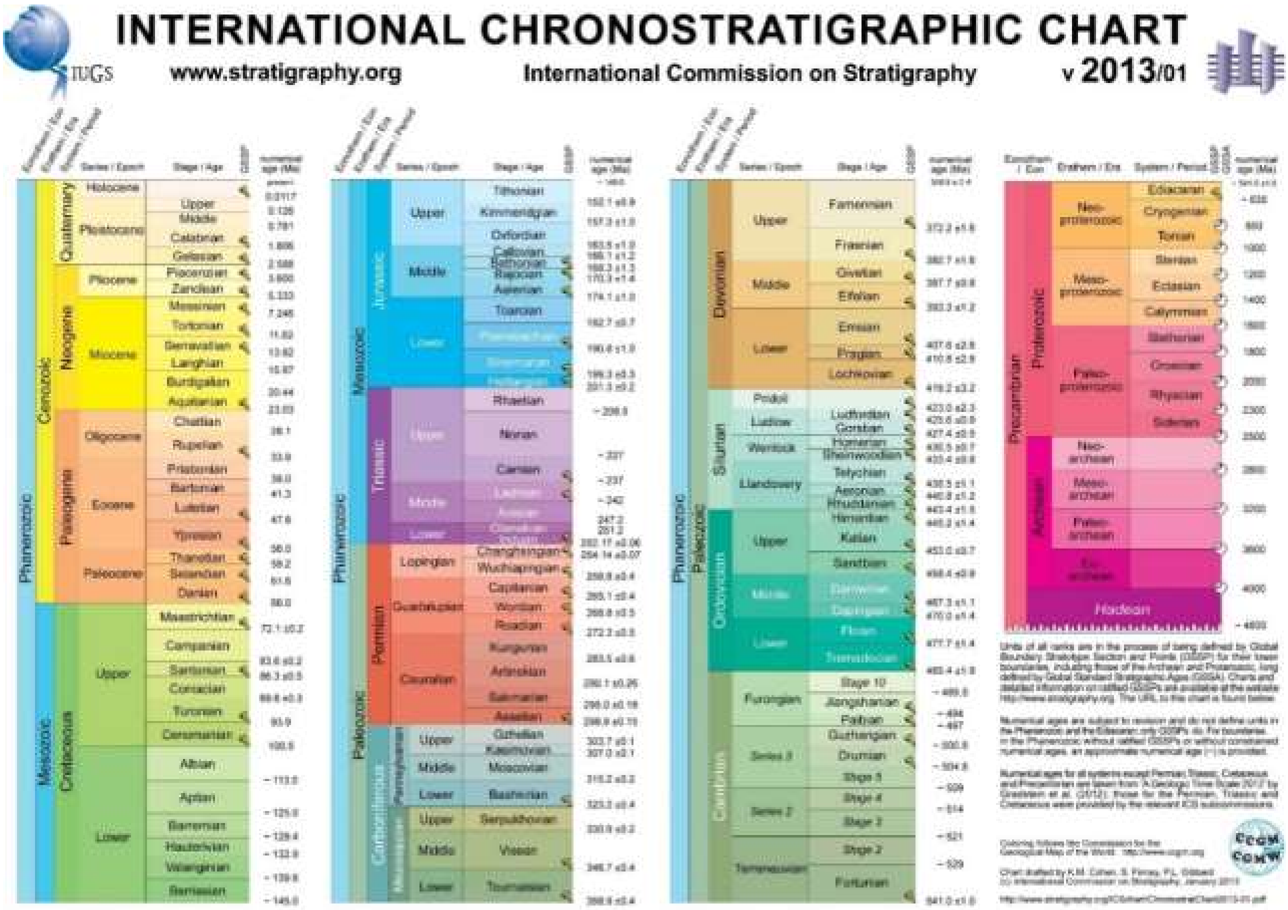

Figure 2.2 The International Chronostratigraphic Chart showing the subdivision of geological time into the various eons, eras, periods, epochs and ages, along with their measured absolute ages (International Commission on Stratigraphy, 2013).

The magnetic patterns and crustal age dating recognised and collected during the various seafloor mapping campaigns were historically interpreted as evidence for seafloor growth and spreading. As previously mentioned, the seafloor stripes shown in Figure 2.1 can be visualised as the preserved historical growth pattern of the Earth, where each stripe represents millions to tens of millions of year's crustal growth. This was an enormous revelation to the Earth sciences at that time. The scientists were finally confronted with physical evidence to show that the continents are in fact mobile and can actually move around the surface of the Earth. How this occurred and what caused the continents to move was not apparent to the early researchers. This observation was then subsequently adopted as the primary basis for Plate Tectonic theory.

From the early researchers' interpretations, basaltic lava was shown to have been intruded within fissures located along the entire length of the mid-ocean spreading ridges. These fissures were considered to have formed as the central spreading zones were *torn apart* and were simply viewed as huge cracks in the seafloor crust which formed as each of the oceans enlarged. Any new cracks were then further intruded with more volcanic lava as the fissures continued to open. What should be appreciated is that this volcanic lava making up the seafloor crust originates from deep within the Earth's mantle and as such the seafloor crusts represent quenched and exposed mantle volcanic rocks, not continental crust. These volcanic rocks are therefore very different to the observed continental crustal rocks, which are predominantly made up of sediments ultimately derived from erosion of much older eroded granite, as well as metamorphic, and lesser volcanic rocks.

In Figure 2.1 it can also be seen that the coloured patterns of seafloor crustal ages are symmetrical about the mid-ocean-ridges and their ages become progressively older when moving away from the ridges. This ageing occurs because new crust is continually being added along the full length of the mid-ocean-ridge spreading centres and each oceanic plate enlarges with time to accommodate for the new seafloor volcanic lava being intruded. The oldest seafloor crust in each ocean is now known to be early-Jurassic in age—shown as pale blue coloured areas—and these rocks are mainly located along the present continental margins. Further to this, it should be apparent from the distribution of coloured stripes that the continents must in fact all be moving away from each other in order to accommodate for this growth pattern of new seafloor volcanic crust. As a consequence of this observation, the surface area of all of the oceans must then be increasing and each of the continents must be moving away from each other.

As previously introduced, the seafloor mapping shown in this bedrock geological map represents a *natural tape recording* of the growth history of the Earth based on reversals in the Earth's magnetic field. These magnetic reversals, in turn, are used to show the factual distribution and intrusive history of the volcanic rocks that now make up the seafloor crusts. By moving back in time and rewinding this tape recording it is important to appreciate that each of the coloured stripes shown in Figure 2.1 must be progressively removed and the intruded volcanic lava within each stripe must be returned to the mantle, where it originally came from. The corresponding edges of each coloured stripe must then be moved closer together and, similarly, each of the continents must move closer together in strict accordance with the coloured striping evidence—regardless of which tectonic theory the reader adheres to.

In Plate Tectonic theory, the fundamental premise is that the radius of the Earth has remained essentially constant with time. As such, as new volcanic lava is intruded along the mid-ocean-ridge spreading centres the seafloor widens further and preserves this lava as new seafloor crust. To maintain an assumed constant radius Earth, an equal amount of new or presumed pre-existing seafloor or continental crust must be disposed of elsewhere and returned to the mantle by a theorised process called subduction. This subduction process forms the most important basis of Plate Tectonic theory and is essential for maintaining a static radius Earth premise.

Alternatively, for an Earth undergoing an increase in radius and surface area over time, the very same volcanic lava intruded along the mid-ocean-ridge spreading centres is again preserved and added to the surface area of seafloor crusts. For an **Expansion Tectonic** Earth, this increase in surface area of each of the seafloors is a direct result of an increase in Earth radius and there is no requirement for any net disposal of excess crust by subduction processes. There is also no requirement to assume, or even consider, the presence of pre-existing seafloor or continental crusts that are currently not present on the present-day Earth surface.

To account for this increase in surface area on an **Expansion Tectonic** Earth various researchers in the past have speculated that an increase in Earth radius may have varied considerably, ranging from a partial expansion process, where some subduction may have occurred, to full expansion. For full expansion, no pre-existing crust or subduction is required to account for the observed geological and geophysical features present on the present-day seafloor, whereas partial expansion was originally proffered to appease scientists and account for subduction-related phenomena.

Other suggestions have also included a possible pulsating Earth process. Here, expansion was said to have caused crustal stretching and later contractions were said to have given rise to crustal uplift to form mountains. In this process it was argued that, in order to have mountains there must have been compression and in order to have mid-ocean-rifting there must have expansion. A pulsating expansion-contraction process was then said to have given rise to the various mountain-building episodes which were in turn accompanied by opening of each of the modern oceans. While hypothetically feasible, this concept is now contrary to modern global mapping and tectonic observation. There is no evidence for this cyclical process shown in the seafloor spreading patterns. This pulsating Earth process also conflicts with current understanding of mechanisms for mountain building.

From this brief introduction to the *Geological Map of the World*, it is important to fully appreciate that by moving back in time we are compelled to restore the intruded seafloor crust back to its original configuration along each of the mid-ocean-ridge axes.

There is no other physically valid or proper method available to explain this unique seafloor mapping phenomenon, as shown throughout all of the oceans.

Similarly, each of the continents must be moved closer together and at the same time the surface area of each of the oceans must be reduced. The seafloor mapping shown in Figure 2.1 is therefore unique in that it shows precisely where the edges of each plate, and hence mid-ocean-ridges, were at any moment back in time. This phenomenon then provides an important mechanism to reassemble and constrain the positions of adjoining crustal plates with a high degree of precision, for any time period ranging from the present-day back to around 200 million years in the past.

3 Measuring Earth Radius

"The oceanic crust of any epoch, originating as a result of spreading, is fully fixed in the geological record, and continues to increase the surface area." Blinov, 1983

At the beginning of human history the size and shape of the present-day Earth was unknown. It was a struggle for early scientists or philosophers to calculate the circumference of the Earth to the nearest hundreds of kilometres and hence mathematically derive an Earth radius, let alone to accuracies suitable for considering any changes in the Earth's size. From this introductory statement I will now state categorically that without fully appreciating or comprehending that the Earth's radius could possibly be changing with time it was, and still is, not possible for scientists to measure the past ancient Earth radius.

It is an unfortunate human trait that many and in fact, I may even be as bold as to say, most humans tend to condition themselves to fail to recognize evidence for something they cannot comprehend. Therefore, throughout history very few people have seriously considered that Earth radius may have, or may still be changing with time simply because they have failed to recognize or even acknowledge the evidence available to test or contradict their preconceived assumptions.

Contrary to all of this though we can in fact measure the ancient Earth's radius at any moment in time, we just need to recognize what it is that we should measure. As will be shown, the key to measuring the ancient Earth radius is written and preserved in the Earth's *rock-record*, that is, in the rocks themselves and this evidence is preserved in the *Geological Map of the World*.

This evidence for determining ancient Earth radii for the various geological time periods and epochs has only been available since the late-1980s, well after Plate Tectonic theory was first conceived and popularized.

3.1 Measuring Post-Triassic Earth Radii

With the completion of the Geological Map of the World it is now a relatively easy process to determine post-Triassic Earth radii using measured surface areas of seafloor crusts. The added advantage of this map is that the seafloor crusts now have known ages, which are in turn used to accurately constrain the moment in time when these rocks were first formed.

Once the areas of each of the coloured seafloor crustal stripes are known, the cumulative areas of the seafloor crust—that is, the total area of crusts younger than the time we want to calculate a radius for—is then simply taken away from the present-day Earth surface area to mathematically derive an ancient Earth radius. This presumes, of course, that any increase in surface area is confined to the seafloor crusts which is not strictly correct but is a reasonable approximation. In contrast, increases in surface area of continental crustal rocks are mainly the result of crustal stretching which is primarily due to on-going changes to surface curvature.

It should also be appreciated that the sum of the time periods shown by the coloured seafloor bedrock mapping represents only about 5 percent of the total known age of Earth history. Whenever Earth expansion is mentioned in the published literature it is this limited timeframe that is typically associated with the concept of Earth expansion. It is rarely, if ever, appreciated that an increase in Earth radius may in fact have also occurred before this time to include the entire pre-Triassic history of the Earth—times prior to about 200 million years ago.

To determine ancient Earth radii for each of the time intervals shown by the coloured seafloor spreading stripes in Figure 2.1 I will initially focus on the seafloor crusts, extending in time from the present-day back to about 200 million years in the past. This 200 million year time-frame covers the age of the oldest known seafloor crusts plus continental shelf sediments deposited around the margins of the continents. By calculating Earth radii from the surface area measurements, scaled small Earth models of the ancient crustal plate assemblages will then be constructed for each of the coloured time periods back to the early-Jurassic Period. These constructed models will in turn be used as a basis to further investigate the origin of the modern oceans.

This surface area data and modeling will also enable any assumptions about an increasing Earth radius scenario to be tested. If these assumptions are correct and an increasing Earth radius concept is shown to be feasible, we will then be in a better position to take the more challenging step towards modelling the remaining pre-Triassic aged continental crusts. Changes to pre-Triassic Earth radius will be further investigated in later chapters and, depending on the outcomes of this investigation, small Earth modelling will be continued back to the beginning of geological time—around 4,000 million years ago. These models will then be used to investigate the origins of the ancient supercontinents and modern continents.

The term *geological crustal budget* is a term I use to account for the surface areas of each of the coloured crustal rocks shown in Figure 2.1. What is meant by this term is that if we create something, in this case an area of new volcanic seafloor crust added along the mid-ocean-ridge spreading axes, we must be able to account for it. We must also be able to balance the overall global geological crustal budget for each of the time-periods involved—in this case the total ancient surface area of the Earth at any moment in time.

As mentioned, the coloured patterns of seafloor crustal rocks shown in Figure 2.1 represent volcanic lava that has been intruded and preserved over a set interval of time along the entire length of the mid-ocean-ridge spreading axes. These spreading axes are shown to be centrally located in each of the oceans. If the surface areas of each of the seafloor crustal stripes are measured, then this information can be used to investigate the variation in the Earth's surface area with time. From this, it is a relatively straightforward process to mathematically derive and investigate any potential changes in Earth radius with time.

These may still seem to be ambitious statements, however, in all global tectonic concepts the generation of new seafloor crusts during the past 200 million years is universally accepted by scientists to have been continuously created along the mid-oceanic-ridge seafloor spreading axes. There is no evidence for seafloor crusts older than 200 million years remaining within the modern oceans, only relatively minor occurrences of buried seafloor volcanic rocks located within some continental sedimentary basins. Only in Plate Tectonic studies is there a need to invoke pre-200 million year old seafloor crusts in order to maintain a constant Earth surface area.

To measure the surface areas of each of the coloured seafloor stripes in Figure 2.1 all projection distortion must be eliminated from the bedrock map and, strictly speaking, this information must be displayed in spherical format, that is, on a spherical globe. The method adopted here requires the existing Geological Map of the World (Figure 1.5) to be displayed as a *24-gore sinusoidal projection map* (Figure 3.1). A sinusoidal projection format is unique in that it gives undistorted, true-to-scale, geological information from anywhere within the map area enabling the information to be both measured and confidently modeled on spherical globes.

Figure 3.1 24-gore sinusoidal map projection of the Geological Map of the World. This projection enables the geological map to be displayed in distortion-free spherical format and forms the primary base-map for both surface area measurement and small Earth model constructions.

The term *gore* simply means that each curved stripe, which in this figure represents fifteen degrees of longitude at the equator, tapers to a width of zero degrees longitude at each pole. In Figure 3.1, twenty four gores have been used to represent the original map area. The unique quality of this type of map projection is that it can then be cut and pasted directly onto a globe during model construction, as shown in Figure 3.2. This sinusoidal map will then form the basis for further detailed small Earth modelling, to be introduced later.

By using this sinusoidal map, the outline of each coloured seafloor stripe can be digitized in turn. The surface areas of successive intervals can then be measured, and an ancient Earth radius derived for each time period shown. The raw data from this exercise is shown in Table 3.1, and a graphical plot of the cumulative surface areas against time is shown in Figure 3.3.

Age		Surface Area			Ancient Radius
Chron	Years (x10^6)	dS (x10^7 km^2)	SdS (x10^7 km^2)	S_a=S_0-SdS (x10^7 km^2)	R_a (km)
C0	0	0	0	51	6370.8
C2	-1.9	0.5342	0.5342	50.4658	6337.15
C3a	-5.9	1.3328	1.867	49.33	6265.43
C6b	-23	4.9213	6.7883	44.2117	5931.49
C15	-37.7	4.1624	10.9507	40.0493	5645.37
C25	-59.2	4.1649	15.1156	35.8844	5343.77
C29	-66.2	1.0462	16.1618	34.8382	5265.3
C34	-84	4.7956	20.9574	30.0426	4889.49
M0	-118.7	5.6758	26.6332	24.3668	4403.46
M17	-143.8	1.9348	28.568	22.432	4225.02
M38	-205	1.9386	30.5066	20.4934	4038.31

Table 3.1 Empirical surface area data derived from mapping by Larson et al. (1985) and CMGW & UNESCO (1990). Areas were originally digitized using a CAD based Graphical Design System software package and ancient Earth radius calculated from this data. Arbitrarily assigned errors are ±5% (from Maxlow, 1995).

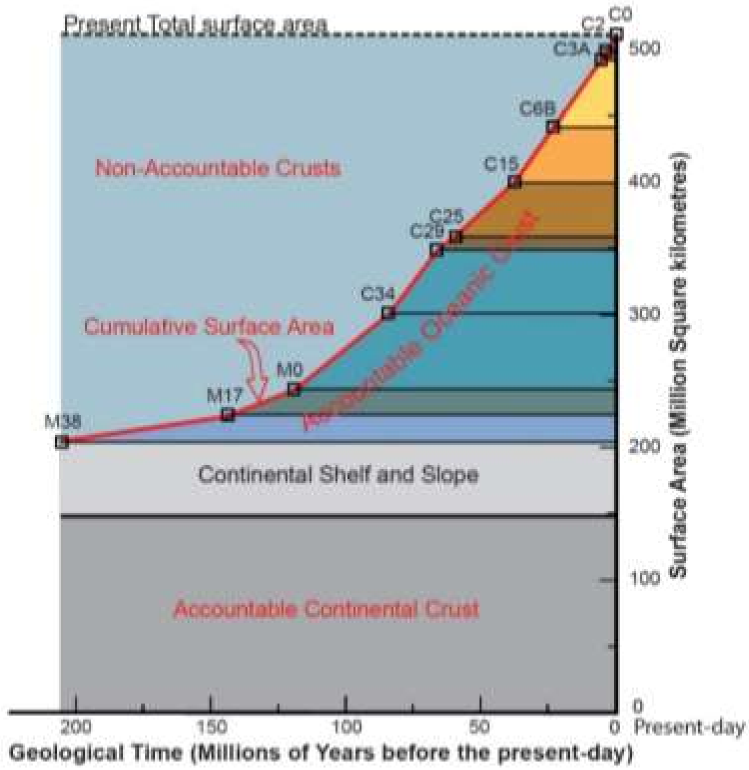

Figure 3.3 Cumulative surface areas of both continental and seafloor crustal rocks as measured from the Geological Map of the World sinusoidal base-map (Figure 2.3). The time scale represents millions of years before the present.

The plotted data shown in Figure 3.3 is a means of graphically displaying the distribution and accountability of the measured empirical surface areas of all Earth's continental and seafloor crusts. This chart covers approximately 200 million years of Earth history, extending from the present-day back to the beginning of the Jurassic Period. In this figure, each of the measured seafloor stripes is simply added together when moving forward in time from the early-Jurassic to the present-day. In other words, the area of new crust intruded along the mid-ocean-spreading-ridges is considered to be cumulative over time and is progressively added to the area of previous seafloor crust for each successive time interval shown.

In this chart the cumulative surface areas of each of the crusts can be compared to the present-day total surface area, shown as a dashed line at the top of the chart. Here, areas of both accountable-oceanic and accountable-continental crusts are shown below the red surface area curve. In this context, accountable-crust represents all continental and oceanic crusts currently existing on the Earth's surface today. The cumulative surface area of each of these accountable-crusts must then equal the present surface area of the Earth at time zero—which is the present-day.

Also shown on this chart is a pale blue area located to the upper left, referred to as non-accountable crusts. This area is located above the measured red cumulative surface area curve and below the dashed total surface area line at the top of the chart. This non-accountable crust represents the additional surface area of inferred crust that must have been present in order to maintain a constant surface area Plate Tectonic Earth.

It is important to note that no record of this non-accountable crust exists on Earth today and there is only very limited evidence to suggest that it ever did.

If a constant surface area Plate Tectonic Earth is to be maintained, this non-accountable crust represents the additional surface area of continental and seafloor crusts that must have previously existed since the early-Jurassic Period. This area also represents the total area of crusts that must have been removed by an inferred subduction process. A subtle outcome of this charting is that an explanation for the accelerating increase in non-accountable crust shown in this chart, and by inference an accelerating increase in subduction, must also be explained. What is meant by this is that the rate of increase in surface areas shown in this chart is actually increasing with time and hence an explanation and a mechanism for this phenomenon must be given by advocates of Plate Tectonic theory.

In contrast, accountable-crust on an **Expansion Tectonic** Earth is a reflection of the actual variation in Earth radius with time. On an **Expansion Tectonic** Earth, non-accountable crust is not required and, in fact, never existed at all. The rate of increase in surface area with time is then simply a reflection of the increase in Earth radius. What causes this increase will be discussed in a later chapter once all empirical evidence has been introduced and discussed.

The accountability of Earth surface areas for both seafloor and continental crusts can be further understood by comparing the basic premises of the four main global tectonic theories, all of which have been promoted in science at various times during the past 100 years of geological study:

- **Constant Earth radius** (Plate Tectonic Earth): In this theory, excess crust intruded along the mid-ocean spreading centres is continuously being disposed of along subduction zones, displacing and recycling pre-existing crust into the upper mantle. To maintain this view of a constant surface area it must be presumed that non-accountable crust existed prior to subduction. Limited, if any, record of this crust exists and an explanation must also be provided for the accelerating rate of increase in the actual, observed surface areas shown.

- **Partial increase in Earth radius**: In this theory, some excess crust is disposed of along subduction zones during limited Earth expansion. To maintain a partial increase in surface area, it must be presumed that some non-accountable crust existed prior to partial subduction. The accelerating increase in observed surface area since the early-Jurassic Period must again be explained.

- **Pulsating Earth radius**: Similarly, in this theory crust is generated at spreading centres during a period of increasing Earth radius and is either compressed to form mountains, or disposed of along subduction zones during a reduction in Earth radius. No evidence for a pulsating Earth radius is shown from the available surface area data and new ideas on mountain building negate the requirement for crustal compression to form mountains.

- **Increasing Earth radius (Expansion Tectonic** Earth): For an **Expansion Tectonic** Earth, new volcanic lava intruded at mid-ocean spreading centres is cumulative with time. The increase in total surface area is a direct result of an increase in Earth radius. On an **Expansion Tectonic** Earth, non-accountable crust never existed, subduction is not required, and the cumulative surface area is a physical measure of the actual change in Earth radius. The measured change in Earth surface area in turn suggests there has been an accelerating rate of increase in Earth radius over time.

From this brief comparison of the various tectonic theories available it can be seen that both **Expansion Tectonic** and Plate Tectonic theories represent the extreme end-points of a whole spectrum of global tectonic possibilities. Plate Tectonic theory is currently the accepted theory in science and has been extensively presented in publications elsewhere. Owen in 1976 has adequately presented partial expansion and Milanovsky in 1980 has adequately presented the pulsating Earth theory. It is important to note that each of the Plate Tectonic, partial expansion, and pulsating Earth theories were introduced well before completion of the Geological Map of the World and these theories must therefore be able of explain the new phenomena shown in this mapping.

The pattern and distribution of the ancient surface area measurements in Figure 3.3 shows that there is no cause to consider a pulsating Earth during the early-Jurassic to present-day periods, in the style suggested by Milanovsky. It also seriously limits the potential for a partial Earth expansion, as suggested by Owen. The evidence instead shows that any potential Earth expansion process is one of full accelerating expansion, where growth in surface area is a direct result of an accelerating increase in Earth radius through time.

From the measured surface area data it is then a relatively simple means to convert this data to an ancient Earth radius for each time interval measured. This converted Earth radius data is shown plotted as a dashed black line in Figure 3.4, along with a curved red line representing an idealised exponential curve which has been fitted to the measured data. The discrepancy between the measured dashed line and the red curve at the lower left end is interpreted to represent masking of seafloor volcanic crusts by sediments deposited around the margins of the continents. The seafloor data shown in both Figures 3.3 and 3.4 will be combined with measurements from continental surface areas in a later chapter to then derive a formula for calculating ancient Earth radius and a rate of change in Earth radius at any moment back and forward in time.

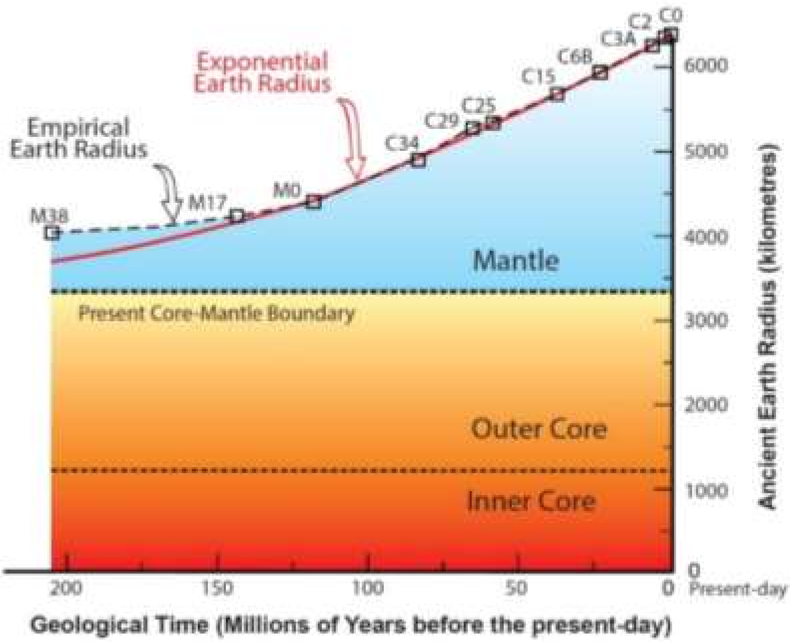

Figure 3.4 Ancient radius of the Earth extending from the early-Jurassic to the present-day calculated from digitised areas of published post-Triassic seafloor mapping data. The red line represents idealised curve fitting of the data.

The implications stemming from these measured surface areas, as well as the derived ancient Earth radii measurements, are that we now have a means to accurately constrain ancient Earth radii for each of the time periods depicted in the coloured seafloor crustal mapping data. From this, by successively removing each coloured seafloor stripe in turn from each of the modern oceans, and reducing the Earth radius back in time to the early-Jurassic Period, we are also in a unique position to make accurate small Earth models of the continental and seafloor plate assemblages.

This derivation of ancient Earth radius and model making technique was not available before completion of the Geological Map of the World in 1990.

4 Post-Triassic Small Earth Models

"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…these difficulties vanish." Carey, 1958

In addition to providing a unique means of measuring an ancient radius of the Earth, the coloured seafloor crustal mapping provides an even more unique means of constraining the precise location of crustal plates at any moment in time back to the early-Jurassic Period. By returning seafloor volcanic rocks back to the mantle, from where they originally came from, surface areas of each of the oceans must, by established protocol, be progressively reduced and each of the continents moved closer together. The uniqueness of adopting an **Expansion Tectonic** 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 seafloor crustal mapping dictate the precise crustal plate assemblages on a pre-determined smaller radius Earth model.

As previously mentioned, at continental and global scales, a sphere cannot be converted into a flat map without first acknowledging the considerable amount of projection distortion involved, especially in the higher polar latitudes. More importantly, we must be acutely aware that information from a flat map cannot be simply cut and pasted or assembled anywhere else on the same map. Doing this would mean that different projection distortions would be transferred from one area of the map into another area that has completely different distortion parameters, even on the same map.

To construct small Earth models of an **Expansion Tectonic** Earth, spherical polystyrene foam spheres were found to be the best means of assembling the various crustal plates. Cutting and pasting of information from anywhere on a spherical globe is then true-to-scale and distortion free. On these small Earth models, the distribution of crustal plates can then be accurately constrained anywhere on the globe during model construction using standard cartographic techniques.

To test the theory of **Expansion Tectonics** and, in particular, the ancient Earth radii as determined from empirical seafloor mapping data, a series of spherical small Earth models (Figure 4.1) were initially made for the present-day and the beginning of the Pliocene, Miocene, Oligocene, Eocene, Palaeocene, Late-Cretaceous, Mid-Cretaceous, Early-Cretaceous, Late-Jurassic, and early-Jurassic Epochs and Periods. These small Earth models were constructed using seafloor geological crustal information displayed on the *Geological Map of the World* sinusoidal base map shown in Figure 3.1, originally digitised with permission from the Commission for the Geological Map of the World and UNESCO (1990).

Figure 4.1 Spherical small Earth models of an **Expansion Tectonic** Earth extending from the early-Jurassic to the present-day. These models demonstrate that the seafloor crustal plates assembled on an **Expansion Tectonic** Earth coincide fully with seafloor spreading and geological data and accord with derived ancient Earth radii.

To minimise geological complexity shown by the continental geology, the small Earth modelling presented in this chapter will initially focus on the seafloor crustal mapping only. All continental geology will simply be coloured grey and left blank. The constructed models shown in Figure 4.1 were first used as the basis for my original research into post-Triassic **Expansion Tectonics**. In later chapters these will be reproduced in more detail in conjunction with modelling of the continental crustal geology. The models shown in Figure 4.1 will now form the basis for discussions on constructing and assembling seafloor crustal plates on an **Expansion Tectonic** Earth.

From the outcomes of this early research (Maxlow 1995) I was able to conclude that:

The seafloor crustal mapping provides a definitive means to test and quantify a potential rate of increase in Earth radius and a means to constrain plate assemblage with a precision not previously available to early researchers.

It was also fully acknowledged in this research that if the concept of **Expansion Tectonics** were wrong then the seafloor crustal mapping will highlight any discrepancies or inconsistencies on each of the small Earth models. This would then require a rethink, revision, or even rejection of the basic assumptions and methodologies adopted here.

4.1 Assumptions

Like most things in life, our actions and achievements must be based on certain assumptions and constructing small Earth models of an **Expansion Tectonic** Earth is no exception. These assumptions are necessary in order to set guidelines during construction and to also attempt to bridge any gaps in the knowledge base. The main problem with making assumptions, of course, is making sure that these assumptions are realistic, that the limitations are fully understand, and the assumptions do not unduly bias the outcome of the modelling exercise.

In order to accurately quantify any variation in the Earth's ancient radius, and similarly to constrain crustal plate assemblage back in time, it is argued that it is necessary to take into account the area and pattern of the seafloor and continental crusts. What the seafloor crustal mapping shows is the *spatial*—the location of the plates on the Earth's surface—and *temporal*—the location of the plates in time—distribution of seafloor crusts within each of the ocean basins. By moving back in time, successively older coloured seafloor stripes from across the active mid-ocean-ridge spreading zones must then be removed and each of the remaining coloured stripes must be reunited along their common spreading ridges. This is a fundamental premise which is dictated by the mapping data itself.

The main assumptions used to construct and assemble crustal plates on each of the **Expansion Tectonic** small Earth models presented here are summarised below. These will be further investigated for bias and realism in later chapters when discussing the distribution of additional geological, geophysical, and geographical information on each of the completed models and especially when modelling the continental crusts.

For the coloured seafloor crusts, on each of the early-Jurassic to present-day **Expansion Tectonic** small Earth models it is assumed that, for an Earth continuing to undergo an increase in radius and surface area with time:

- The Earth's overall seafloor and continental crustal budget increases with time and all increases in surface area are cumulative with time.

- Once formed, the surface area of seafloor crust, as represented by the bedrock geological mapping in Figure 1.5, is fully fixed in the geological rock-record.

- Seafloor and continental crusts are not removed by subduction processes.

- There are no pre-existing seafloor or continental crusts to account for.

The only stipulation required during cutting and pasting of crustal information between each successive small Earth model is that:

- Continental and seafloor crustal plates must undergo small vertical and surface area adjustments to allow for a progressive change in surface curvature of the Earth with time.

What each of these assumptions, as well as the cutting and pasting stipulation, mean is that, for an Earth that is progressively increasing its radius through time, seafloor crust accumulates as a direct result of an increase in Earth's surface area. Once formed, the seafloor crusts then remain firmly fixed in the geological rock-record, the crusts are not removed or returned to the mantle by subduction processes, and similarly there is no need to invoke the existence of non-accountable or pre-existing crusts. This course of action, of course, goes against conventional tectonic wisdom; however we are not dealing with or replicating conventional Plate Tectonic models. We are simply removing the conventional premise that Earth radius has remained constant throughout history and empirically testing the revised premise that Earth radius is increasing with time.

To be consistent with the geological evidence, it is also acknowledged that both the continental and seafloor crusts must undergo some, to variable, crustal distortion, in particular during on-going changes to surface curvature. It is also acknowledged that localised crustal interaction between plates during changing surface curvature, as distinct from plate subduction, may also occur along plate or crustal boundaries but only at a relatively local scale and not to the extent that is required in conventional Plate Tectonic theory.

What this means is that when moving forward in time from the older, smaller radius models, to the younger, larger radius models, the surface curvature of the Earth will progressively flatten during changing Earth radius. This changing surface curvature represents the primary mechanism for most, if not all geological processes observed on Earth's surface today. This includes folding and faulting currently observed in all continental crusts, as well as uplift of the crust along continental margins to form mountain belts and escarpments. These processes also apply to the seafloor crusts where distortion of the new volcanic lava is accommodated for by intrusion and preservation of new lava at ever changing Earth radii and surface curvatures.

These are important points to dwell on. Most previous model makers did not have the seafloor crustal mapping at their disposal to assist in constraining plate assemblages. Instead, they relied on a visual fit-together of the continental crusts to build their models. I can assure the reader that one cannot simply take a fragment of crust from a present-day Earth model and expect to paste it onto a smaller radius globe—it doesn't work because the surface curvatures are vastly different.

In reality, from an **Expansion Tectonic** Earth perspective, the Earth is increasing in size at an extremely small rate each year. During this process the crusts creep and distort at an imperceptibly small rate in order to keep pace with the ever changing surface curvature. The joints, fractures, faults, and folds in existence on Earth today simply absorb this minute curvature adjustment, generally without us being aware of the processes in action. Catastrophic events, such as earthquakes, volcanic eruptions, and so on are an exception to the rule, however only at the human perception scale. To model back in time, all of these geological processes must then be reversed and the changes in surface curvature must be accommodated for on each of the small Earth models.

This progressive curvature adjustment or flattening of the Earth's surface curvature results in a gradual deformation of the existing crust—what I refer to as a *plastic deformation* process—which occurs over a vastly extended period of geological time. During small Earth model construction, when moving back in time these small crustal changes must be accommodated for and removed. During cutting and pasting of the map fragments onto the small Earth models any wrinkles occurring along the edges of the paper fragments during plate assemblage, for example, are accommodated for by either subtly stretching or compressing the paper fragments during the pinning and pasting stage. This is necessary anyway because each gore still represents a segment of a flat map being pasted onto a curved surface of the globe.

Each of these assumptions, as well as the stipulations used to construct the **Expansion Tectonic** small Earth models in turn, is consistent with the main assumption. That is:

For an Earth undergoing an increase in radius, the surface area of the Earth increases as a direct result of an increase in Earth radius with time.

4.2 Post-Triassic Model Construction

Model construction was carried out and will be further discussed in two main phases. The first construction phase coincides with the past 200 million year time interval, extending from the present-day back to the beginning of the Jurassic Period. This phase uses the coloured, relatively well age-dated seafloor mapping to constrain the assemblage of seafloor crustal plates and covers the closure of each of the modern oceans. The second construction phase will be dealt with in later chapters and will extend small Earth model coverage further back in time, beyond the early-Jurassic Period, to the beginning of the Archaean Era—around 4,000 million years ago.

This second model construction phase is more difficult to achieve because, while age dating of the continental crusts exists in detail, its use in model construction is complicated by many overprinting phases of sedimentary deposition, erosion, metamorphism, and tectonism. During this extended interval of ancient time there were also no seafloor crusts to guide crustal assemblage. During this second construction phase I will instead be focusing on reducing the surface areas of an identified network of continental sedimentary basins and assembling the remaining, more ancient, continental crusts on pre-determined smaller radius Earth globes.

Because of the complexity of the geological mapping data, it was easier to construct hard copy spherical models rather than attempt to develop digital models. A series of small Earth models were then constructed using high density polystyrene foam spheres. Two main methods used to assemble and model the mapping data include: Method 1) uses spherical scale models pre-cut to the ancient radii as determined from the surface area data; and Method 2) uses foam spheres of the same diameter and then digitally rescaling the sinusoidal base map to represent the actual small Earth model radii. The first method was used to construct the seafloor crustal models shown in Figure 4.1 and the second method will be used later to assemble the continental crustal data.

The construction Method 1 used to assemble the seafloor crustal plates on spherical scale models is very simple and very basic (Figure 4.2). Each coloured seafloor crustal stripe is simply removed from the geological base map in turn and the remaining pieces of map are reassembled by pinning and pasting the crustal plates onto the pre-determined smaller radius Earth model. This, in effect, can be likened to a spherical jigsaw puzzle where the pieces of plates cut from each of the paper gores in the 24-gore sinusoidal base map (Figure 3.1) are reassembled together on a three dimensional scale model sphere.

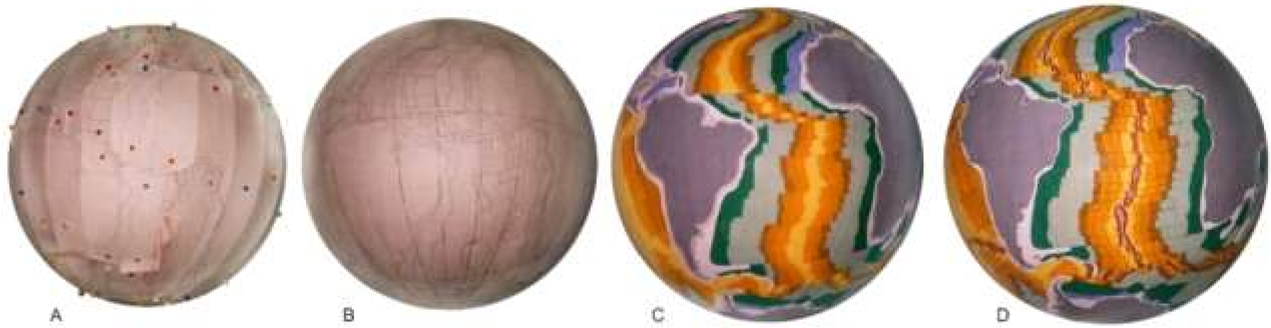

Figure 4.2 Small Earth scale model construction details of various ages and size models: Figure A, preliminary pin-up of plate fragments; Figure B, final paste-up; Figure C, painting of seafloor striping in progress; Figure D, completed present-day small Earth model.

For each model, as the youngest coloured seafloor crustal stripes are progressively removed, the remaining plate boundaries are then reassembled along their common mid-ocean-ridge spreading axes on a reduced radius small Earth model. Of interest is that, on an **Expansion Tectonic** Earth, the mid-ocean-ridge spreading axes do not move. They instead retain their global spatial integrity throughout time. It is the configuration of the mid-ocean-ridge spreading zones that therefore dictate precisely the assemblage of each adjoining crustal plate boundary. Once the paper fragments are assembled and pinned in place, each piece is then glued into its final assembled position and in this modelling exercise each model was then hand painted.

While this outline of small Earth model construction may appear to be brief, the actual construction methodology is also quite basic.

Each coloured stripe is simply taken away in turn and the remaining crustal plates are re-assembled on a predetermined smaller radius Earth model.

The method of constructing small Earth models adopted here then results in a series of models that adhere precisely with the coloured time-scales depicted in the seafloor bedrock mapping. The models also adhere to the ancient Earth radii as determined from measurements of surface areas of this same mapping data. By making more models than required we are also in a far better position to minimise crustal distortion caused by changes in surface curvature, thus achieving the goal of accurately constraining crustal plate assemblages with time.

4.3 Post-Triassic Small Earth Models

The early-Jurassic Period to the present-day, as covered by the first phase of small Earth models, represents about 200 million years of Earth history. This interval of time is made up of part of the earlier Mesozoic Era and the later Cenozoic Era. Each of these eras is further subdivided into distinct geological periods and epochs, as shown in Figure 2.2.

Compared to the total Earth history though, this interval of time represents only about 4 percent of all measured geological time. It is also the interval of time that is most easily modelled from seafloor crustal data and is traditionally considered by model makers, along with all proponents of **Expansion Tectonics**, to be the period of time most representative of the growth period of Earth expansion.

What we are essentially trying to achieve on each of these small Earth models is a snapshot in geological time which coincides with the beginning of each coloured seafloor stripe. This allows us to proceed back in time in precise, well-defined steps that reflect the empirical mapping data. Modelling is also governed by the need to fully appreciate the influence of distortion of the Earth's surface crust during on-going changes in surface curvature, as well as how distortion influences the assemblage of each model.

By moving back in time, rigid fragments of continental or seafloor crusts are not simply reassembled on a smaller radius Earth model. The crustal plates are instead assembled by retaining the integrity of the crusts as they are preserved in the geological rock-record, as well as making allowance for distortion of the crusts during changes to surface curvature, each according to their tectonic histories.

For the completed small Earth models shown in Figure 4.3, as the coloured seafloor stripes are removed in turn it can be seen that the remaining coloured stripes neatly close together on each successive model. Each crustal plate assembles together in a unique, orderly, and predictable manner, during systematic closure of all of the oceans. By removing the coloured seafloor stripes in succession and refitting the plates together on a smaller radius Earth model, each plate is 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. The remaining one percent misfit is simply a combination of map error, cartographic discrepancies, as well as the influence of unaccounted crustal distortion or graphical limitations inherited during model making.

The outcome of this small Earth modelling exercise demonstrates that:

For each of the established seafloor crustal plates there is only one unique plate-fit-option for each of the models shown.

From this, it can be seen that there is no need to introduce non-accountable pre-existing crusts or to randomly fragment continental crusts in order to accommodate for the seafloor evidence. What this means is that, apart from local fine-adjustment along the plate margins, there are no alternative assemblage options available. The seafloor mapping in fact dictates precisely where and how the plates are assembled back in time for each time interval shown. It is also emphasised that this modelling represents the first time that the published 1990 bedrock geological mapping has been used to accurately assemble and constrain crustal plates on **Expansion Tectonic** small Earth models. These models can therefore be considered as unique.

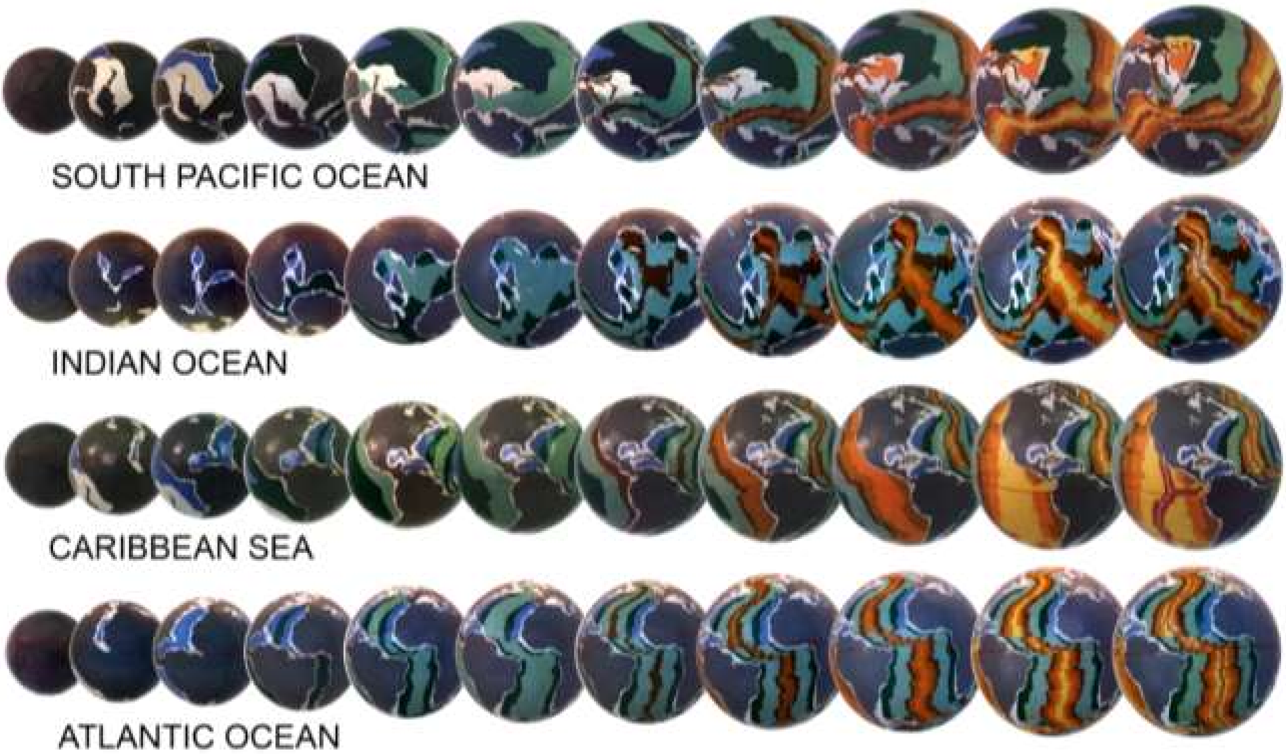

Figure 4.3 Spherical small Earth models of the Jurassic to present-day **Expansion Tectonic** Earth. Each small Earth model demonstrates that the seafloor crustal plate assemblage coincides fully with seafloor spreading and geological data and accords with the derived ancient Earth radii.

On the early-Jurassic to present-day small Earth models shown, the distinguishing feature of this interval of time is that it covers the break-up and dispersal of the original supercontinent called Pangaea. This break-up is also accompanied by opening of each of the modern oceans. On an **Expansion Tectonic** Earth the Pangaea supercontinent, which comprised an assemblage of all of the present-day continental crusts, simply wrapped itself around to enclose the entire ancient Earth with continental crust. It is the subsequent rupture and break-up of Pangaea during increase in both Earth radius and surface area that then lead to the formation of the modern continents and opening of the modern oceans. On each of the small Earth models these modern oceans are then shown to progressively increase their surface areas from the early-Jurassic to the present-day in strict accordance with the seafloor mapping data.

As previously discussed, this post-break-up growth history of the modern oceans is now preserved as volcanic rocks within the seafloors and the evidence for this growth history is uniquely shown by the coloured seafloor mapping. As well as the presence of volcanic rocks, it can be seen in Figure 4.3 that sediments, eroded from the exposed lands during initial continental break-up, are also preserved along the margins of each continent and in submerged remnant plateaux within the oceans. These sediments are shown as white areas around the margins of the continents in Figure 4.3. Small, remnant fragments of much older continental crusts have also been identified and mapped by others in a number of areas on the seafloors. These fragments are considered to represent small areas of continental crusts that have either been eroded or fragmented and left behind as the Pangaea supercontinent first ruptured, broke-up, and dispersed.

On **Expansion Tectonic** small Earth models the continental shelves, marine plateaux, and remnant ancient seafloor crusts are shown to merge during the early-Jurassic Period to form a global network of marine sedimentary basins. This mergence suggests that during this time the existing network of continental sedimentary basins, plus the marine basins, represents a network of ancient continental seaways.

By progressively returning the eroded sediments from these continental and marine sedimentary basins back to the lands where they came from, additional small Earth modelling shows that each continent further re-unites with adjoining continents along their mutual continental shelf margins, at an even smaller Earth radius of approximately 50 percent of the present Earth radius.

It is interesting to note that during this construction phase, as the seafloor crusts are progressively removed and each plate and continent is re-united with its adjoining continental neighbour, a network of continent-to-continent *docking-points* is established. The term docking-point is used here to refer to the re-uniting of each continental crustal fragment along a section of coastline or continental landmass, rather than indicating a specific point location. These docking-points represent areas of coastline where two or more previously separated continents precisely touch and lock back together, somewhat like the lugs on a piece of jigsaw puzzle. These docking-points then represent important cartographic and geographic reference points identified during model construction and they are used here to further constrain the positions of the continents on each successive small Earth model. It was observed during model construction that the location and significance of these docking-points continued to remain throughout the Mesozoic Era and their on-going usage will become increasingly important later when even older, smaller radius Earth models are constructed using continental crusts.

From the model studies briefly introduced in this section it is important to again reiterate a very important observation.

By globally removing the seafloor crustal geology from each of the coloured stripes in succession and refitting the remaining crustal plates together on small Earth models, all plates are shown to reunite with one, unique assemblage. Each crustal plate is then shown to assemble with a better than 99 percent fit-together, for each model constructed.

If the Earth were not increasing its radius, or was undergoing a partial or pulsating increase in radius, then ***this unique fit-together of all plates and continents would not occur.*** Similarly, if the Earth were not increasing in radius then large gaps or overlaps in the reconstructed plates should occur—as happens in Plate Tectonic assemblages—and the need to fragment continental and seafloor crusts to accommodate for the crustal evidence would become increasingly apparent and necessary. Each of these gaps or overlaps, in turn, would also outline areas where presumed, pre-existing crusts should have supposedly once been.

Instead, the early-Jurassic to present-day **Expansion Tectonic** small Earth models demonstrate conclusively that large gaps or overlaps in the crustal plates do not occur, hence the near perfect cartographic match between plates. The fact that large gaps or overlaps do not occur, on any of the models, demonstrates the significance of the coloured seafloor mapping as a valuable tool for reconstructing and constraining the unique fit-together of all past plate assemblages.

5 Origin of the Modern Oceans and Seas

"It is difficult to believe that chance alone can explain this fitting together of the continental margins." Barnett, 1962

In discussing the origin of the oceans and seas it will be shown that, on an **Expansion Tectonic** Earth, prior to the late-Permian to early-Triassic—about 250 million years ago—there were no modern oceans, only ancient continental seas. The transition from ancient seas to modern oceans came about when the Pangaea supercontinent first started to break-up to form the modern continents and intervening oceans, thus initiating draining the waters of the ancient continental seas into the newly opening oceans. In this chapter distinction is made between the terms *modern oceans* and *ancient continental seas*, and by continental seas I am referring to bodies of seawater that covered low-lying parts of the ancient continental lands—sometimes referred to in geology as *epeiric seas.*

It is also important at this stage to reflect on a number of observations from the Geological Map of the World to further understand what is shown in the coloured seafloor spreading data, in particular how it relates to the origin of the modern oceans. In Figure 5.1 it can be seen that the mid-ocean-ridges are centrally located within each of the modern oceans—shown by the centrally located pink Pleistocene stripes. These mid-ocean-ridges include *asymmetric-style* spreading, located along the perimeters of the northeast and southeast Pacific Ocean, and *symmetric-style* spreading as seen elsewhere. A combination of both asymmetric and symmetric-style spreading can also be seen in the Indian Ocean. Here, asymmetric refers to the one-sided, near-continental-margin-spreading zones and symmetric refers to the parallel, two-sided spreading zones that can be seen straddling each of the mid-ocean-ridges proper.

Plate Tectonic studies interpret the asymmetric-style spreading patterns as evidence for subduction, in particular along the west coasts of the Americas. Here seafloor crusts are said to be recycled beneath the continental crusts by convection cells located within the lower crust and mantle. The problem with this argument is that asymmetric-style spreading phenomena are limited to the west coasts of North and South America and east coasts of Asia and Southeast Asia, both of which are also shown to be opening. In contrast, the symmetric-style spreading was originally interpreted during the 1960s from a limited area in the North Atlantic Ocean, demonstrating that this ocean is opening and increasing its surface area. Completion of the Geological Map of the World has since shown that this symmetric-style spreading occurs in all oceans which suggests, by inference, that all of the oceans are in fact increasing their surface areas.

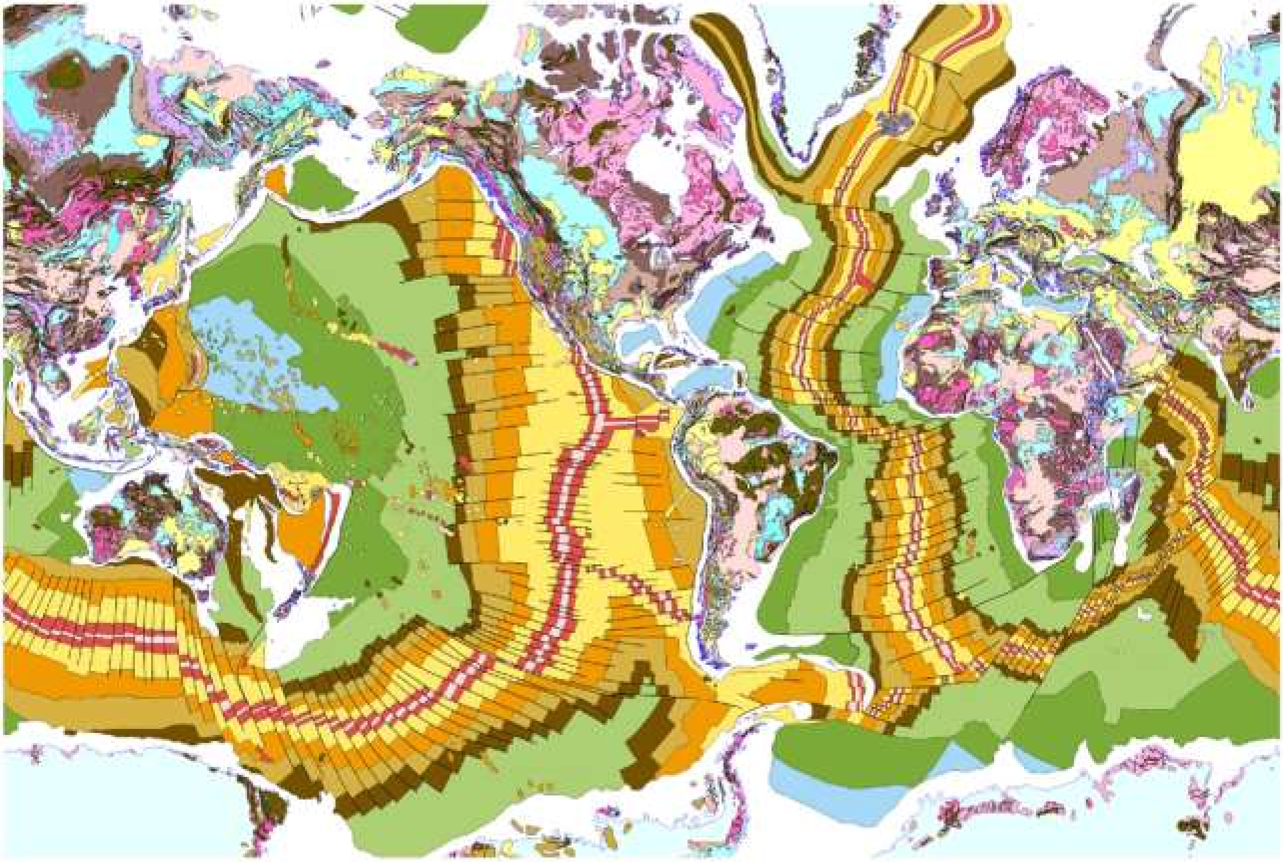

Figure 5.1 Geological Map of the World (digitized with permission from the Commission for The Geological Map of the World and UNESCO, 1990).

The coloured seafloor stripes also make a distinction between the earlier Mesozoic and the later Cenozoic seafloor growth history, where the symmetric pink through to brown coloured stripes coincide with the Cenozoic Era and the greens and pale blue coloured stripes coincide with the Mesozoic Era. In this context, the earlier Mesozoic Era generally shows a more primitive asymmetric-style of mid-ocean-ridge spreading, while during the transition from the Mesozoic to Cenozoic Eras—the transition from green colours to brown in Figure 5.1—symmetric-style mid-ocean spreading ridges become fully established in all of the modern oceans.

In many cases, the symmetric-style Cenozoic spreading patterns can be seen to crosscut the previously established asymmetric-style Mesozoic spreading patterns. From this evidence it can also be seen that the Cenozoic is then characterised by the initiation and propagation of symmetric-style spreading patterns throughout all of the modern ocean basins. Further break-up, rifting, and geographic isolation of the modern continents then accompanied this rapid and unprecedented phase of symmetric-style spreading in all oceans.

In order to commence discussion on the origin of each of the oceans in detail a few observations relating to ancient geography and climate will be briefly introduced here. When geographical data relating to the distribution of the ancient seas and shorelines are plotted on each of the constructed small Earth models it will be shown that, prior to 250 million years ago, there were no deep oceans, only a network of relatively shallow continental seas generally less than a few kilometres deep.

What this observation implies is that, when moving back in time, as well as returning the seafloor volcanic lava back to the mantle where it originally came from, a proportion of the ocean waters and atmospheric gases must also be returned back to the mantle. This is an empirical observation and must be considered in order to comply with the known distribution of ancient continental seas and shorelines. It will be shown later from this shoreline evidence that there is no justification in inferring that the total volume of ocean waters has remained near-constant over time. If it were constant then this would suggest that at some time in the past the Earth would have been completely covered by water to a depth of many kilometres. The geology preserved in the continental rocks shows that the Earth clearly wasn't completely covered by water during ancient times.

It will be shown in coming chapters that each of the modern oceans initially started as small marine sedimentary basins forming a series of relatively shallow seaways. Opening of these seaways coincided with where the Pangaea supercontinental crust first started to rupture and break-up during late-Permian times, some 250 million years ago. These marine sedimentary basins and seaways will also be shown to have been located over areas of low-lying ruptured continental crust that had earlier undergone considerable crustal thinning during a prolonged period of continental crustal stretching and extension. These marine basins may have also contained small areas of intruded volcanic seafloor crustal rocks—referred to in geology as *ophiolites.*

During opening of each of these primitive seaways, as well as draining the waters from the ancient continental seas, sediments were eroded from the exposed lands and re-deposited into new low-lying areas. The huge volume of new sediment eroded from the exposed lands initially covered the newly formed seafloor ophiolite volcanic rocks. This erosion of the lands occurred as a direct result of changing surface curvature of the Earth, where the continental crust initially remained elevated within the central parts of the exposed lands and depressed around the margins. This erosion of the exposed lands, in part, assisted in maintaining a changing surface curvature by lowering the elevated land surfaces and filling the adjoining low-lying sedimentary basins with eroded sediment.

By the mid- to late-Jurassic times—some 165 million years ago—the emerging modern oceans had opened wide enough, beyond the limits of the deposition of sediments, to finally expose the intruded seafloor volcanic lava. These exposed volcanic lava rocks were then subsequently preserved as the coloured seafloor crust shown on the bedrock geological map in Figure 5.1. It is emphasised that it was this exposure and preservation of the seafloor volcanic rocks that gave rise to the coloured seafloor patterns seen in the Geological Map of the World. This process is still continuing today along the present mid-ocean-ridge spreading zones. It should also be noted that this conflicts strongly with the Plate Tectonic requirement for extensive removal of seafloor crust by subduction as well as the presence of pre-existing crusts.

As will be shown on each of the **Expansion Tectonic** small Earth models, opening of the modern oceans was initially centred in the North Pacific, South Pacific, Arctic, and North Atlantic Ocean regions. Opening of the South Atlantic and Indian Oceans then commenced during mid- to late-Jurassic times, and the Southern Ocean commenced opening during the Paleocene. Opening of each of these modern oceans was also accompanied by marked variations in sea-levels. These sea-level changes were accompanied in turn by climate changes and extinction events occurring during crustal break-up, as well as disruptions to the previously established climate zones, polar ice-caps, species habitats, and migration routes.

The origin of the modern oceans will now be looked at in more detail on each of the constructed **Expansion Tectonic** small Earth models to see what happens to these oceans when the mid-ocean-ridge spreading zones progressively open as the Earth steadily increases in size. The observations presented in this chapter are taken directly from the **Expansion Tectonic** small Earth models and can therefore be considered as empirical observations. These models are elaborated on still further in publications external to this document as more specific topics, including additional geological, geographical, and geophysical evidence are introduced.

5.1 Modern Oceans

On all Plate Tectonic reconstructions large, ancient, essentially theoretical Tethys, Iapetus, and Panthalassa Oceans are required to maintain a constant radius Earth premise. The hypothetical Panthalassa Ocean was considerably larger than the present Pacific Ocean, having to accommodate for the surface areas of the closed Atlantic, Southern, and Indian Oceans. This Panthalassa Ocean in turn is said to have merged imperceptibly with an equally theoretical Tethys Ocean. With time these, and other lesser oceans, are then depicted as periodically opening and closing. Similarly, ancient supercontinental fragments are also depicted as randomly colliding, amalgamating, re-fragmenting, and dispersing across each of the ancient oceans throughout Earth history.

On an **Expansion Tectonic** Earth these Panthalassa, Tethys, and Iapetus Oceans cannot be reconciled in their entirety. Instead, these same ancient oceans initially formed a network of much smaller continental seas covering low-lying areas of the ancient Pangaea supercontinental lands. These will be shown here to be represented by a primitive Panthalassa Sea, located between Australia, Asia, and North America; a Tethys Sea, located within the present Eurasian continent; and an Iapetus Sea, located between the West African and North American cratons, possibly extending into South America.

On an **Expansion Tectonic** Earth the modern oceans initially opened within ruptured areas of continental crust where supercontinental crust had failed to keep pace with changes to the Earth surface area and surface curvature. On small Earth models these rupture zones were initially located within the present northwest Pacific and North Atlantic Ocean regions respectively. The rupture zones then progressively opened and rapidly extended in surface area throughout the Mesozoic and Cenozoic Eras forming what are now the modern Pacific and Atlantic Oceans.

By late-Triassic to early-Jurassic times, rupture of the supercontinental crusts had also occurred in the north-polar Arctic Ocean and south-polar South Pacific and Atlantic Ocean regions. These rupture zones commenced as *passive margin* extensional basins—a simple opening process accompanied by extensive deposition of shallow marine sediments. By the late-Jurassic, opening of these rupture zones then shifted from a polar to a more elongate meridional position centred on the North Atlantic and Pacific Ocean regions. On-going changes in surface curvature, accompanied by further rupture and subsequent rifting, then saw the preservation of early-Jurassic seafloor crust within the newly emerging North Pacific Ocean, followed by late-Jurassic seafloor crust in the North Atlantic and Indian Oceans. Similarly, the Southern Ocean commenced opening during the Paleocene Epoch.

Throughout the Cretaceous Period, each of these new oceans continued to increase their surface areas and were accompanied by further break-up and rifting of the modern continents. Within these newly formed oceans, mid-ocean-ridge spreading axes were initiated and continued to develop as either: 1) asymmetric spreading patterns along the perimeters of the North and South Pacific Oceans; 2) as symmetric spreading patterns in the North and South Atlantic and Southern Ocean or; 3) a combination of both asymmetric and symmetric-type spreading patterns in the Indian Ocean. Not until the Mesozoic to Cenozoic transition did modern symmetrical mid-oceanic-ridge spreading patterns become firmly established throughout all of the modern ocean basins. This consistency of timing and sequence of ocean basin development agrees fully with the constraints imposed by the coloured seafloor spreading evidence.

On an **Expansion Tectonic** Earth it is again interesting note that the Cenozoic Era is characterised by initiation and extension of modern-day symmetrical-style spreading patterns throughout all of the modern ocean basins. This spreading was accompanied by further rifting and isolation of continental areas, such as Australia, Antarctica, and Greenland, as well as breaching of existing land connections between Antarctica and Australia, Antarctica and South America, North America and Europe, and Africa and Europe.

During this 250 million year history, extending from the late-Permian to the present-day, the Earth underwent a considerable and unprecedented increase in radius and surface area which was also accompanied by substantial changes in surface curvature. It should be appreciated that, just like rupturing of the continental crusts, seafloor crusts were also subject to on-going distortion and disruption during changing surface curvature. This is particularly evident in the North Pacific Ocean where rupture first commenced and where extensive areas of older Mesozoic crusts now occur. These changes to surface curvature of seafloor crust in the Pacific Ocean in particular has given rise to a complex interplay of island-arc volcanism, particularly along what are now referred to as the western Pacific Ocean island-arc and trench margins.

From this brief overview and introduction to **Expansion Tectonic** small Earth model studies of the modern oceans, the history of each of the modern oceans will now be looked at in more detail. In these descriptions of the modern oceans I emphasise that, when talking about movement or migration of continents on an **Expansion Tectonic** Earth, this movement refers to an apparent migration of the continental crustal fragments as a direct result of opening and widening of the modern oceans. Any movement of the continents simply accommodates for this opening of the oceans and has nothing to do with conventional continental drift or mantle convection theory.

5.1.1 Arctic Ocean

The Arctic Ocean originated as a very ancient marine sedimentary basin which first formed and commenced opening as the ancient Pangaea supercontinental crust started to rupture around 250 million years ago (Figure 5.2). This early Arctic Ocean basin was originally located in mid- to high-northern latitudes. Successive small Earth models then show that over time, as the ocean continued to open, the ocean basin and surrounding continents progressively migrated into the north polar-regions of today.

In Figure 5.2 it can be seen that the older Arctic Ocean shown in the lower right models is made up of a large expanse of marine sediments, shown as white areas located around the margins of the ancient continents, plus two seafloor basins shown as green colours. These green coloured seafloor basins are called the Amerasia and Eurasia Basins. The basins are Cretaceous in age and are shown to crosscut and displace the extensive white areas of marine sediments which were first deposited along the newly emerging continental shelf margins prior to exposure and preservation of the volcanic seafloor crusts.

Figure 5.2 Arctic Ocean small Earth spreading history, extending from the present-day back to the early-Jurassic.

On an **Expansion Tectonic** Earth, opening of the Arctic Ocean occurred as a result of crustal rupture and break-up of the ancient Pangaea supercontinent located between the newly formed North American and European continents. This break-up was then followed by on-going seafloor crustal stretching and opening of the Arctic Ocean within this region. The initially small Arctic Ocean basin progressively increased in surface area and its boundaries continued to extend further to the southeast during the Mesozoic Era.

The presence of exposed coloured seafloor crustal rocks within the Amerasia and Eurasia Basins shows that there was an initial period of seafloor spreading in each of these areas during the Cretaceous Period. The lack of any further seafloor crusts suggest that spreading then effectively ceased during late-Cretaceous times. Today, there are no active spreading centres in the older Arctic

Ocean regions. Spreading is now located within the adjoining Nansen-Gakkel mid-ocean-ridge, which is a northern extension of the North Atlantic Ocean mid-ocean spreading ridge.

From the late-Cretaceous to the present-day the North Atlantic mid-ocean-ridge continued to extended into the Arctic Ocean region, crosscutting pre-existing marine sedimentary basins in this area. This progression into the Arctic Ocean gave rise to further fragmentation of the ancient continental crust and opening of new oceans located between Greenland, Canada, and Russia. During this opening phase, sediments eroded from the lands were initially redeposited within the early Arctic Ocean basin. Deposition of sediments then progressively changed from deposition within a shallow marine basin to deposition within marine continental shelf settings which then bordered a true deep-ocean-spreading ridge.

Throughout much of this time the present-day Alaskan and Siberian Peninsulas remained joined, forming an important land-bridge between the two continents and effectively isolating the Arctic Ocean from the emerging Pacific Ocean. During this lengthy period of time there was also continental crustal stretching between the two land masses, which was accompanied by faulting along each of the peninsulas during opening of the Arctic Ocean basins. The continental crust that now makes up Greenland and the Canadian Arctic Islands also fragmented during this time and these fragments began to gradually rift apart as the oceans continued to open.

From 65 million years ago to the present-day the Arctic Ocean basin was characterised by an on-going phase of symmetric-style seafloor and continental crustal extension and opening. This phase has resulted in further separation of the Canadian Arctic Islands, opening of Hudson Bay, and further rifting between Greenland and Canada. Separation of the Alaskan and Siberian Peninsulas across the Bering Strait occurred within the past 2 million years and this crustal separation, rifting, and extension is continuing to the present-day.

5.1.2 Atlantic Ocean

The ability to match the east coast of South America with the west coast of Africa has long been recognised by mapmakers for many centuries. This remarkable fit-together now forms the conceptual basis for both early Continental Drift and Plate Tectonic studies. The closing of the Atlantic Ocean and reconstruction of these continents also forms the basis for assemblage of the Pangaea supercontinent. This fitting together of the South American and African continents is further substantiated by an extensive array of geological evidence dating back to the investigations of Wegener.

On conventional reconstructions of the Atlantic Ocean, the corresponding margins of northern Brazil in South America and Guinea in Africa are traditionally fitted together according to their geological matches. But, unbeknown to most people, fitting these coastlines together produces a narrow triangular gap which widens south between the continental margins of South America and Africa south of the Niger Delta region. To minimise this misfit, the margin of South America may also be fitted against southern Africa south of the Niger Delta region. This then produces a narrow triangular gap between the

Guinea and north Brazil coastlines, widening northwards. Unfortunately, this also produces a significantly greater area of misfit in the Florida and Central American regions.

It is significant to note that in 1958, when Carey first reassembled these continents on a spherical model representing the Earth's modern dimension, Carey noted these very same misfits. He commented that *"...if all the continents were reassembled into a Pangaean configuration* on *a model representing the Earths modern dimensions, the fit was reasonably precise at the centre of the reassembly and along the common margins of north-west Africa and the United States east coast embayment, but became progressively imperfect away from these areas."* Carey concluded from this research that the fit of these ancient continents *"...could be made much more precise in these areas if the diameter of the Earth was smaller at the time of Pangaea."*

Opening of the North and South Atlantic Oceans on an **Expansion Tectonic** Earth is shown sequentially in Figure 5.3. Opening is shown to have commenced in the lower right models during the early- to late-Jurassic in the North Atlantic region, located between North Africa and North America. This opening North Atlantic region later extended south to merge with the opening South Atlantic Ocean, as well as west into the Gulf of Mexico and Caribbean regions.

On **Expansion Tectonic** small Earth models it is significant to note that, just as Carey concluded, when the North and South Atlantic Oceans are closed misfitting between the continental margins of North and South America, Europe, and Africa is entirely eliminated. Opening of these oceans during the Mesozoic and Cenozoic Eras is then shown to be progressive and symmetrical. Subsequent opening of the Atlantic Ocean is also shown to have occurred in conjunction with opening of both the Arctic and Indian Oceans.

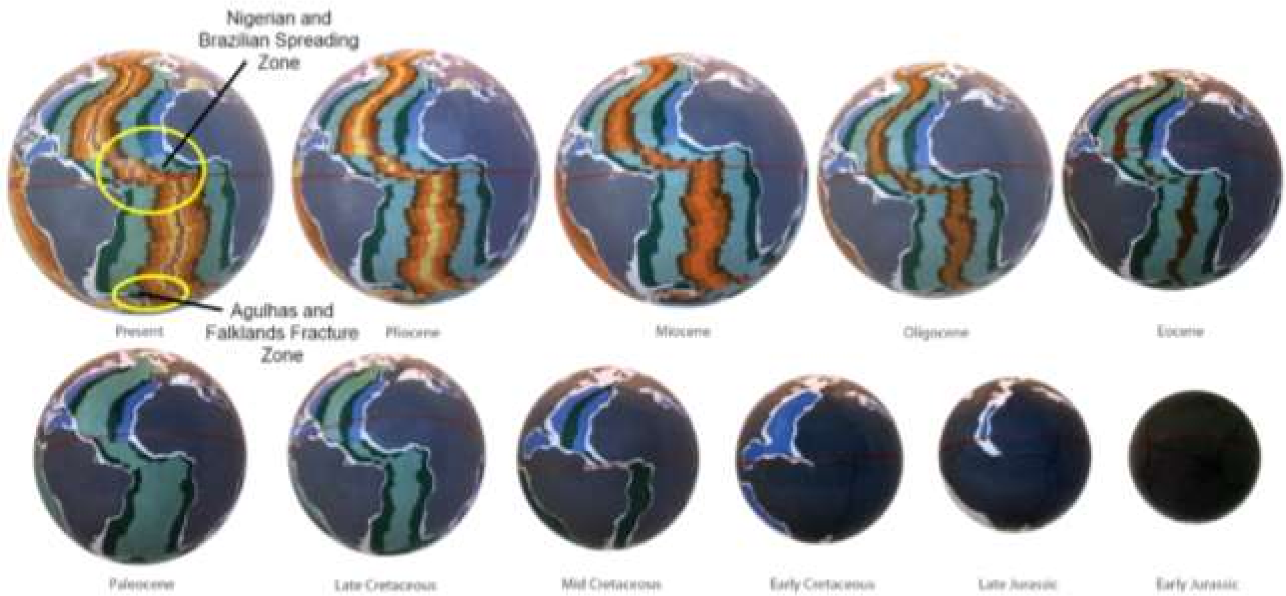

Figure 5.3 Atlantic Ocean small Earth sequential spreading history, extending from the present-day back to the early-Jurassic.

5.1.2.1 North Atlantic Ocean

Opening of the North Atlantic Ocean on an **Expansion Tectonic** Earth is shown in Figure 5.3 to have commenced as a narrow rift basin, located between the east coast of North America and west coast of Africa. Over time, this rift basin continued to open and progressively extend north into the Arctic Ocean and south into the South Atlantic Ocean. From the early-Jurassic a small counter clockwise rotation of the combined South American and African supercontinent, relative to North America, accelerated opening of the North Atlantic region and also extended the ocean west into what is now the Caribbean Sea. This rotation occurred in sympathy with opening of the Pacific Ocean as each of the adjoining continents continued to adjust for changing Earth radius and surface curvature.

During the early-Cretaceous—about 130 million years ago—the newly formed North Atlantic spreading ridge continued to extend north into the Grand Banks continental shelf, then located between Canada and Iberia. This occurred in response to both continental plate motion and opening of the Caribbean Sea. Rifting between South America and Africa also commenced which then initiated a progressive extension of the spreading ridge into the previously separated North and South Atlantic Oceans.

By the Late Cretaceous—around 80 million years ago—the North Atlantic mid-ocean spreading ridge had continued to extend further north into the Arctic Ocean. This spreading ridge then branched northwest into the Labrador Sea rift zone, located between Canada and Greenland, and northeast into the Mediterranean Sea. The extension and branching of this spreading ridge gave rise to continental break-up and rifting between Canada and Greenland, as well as rifting and rotation of Spain relative to both France and England.

From the late-Cretaceous to the present-day, the North Atlantic mid-ocean-ridge has continued to open in conjunction with both the Nansen-Gakkel spreading ridge within the Arctic Ocean and the South Atlantic spreading ridge. Spreading within each of these areas has resulted in a progressive enlargement of both the North and South Atlantic Oceans and was accompanied by symmetrical seafloor spreading.

5.1.2.2 South Atlantic Ocean

The South Atlantic Ocean, as shown in Figure 5.3, commenced opening between the southern South American peninsular and the South African region as a long narrow rift zone and has continued to steadily open to the present-day. The pattern of coloured seafloor stripes shows that this opening occurred in sympathy with opening of the Indian Ocean. Because of this, these two oceans can be considered as extensions of the same continental crustal rupture and opening event.

Separation between the west coast of Africa and east coast of South America commenced during the late-Jurassic—around 155 million years ago. This opening occurred along the now separated Agulhas and Falklands fracture zones, presently located in the southern South Atlantic Ocean. During late-Jurassic times, continental rifting and separation of the two continents progressively extended north. The South Atlantic spreading ridge then eventually merged with the North Atlantic spreading ridge during the early-Cretaceous along the Nigerian and Brazilian rift zone. From that time on the North and South Atlantic Oceans have remained united as a single Atlantic Ocean.

From the late-Cretaceous—around 80 million years ago—to the present-day spreading in both the North and South Atlantic Oceans has continued along a common mid-Atlantic spreading ridge. Subsequent spreading in both regions continued to be symmetrical, with a slow clockwise rotation of South America, relative to Africa, giving a slightly greater spreading rate in the southern South Atlantic Ocean.

5.1.3 Caribbean Sea

The Caribbean Sea is made up of the Mexico, Colombian, and Venezuelan Basins, which are shown in Figure 5.4 to be separated by what is referred to as the Antilles Arc. On an **Expansion Tectonic** Earth the development and subsequent opening of the Caribbean Sea was intimately related to the continental plate motion histories of both South America and Africa, relative to North America. Bedrock geological mapping of the seafloor shows that opening of each of the Caribbean basins was most active during the Jurassic Period. This was then later reactivated along the Antilles Arc during the Paleocene—around 65 million years ago—and has continued to open as a relatively restricted basin to the present-day.

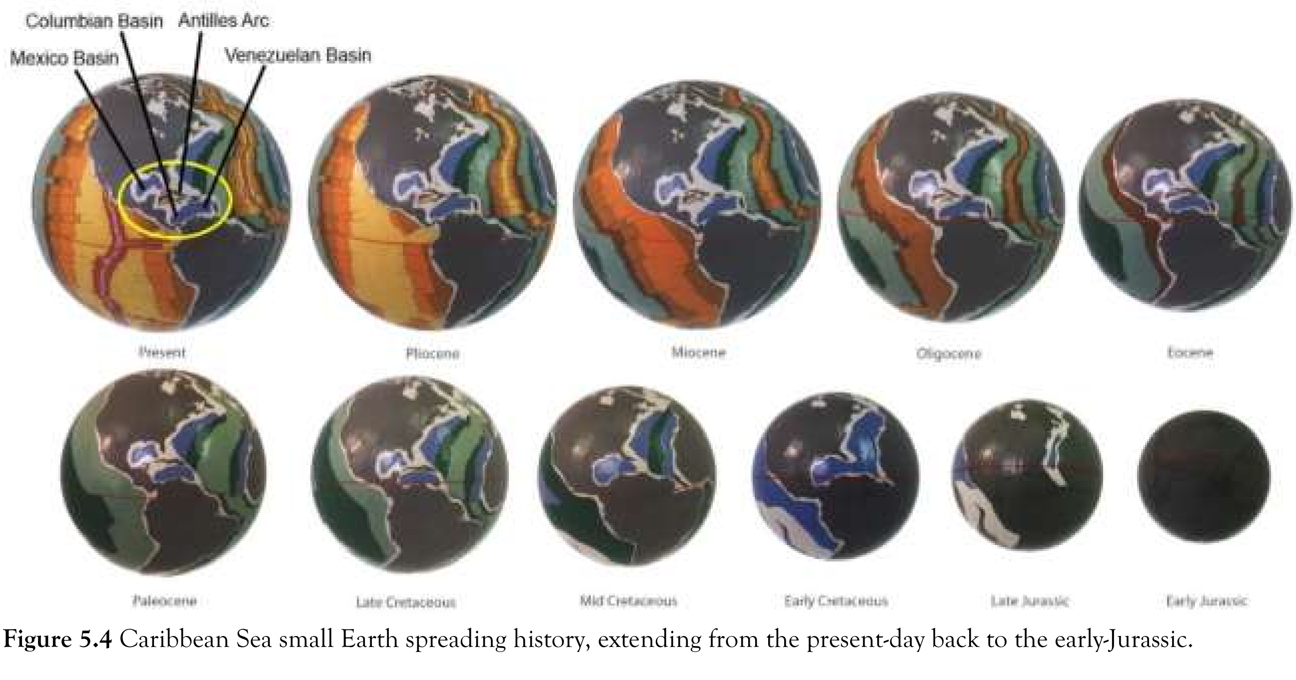

Figure 5.4 Caribbean Sea small Earth spreading history, extending from the present-day back to the early-Jurassic.

Plate Tectonic reconstructions of the Atlantic Ocean traditionally fit the Brazil and Guinean coastlines of South America and Africa together. This fit helps to minimise any misfit in the Caribbean Sea region. The Caribbean region is then seen as a buffer zone between the North American plate, the South American plate, and subducting oceanic plates of the Pacific Ocean. On these reconstructions the Caribbean region is considered to be a preserved piece of the ancient Pacific Ocean, referred to as the Farallon plate, which is inferred to have originated from outside of the Caribbean region.

On an **Expansion Tectonic** Earth, early development of the Caribbean Sea was intimately associated with opening of the North Atlantic Ocean along with subsequent rifting of Africa away from the Americas. Opening of the Caribbean Sea commenced during the Triassic to early-Jurassic Periods as a result of north-south crustal stretching and extension between the North and South American continents. Subsequent development of the Caribbean Sea was then closely related to a northwest migration of North America, relative to the still joined South American and African supercontinent. The Colombian and Venezuelan basins then opened during the Jurassic to Cretaceous Periods and were later separated by the Antilles island-arc.

This early opening phase lasted until the early-Cretaceous—around 130 million years ago—when rifting and eventual break-up between South America and Africa first began. During this phase, the Nicaraguan and Panama Peninsulas remained joined to South America. After separation of South America from Africa, South America then began to slowly rotate clockwise, relative to North America, in response to opening of the South Atlantic Ocean. This gave rise to further crustal extension and opening within the Caribbean basins, as well as isolation of the Antilles island-arc.

From the Paleocene Period to the present-day, South America has continued to slowly rotate clockwise, relative to North America, and was accompanied by fault movement along the length of the Antilles Arc. This fault movement extended along the western margin of Mexico and has since continued into the Gulf of California where it is known as the San Andreas Fault.

On an **Expansion Tectonic** Earth, an external origin for the Caribbean crustal region, as proposed in Plate Tectonic studies, is unnecessary. Small Earth model studies show that sourcing a fragment of crust from the Pacific region is untenable and is inconsistent with the established seafloor crustal mapping. Instead, opening of the Caribbean Sea region is shown to be intimately associated with opening of the North Atlantic Ocean as well as on-going crustal plate motion between North and South America and Africa.

5.1.4 Indian Ocean

Reconstructions of the Indian Ocean and assemblage of the surrounding continents is crucial to understanding the assemblage, break-up, and dispersal history of the Plate Tectonic Gondwana and Pangaea supercontinents. These conventional reconstructions place the precursor to the Indian continent within an ancient southern Gondwana supercontinent, located adjacent to Africa, Madagascar, and Antarctica. The Indian Ocean is then inferred to have formed during the subsequent break-up and dispersal of the Gondwana continental fragments during a later Pangaean supercontinental assemblage cycle.

On this conventional reconstruction an inferred ancient Tethys Ocean was located between a southern Pangaea supercontinent, made up of fragments of the Gondwana supercontinent, and a northern Laurasian supercontinent.

During break-up of these supercontinents, India is then inferred to have broken away from Gondwana to migrate north as an island continent during subsequent opening of the Indian Ocean. This northward migration of India during the Mesozoic to early-Cenozoic Eras requires subduction of some 5,000 lineal kilometres of inferred pre-existing seafloor crust in order to close the ancient Tethys Ocean. India is then said to have collided with the Asian continent to form the Himalaya Mountains during the Cenozoic Era, leaving behind no trace of this pre-existing ocean crust.

In contrast, on an **Expansion Tectonic** Earth, small Earth modelling shows that the Indian continent remained firmly attached to the Asian continent throughout the Mesozoic and Cenozoic Earth history (Figure 5.5). The Indian Ocean is then shown to have opened during a post-Triassic phase of crustal rupture of the Pangaea supercontinent, in sympathy with opening of the adjoining Atlantic Ocean basin.

Opening of the Indian Ocean on an **Expansion Tectonic** Earth is shown in Figure 5.5 to have commenced during the early-Jurassic Period. This occurred as a result of initial crustal rupturing within two separate areas, located adjacent to both India and Madagascar, in what are now the Somali Basin and the Bay of Bengal. Opening, and a southward extension of the Somali Basin continued up to the mid-Cretaceous Period which later became the Mozambique Channel located between Madagascar and Africa. During that time the Indian, Madagascan, and Sri Lankan continents and islands continued to remain firmly attached to the ancient Asian continent.

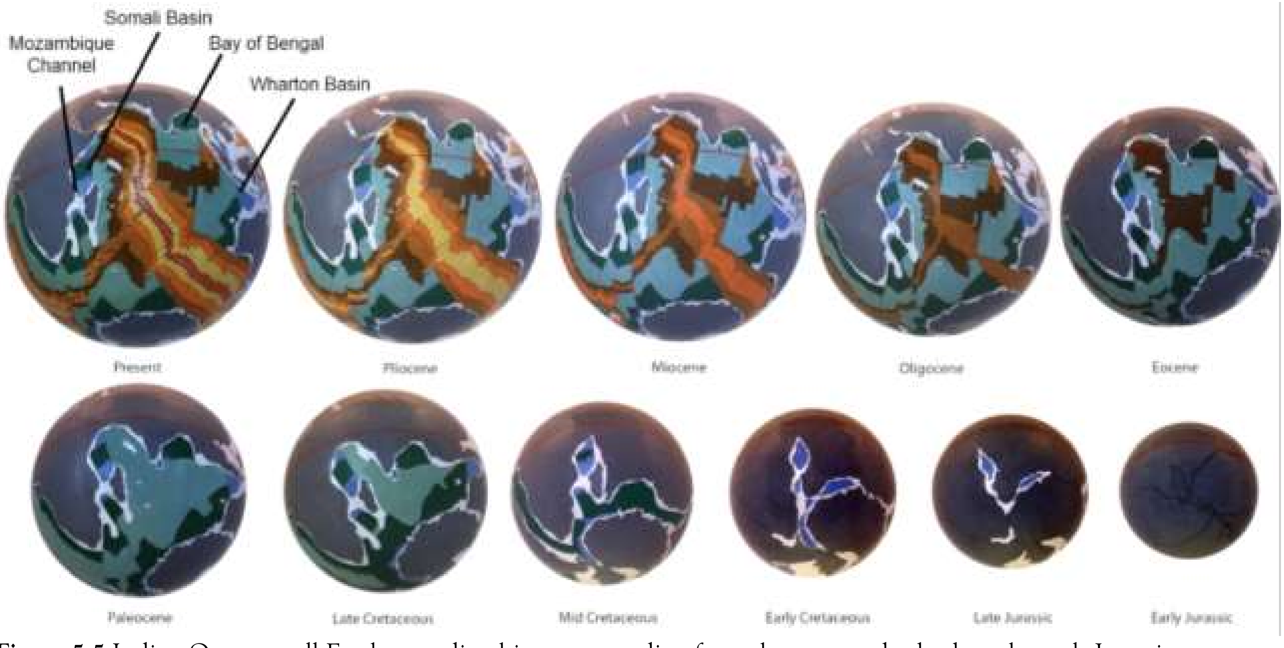

Figure 5.5 Indian Ocean small Earth spreading history, extending from the present-day back to the early-Jurassic

Crustal break-up and opening between Africa, Madagascar, India, and Antarctica then progressively extended south during the early- to late-Jurassic. During that time the Somali Basin and Bay of Bengal areas merged south of Madagascar. The merging of these basins formed what is referred to as a *triple-junction*—the junction of three separate spreading ridges and crustal plates—south of Madagascar and this region now represents the birthplace of the modern Indian Ocean basin.

The Mozambique Channel represents the northern limb of this early Indian Ocean triple junction. The southern limb of the triple junction extended south, around the tip of South Africa, to form an extension of the South Atlantic Ocean, which opened near the present Falkland Islands. The east limb then extended east to form the emerging Wharton Basin, which lay adjacent to West Australia.

By the mid-Cretaceous Period, the Mozambique Channel spreading ridge was abandoned and a new spreading ridge commenced opening between Madagascar and India. Once abandoned, the Somali Basin, Mozambique Channel, and Madagascar continent then remained as part of the African plate as seafloor crustal extension and opening progressively shifted to the east.

From the mid-Cretaceous to Paleocene times seafloor spreading continued between Madagascar, Africa, and India forming the Arabian Sea. During that time the Indian Ocean underwent a rapid north-south and east-west opening between Australia, Antarctica, Africa, and South East Asia, with a rapid northward opening and displacement of the Indian and Asian continents relative to Antarctica.

During the Paleocene—65 million years ago—to the present-day, symmetrical seafloor spreading radiated from a new triple junction located within the central Indian Ocean. This new spreading crosscut and displaced the older, previously established Mesozoic seafloor crust. Spreading then extended into the southern Indian Ocean, east between Australia and Antarctica and northeast into the Gulf of Aden. In the southern Indian Ocean region, the southwest limb of this spreading ridge split across older spreading patterns and now forms an extension of the South Atlantic Ocean mid-ocean-ridge system.

The north-south Ninety East spreading ridge, located within the eastern Indian Ocean, was abandoned during the Eocene. A new spreading ridge then extended southeast from the central Indian Ocean triple junction into a newly opening rift zone located between the Australian and Antarctican continental plates. This rifting initiated separation and northward migration of Australia relative to Antarctica, as well as initiation and relatively rapid opening of the Southern Ocean.

As spreading continued, the Gulf of Aden opened during the Miocene along a northwest extension of the central Indian Ocean and Carlsberg spreading ridges. A second triple junction has since formed at the western end of the Gulf of Aden during the Pliocene. This triple junction is now represented by the actively spreading Red Sea ridge and the East African Rift Valley system.

5.1.5 Pacific Ocean

At present the Pacific Ocean occupies nearly half the surface area of the Earth and can be arbitrarily subdivided into North Pacific, Central Pacific, and South Pacific Ocean regions. In all Plate Tectonic reconstructions, the precursor to the Pacific Ocean was a much larger ancient Panthalassa Ocean. This largely hypothetical early-Mesozoic Panthalassa Ocean is inferred to have possessed an old seafloor crust, which was formed by spreading along ancient mid-ocean-ridge zones during the Palaeozoic Era—the era prior to the Mesozoic Era—extending into the Triassic Period.

The Mesozoic and Cenozoic Plate Tectonic history is then depicted as an east-west and north-south contraction and reduction in surface area of the ancient Panthalassa Ocean in sympathy with opening of the Arctic, Indian, and Atlantic Oceans. This ancient ocean is thought to have eventually contracted in area to the size of the modern Pacific Ocean and is inferred to be still shrinking. During that time, all pre-Mesozoic crust is inferred to have been subducted beneath the continents along subduction zones located around the margins of the Pacific Ocean basins. This inferred subduction must have also included a substantial amount of new Mesozoic and Cenozoic seafloor crust, which is currently being generated within the East Pacific Ocean mid-ocean-ridge zone.

On all Plate Tectonic reconstructions, the North American continent progressively overrides the eastern North Pacific Ocean region. This supposedly occurs during a westward displacement of the North American continent during opening of the North Atlantic Ocean. The North Pacific Ocean spreading ridge is then inferred to have been entirely overridden and subsequently dislocated beneath the Pacific margin of the North American continent.

In contrast, on an **Expansion Tectonic** Earth an expansive pre-Mesozoic Panthalassa Ocean, and similarly an ancient Tethys Ocean, did not exist. Subduction of between 5,000 to 15,000 lineal kilometres of pre-existing East Pacific seafloor crust beneath the American continent is also not required. In Figure 5.6 the Pacific Ocean is instead shown to originate during early-Jurassic times as two separate marine sedimentary basins. A North Pacific basin was located between northwest Australia, Canada, and China, and a South Pacific basin was located between east Australia, South America, New Zealand and Antarctica.

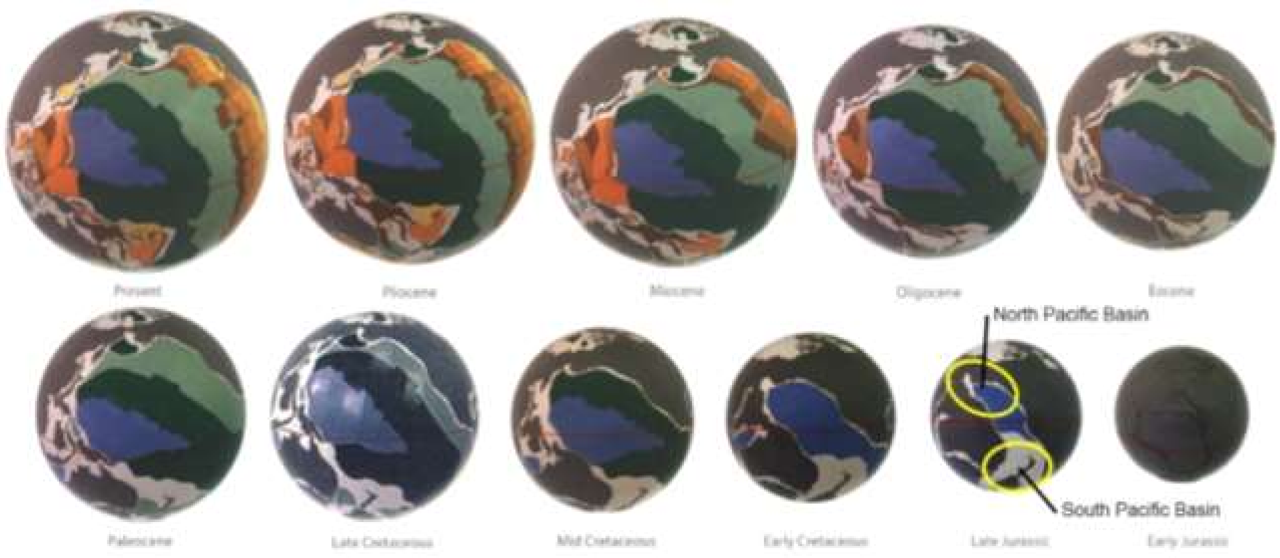

Figure 5.6 North Pacific Ocean small Earth spreading history, extending from the present-day back to the early-Jurassic.

Both of these marine basins progressively opened to the south and north, along the west coasts of North and South America respectively. These basins then merged to form a single Pacific Ocean basin during the mid- to late-Jurassic

Period. Remnants of this early basin history are now preserved as continental margin and marine plateau sediments within the South East Asian and Coral Sea regions—shown as white areas in Figures 5.6 and 5.7.

On an **Expansion Tectonic** Earth, the subsequent evolution of the North and South Pacific Oceans involved a period of rapid northeast to southwest crustal extension and opening between North America, South America, and Australia. By the late-Jurassic, a deep ocean had extended southeast and south along the west coasts of North and South America. This coincided with the initiation, exposure, and preservation of new volcanic seafloor crust in the South Pacific Ocean.

Figure 5.7 South Pacific Ocean small Earth spreading history, extending from the present-day back to the early-Jurassic.

Throughout the Mesozoic Era the North Pacific Ocean underwent a very rapid enlargement, with asymmetric spreading axes extending southeast into the South Pacific region. This spreading and mid-ocean-ridge development curved along the west coasts of North and South America and extended west into the Coral Sea region during the Cretaceous.

During the mid- to late-Jurassic, crustal rifting and opening between New Zealand, New Caledonia, South America, Australia, and Antarctica isolated the Coral Sea plateau, as well as the Lord Howe Rise and New Zealand. This rifting phase then left New Zealand as an island continent, which has remained isolated from surrounding continents to the present-day.

Development of the Pacific Ocean on an **Expansion Tectonic** Earth during the Cenozoic Era is characterised by the initiation and rapid development of symmetric-style seafloor spreading. This initially commenced within the Tasman Sea region, located southeast of Australia, during the Paleocene and continued to extend east towards South America during the Eocene. From there symmetric spreading continued north, forming the present East Pacific spreading ridge, and then continued to extend along the west coast of North America to its present location adjacent to California.

The opening and formation of the Pacific Ocean on an **Expansion Tectonic** Earth differs slightly to each of the other oceans. Because of the long period of time involved in opening the Pacific Ocean, the large area of older seafloor crust in the North Pacific region has been subject to considerable crustal stretching and distortion as a result of the changing surface curvature of the Earth. This changing surface curvature was generally absorbed as extension within the thin seafloor crust, but it also gave rise to complex plate interaction and jostling between and along adjoining plates, in particular between the various seafloor and continental plate margins.

Between the North Pacific Ocean plate and the Australian, South East Asian, and Chinese plates, complex crustal interaction has also given rise to the South East Asian island-arc-trench systems, which are now characteristic of the western Pacific region. On an **Expansion Tectonic** Earth, this region represents a complex interplay of plate motions that were generated during on-going adjustments to surface curvature, especially within the older North Pacific Ocean region.

It should be noted that the development of the Pacific Ocean on an **Expansion Tectonic** Earth cannot be reconciled with Plate Tectonic reconstructions on a constant sized Earth. On an **Expansion Tectonic** Earth the restrictions imposed by an early-Mesozoic Panthalassa and Tethys Ocean, as well as circum-Pacific subduction of pre-existing seafloor crust, simply did not exist and were not required during small Earth plate reconstruction. Instead, a process of asymmetric to symmetric evolution of the East Pacific Ocean spreading ridge readily explains the complex crustal patterns shown by the Pacific Ocean seafloor mapping. Likewise, the island-arc-trench systems and extensional back-arc-basins are readily explained by crustal interaction along the plate margin boundaries during relief of surface curvature, especially in the older crustal regions.

5.1.6 Mediterranean Sea

The Mediterranean to Middle East region is a complex and contentious region on Plate Tectonic reconstructions. In order to reconstruct the continents on a constant radius Earth, both Europe and Asia must be fragmented in order to close the Atlantic and Indian Oceans. On all conventional reconstructions the Mediterranean region then forms the western apex of a large triangular-shaped ancient Tethys Ocean. From there, this ocean is inferred to widen eastward towards an even larger ancient Panthalassa Ocean which separated the ancient supercontinents of Gondwana in the south and Laurasia in the north.

The evolution of the Mediterranean to Middle East regions on an **Expansion Tectonic** Earth is shown in Figure 5.8. Here, the Mediterranean Sea represents the remnants of a more extensive continental Tethys Sea—as distinct from a conventional Tethys Ocean. The Tethys Sea will be shown later to have had an extensive crustal and sedimentary basin history, extending back to the early Precambrian times.

Figure 5.8 Mediterranean Sea small Earth spreading history, extending from the present-day back to the early-Jurassic.

On an **Expansion Tectonic** Earth the Mediterranean region initially developed during pre-Triassic times as a result of crustal extension between the ancient African and European continents. Crustal rupture within the ancient continental Tethys Sea then commenced during the Jurassic, which initiated opening of the modern Mediterranean Sea and crustal development within the Middle East region. The ancient Tethys Sea, in effect, represents the seabed of what is now the continental region of central Europe, the Middle East, and Asia.

Opening of the Caspian Sea followed during the early-Cretaceous Period. The Black Sea then followed during the mid-to late-Cretaceous and the Aral Sea during the Paleocene. These small seas all represent regions of continental crustal rupture and opening, which was initiated during complex clockwise crustal rotation occurring between the combined African-Arabian plate and central Europe.

Seafloor bedrock mapping shows that crustal extension within the Mediterranean to Middle East region was only active during Jurassic and early-Cretaceous times. From mid-Cretaceous to Miocene times complex crustal motions, including some localised compression between Africa and Europe, formed the Alpine Mountain belts. This event was followed by a continuation of continental crustal extension and renewed basin opening forming the young sedimentary basins presently located within much of central Europe.

The Alpine Mountain building event coincided with a northward extension of the North Atlantic Ocean spreading ridge which was marked by the opening of the Bay of Biscay, located between Spain and France, during the late-Cretaceous. Similarly, opening of the Persian Gulf and Red Sea also commenced during the Eocene and these are continuing to open to the present-day. Seafloor spreading was re-activated in the western Mediterranean region during the Miocene and was accompanied by continental rifting between West Africa and Spain.

On an **Expansion Tectonic** Earth separation of the Gondwana and Laurasia supercontinents by a large Tethys Ocean, and similarly a north-south closure of the Tethys Ocean during the Mesozoic and Cenozoic Eras, is not required. Instead, opening of the Mediterranean to Middle East region occurred as a result of clockwise rotation and crustal extension between Europe and the Middle East, relative to the adjoining African-Arabian continent. This continental crustal motion, extending from the Iberian Peninsula to the Tibetan Plateaux, also resulted in the rotation of Italy and fragmentation of the Alpine mountain belts during the mid-Cretaceous to present-day times.

These **Expansion Tectonic** Earth reconstructions also present a straightforward development history for the Black Sea region, the mountain belts of the Balkans, Turkey, and the Caucasus, the development of the southern Russian platform north of the Black Sea and the development of the Aegean Sea during the late-Cenozoic.

5.1.7 South East Asian Seas

The South East Asian region comprises the Philippine, South China, Celebes, Banda, and Java Seas. In this region the present-day South East Asia to New Guinea and Japanese Island chains represent complex island-arc systems. Plate Tectonic reconstructions on a constant sized Earth are particularly vague when it comes to reconstructing South East Asia. On these conventional reconstructions the region is represented by small remnant crustal fragments, which are inferred to have existed at the eastern end of a large ancient Tethys Ocean where it merged with an even larger Panthalassa Ocean. During closure of both the Tethys and Panthalassa Oceans, the South East Asian Seas were then interpreted to represent marginal or back-arc basins. These basins were further separated from the various island-arcs by spreading along zones of inferred crustal subduction and deep trench development.

The development of the South East Asia basins and seas on an **Expansion Tectonic** Earth is shown in Figure 5.9. This development of the South East Asia region is complex and progressive. Small Earth model studies show that development within this region was intimately associated with the formation and subsequent plate interaction of the North Pacific oceanic plate. On these small Earth models the region is shown to represent the fragmented remains of ancient intercontinental marine and continental sedimentary basins, as well as associated volcanic activity.

The South East Asian region initially formed during early-Jurassic times. This region represents an area of marine basin opening, accompanied by deposition of sediments, and was located between the early Australian, North American, and Chinese continents. These basins first formed in conjunction with the initial rupturing and opening of the North Pacific Ocean. At that time, sediments eroded from the surrounding lands were being redeposited within the newly formed marine basins. These sediments were mixed with volcanic rocks, erupted along the precursors to the modern mid-ocean-ridge spreading zones, to form the early island-arc systems. Remnant sediments from this early opening event are now preserved as both continental shelf and marine plateau sediments, which are exposed as the South East Asian islands and submerged plateaux throughout the South East Asian Sea region.

Figure 5.9 Southeast Asian and Southwest Pacific Basin small Earth spreading history, extending from the present-day back to the early-Jurassic.

Development of the South East Asia region has been further complicated by the plate motion history of Australia, relative to Asia, during opening of both the Pacific and Indian Oceans. Progressive crustal extension and opening between each of these continents occurred during late-Cretaceous to Pliocene times which then resulted in opening of the South China, Celebes, and Banda Seas, as well as fragmentation of the early South East Asian island-arc system.

The crustal fragments making up the South East Asian region have since undergone complex clockwise rotation, crustal fragmentation, plate interaction, and on-going island-arc volcanism. These events all occurred during an extended period of southeast to northwest crustal extension between the Asian and Australian continental plates. This interpretation of the South East Asia region contrasts strongly with the Plate Tectonic requirement for continental collision, the closure of pre-existing Tethys and Panthalassa Oceans, and complex subduction of the Australian and North Pacific plates beneath the Asian and Philippine plates.

5.1.8 Southwest Pacific Ocean

The Southwest Pacific Ocean region is also structurally complex and comprises the Coral and Tasman Seas. The region is predominantly made up of remnants of ancient seafloor crust and marine sediments. These sediments were initially deposited and later fragmented during Cretaceous to Paleocene times and again during Miocene to present-day times. The region has been further complicated by crustal plate motion and plate interaction occurring along the margins of the Indo-Australian and Pacific plates.

The southwest Pacific Ocean region is shown on **Expansion Tectonic** small Earth models in Figure 5.9 above. This region represents the fragmented remains of earlier marine basins and sediments, deposited within an early pre-Triassic South Pacific Ocean basin. Initially, this area opened as a passive marine basin during pre-Triassic times. The newly formed basin then formed part of the early South Pacific Ocean, prior to merging with the North Pacific Ocean during the Triassic Period.

During pre-Triassic times, West Antarctica and New Zealand were assembled adjacent to Australia and South America. Subsequent rifting and opening between South America, New Zealand, and West Antarctica initiated formation of the South Pacific Ocean. During Triassic to early-Jurassic times, New Zealand and New Caledonia were separated from Australia during opening of the Tasman Sea. These remained attached to Ecuador in Central America until final separation from South America during the mid-Jurassic times.

During the mid- to late-Jurassic an early New Zealand and New Caledonian continent comprising the Coral Sea plateau, Lord Howe Rise, and New Zealand island-arc complex were well established. This ancient continent then further fragmented and was partly submerged to form the present Southwest Pacific region. Asymmetric seafloor spreading first developed in the South Pacific Ocean and this spreading extended west during the Cretaceous into the Tasman Sea. This event further isolated the Lord Howe Rise and New Zealand continent from Antarctica and Australia.

On an **Expansion Tectonic** Earth, the Tongan to South Solomon and New Hebrides trench and island-arc systems represent complex zones of plate interaction between the New Zealand and New Caledonia continental plate and the South Pacific Ocean plate margins. This complex interaction developed during on-going changes in Earth surface area and surface curvature over time. The interaction of these plates resulted in a slow clockwise rotation of the southwest Pacific Ocean region along each of the established trench and arc systems. In addition, the New Zealand and New Caledonian plate was further fragmented and displaced during the Cenozoic Era.

The rapid development of symmetric-style seafloor spreading in the South Pacific Ocean resulted in further opening of the southwest Pacific Ocean region during the Cenozoic. Complex plate interaction and motion along the Kermadec and Tongan trench and arc systems again accompanied this opening during the early-Miocene. This crustal motion was also related to movement along the Alpine Fault system of New Zealand, which continues to the present-day.

On an **Expansion Tectonic** Earth, the southwest Pacific Ocean basin region cannot be reconciled with conventional Plate Tectonic reconstructions. Instead, this region simply represents a complex interplay of extensional crustal motion and opening between Australia, North America, South America, and Antarctica in conjunction with opening of the North and South Pacific Oceans during on-going changes to Earth radius and surface curvature.

5.1.9 Southern Ocean

The Southern Ocean is located between the present Australian and East Antarctican continents. The ocean arbitrarily merges with the South Pacific and Indian Oceans to the east and west respectively. Rifting and opening of the Southern Ocean first commenced in conjunction with opening of the Atlantic and Indian Oceans during the late-Jurassic. Further opening then initiated final separation of Australia and Antarctica during the Paleocene, some

65 million years ago. Symmetric-style seafloor spreading in the Southern Ocean has since extended west, in conjunction with the eastern arm of the central Indian Ocean spreading ridge, and east to form an extension of the East Pacific spreading ridge.

Opening of the Southern Ocean is a paradox on Plate Tectonic reconstructions and very little mention of this ocean is made in conventional literature. This paradox arises because there are no subduction zones available to absorb the extensive plate motion required to continue opening the ocean.

On **Expansion Tectonic** Earth reconstructions (Figure 5.10), opening of the circum-polar Southern Ocean forms part of the extensive global network of mid-ocean spreading ridges. The opening and northward migration of the southern continents simply represents a natural consequence of break-up of the Pangaea supercontinent and increase in surface areas of the Southern and adjoining ocean basins during an increase in Earth radius.

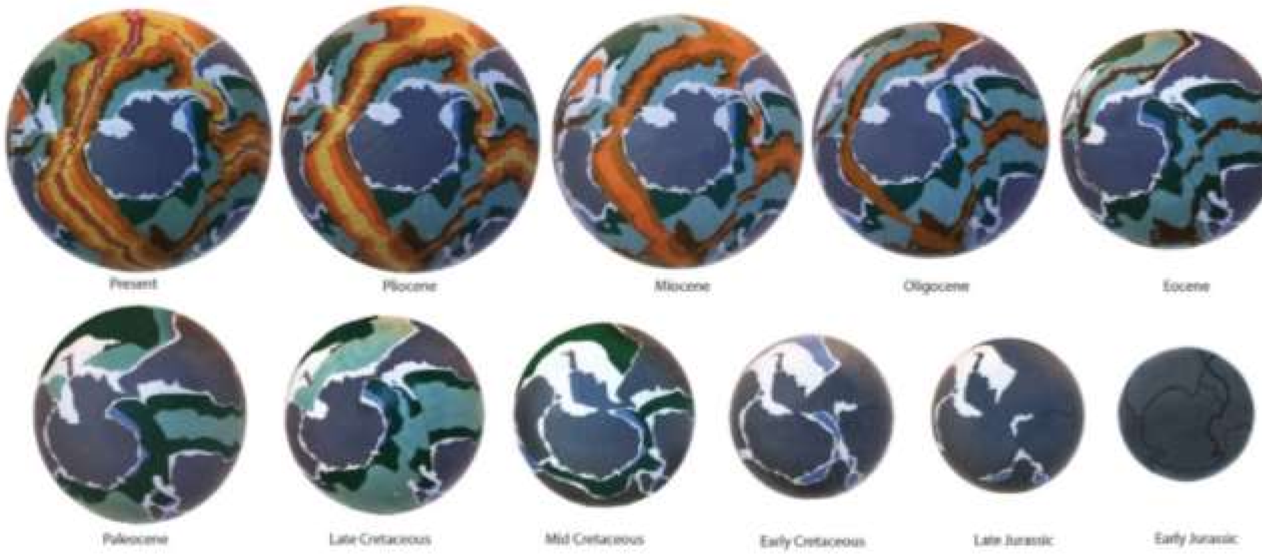

Figure 5.10 Southern Ocean small Earth spreading history, extending from the present-day back to the early-Jurassic.

Each of the **Expansion Tectonic** small Earth models shown in Figure 5.10 demonstrate that the Southern Ocean spreading ridge is intimately associated with the global network of ridges exposed within all of the modern oceans. No arbitrary disruption of the Southern Ocean mid-ocean-ridge network is required during subsequent opening. In addition, no pre-existing crust needs to be removed by subduction processes and arbitrary fragmentation of continental crust is also not required.

It is appropriate to also mention that the entire Southern Ocean mid-ocean-ridge has continued to increase in length and has migrated north over time. What this simply means is that the Southern Ocean ridge was once the length of the perimeter of Antarctica, but has since moved away from the margin during opening and is now much longer. This movement and increase in length is a simple reflection of the northward migration of adjoining continents during an increase in the surface area of the Earth over time.

5.2 Observations to Date

The outcome of this discussion on the origin of the modern oceans shows quite clearly that, not only does the published seafloor bedrock mapping provide a unique means of constraining the precise location of the crustal plates at any moment in time back to the early-Jurassic Period, but it also provides a unique framework for discussing the origin of the modern oceans and seas. By moving back in time and returning the seafloor volcanic crust back to the mantle, from where it originated, it is then a simple matter of progressively reducing the surface areas of each of the ocean basins and moving each of the continents closer together.

In contrast to Plate Tectonic reconstructions, the uniqueness of adopting **Expansion Tectonic** small Earth models means:

There is no need to consider where, or when pre-existing crusts occurred. The small Earth models also remove the need to invoke hypothetical ancient oceans to maintain a constant surface area Earth, or subduction to dispose of excess crusts. Instead, all that is needed is to let the configuration of the seafloor bedrock mapping dictate the precise crustal plate location and assemblages on a pre-determined smaller radius Earth model.

A further outcome of this discussion is that initial opening of the modern oceans on an **Expansion Tectonic** Earth consistently occurs during the Permian and Triassic Periods. This opening was intimately associated with break-up of the ancient supercontinents and formation of the modern continents. By continuing to move further back in time and closing off each of the modern oceans in turn, the origin of the modern continents can now be discussed in conjunction with modelling the ancient supercontinents and ancient continental seas.

6 Modelling Continental Crusts

"...it is theoretically possible for the continents, without shelves, to fit together at approximately 40 percent of the present Earth radius by considering that continental shelves were formed after the continental crust had fragmented." Vogel, 1983

As has been seen, by continuing to model the seafloor crustal mapping back in time to the early-Jurassic Period, seafloor volcanic lava and sediments deposited around the continental shelves must be progressively removed from each small Earth model in turn. Once all of the seafloor volcanic lava and sediments are removed and returned to where they came from, the remaining continental plates re-unite to form a complete pan-global supercontinental crust on an ancient Earth with a radius of about 55 percent of the present Earth radius. On this small Earth model, as well as the continental crusts assembling together, the remaining continental shelf sediments, located around the margins of the present-day continents, also merge to form a network of shallow seas coinciding with continental sedimentary basins. These seas, in turn, surround and define the geography of the exposed ancient Pangaean land surface.

When Vogel constructed his small Earth models during the 1980s he also suggested that it is *"...theoretically possible for the continents, without shelves, to fit together at approximately 40 percent of the present Earth radius by considering that continental shelves were formed after the continental crust had fragmented."* What he meant by this statement is that the continental shelves are where sediments, originally eroded from the lands, were finally deposited. By moving back in time it is then necessary to return these sediments back to the lands from where they were previously eroded from. By returning the sediments to the lands, it is inferred that any exposed volcanic seafloor crusts beneath these sediments can, just as was done with the younger small Earth models, also be returned to the mantle. It is then conceivable to consider that the ancient Earth could be further reduced in surface area and hence in radius.

What this simply means is, by moving back in time to before the early-Jurassic Period, on an **Expansion Tectonic** Earth all of the seafloor volcanic lava has been returned to the mantle. Similarly, eroded sediments deposited around the continental shelves must be progressively returned to the continents. In addition to the seafloor volcanic lava and sediments it is also conceivable to further consider that the bulk of the ocean waters and much of the atmospheric gases must similarly be returned to the mantle. Black smokers discharging hot water and gases from along the seafloor mid-ocean-ridges are modern-day examples of this new water and gas discharge process in action and by reversing this, and other discharge processes, back in time the water and gases are simply returned to the mantle where they came from.

Before continuing to model continental crust on an **Expansion Tectonic** Earth, two important points arising from the small Earth seafloor modelling must be discussed. After having progressively removed all of the seafloor volcanic lava and assembling the remaining continental crustal plates together on a Pangaean small Earth model, the reader must firstly fully understand what the remaining primitive continental crust is made of. Secondly, before attempting to model the continental crust back to the Archaean, an understanding of the mechanics of how this crust would potentially behave during any subsequent change in Earth radius must also be made.

I often think of the assemblage of continental crust on an **Expansion Tectonic** Earth in context with archaeology. In archaeology, scientists rely on finding fragments of pottery in order to identify where and when the pottery was first made and from this to date the history preserved in the particular archaeological excavation. Being of rigid pieces of fired clay, if enough fragments of pottery were discovered they could be glued together to assemble the broken pieces of pottery back to their original form. From this evidence the precise size, shape, purpose, and type of pottery, as well as the location of manufacture and relative age can be readily determined.

Until relatively recently the present-day continental crusts have been viewed in this same context, that is, the continental crusts were considered to act as rigid fragments that could only be assembled together on a constant radius present-size Earth. In the context of an **Expansion Tectonic** Earth, early researchers went further to consider that these same rigid fragments may have instead preserved the radius of an ancient Pangaean Earth. From this perspective, the continental crustal fragments were then considered to assemble together to represent the size and shape of the ancient Earth. If these crustal fragments were truly rigid it would then be conceivable to expect them to only assemble on an Earth of either the present-day or ancient Earth radius. The complete assemblage on an ancient small Earth would then adequately quantify an **Expansion Tectonic** process.

In contrast to rigid crustal fragments, if the fragments were instead made of complexly folded and distorted sediments—unfired clay in the archaeology analogy—there would be no hesitation in unfolding these crustal fragments to fit a model that was dictated by the original shape and size of the fragments, rather than to a preconceived rigid crustal premise. Modern understanding of the continental crusts now tell us that this is precisely how the continental crusts should be considered, as complexly distorted crusts that must adhere to the complex geological history preserved in all rocks.

At this stage, while the fundamental concept of fitting any form of continental crust on a smaller radius Earth may seem incomprehensible, what has been done with the seafloor volcanic lava and sediments so far does not contravene the published seafloor or sedimentary data. Nor does it contravene accepted opinion that:

> *...new volcanic magma from deep within the Earth must rise through these weak zones* [mid-ocean-ridges] *and eventually erupt along the crest of the ridges to create new oceanic crust.*

It is, of course, the origin of seafloor volcanic lava as well as the waters and atmospheric gases derived from the mantle that is so difficult to comprehend when trying to understand **Expansion Tectonics**. Where does this enormous amount of material go to when moving back in time and conversely, where does it all come from when moving forward in time? While perfectly valid, these fundamental questions will be suppressed for the moment and considered in more detail later in this document.

6.1 Continental Crustal Stretching

Crustal stretching is a term that refers to the ability of crustal rocks to stretch and thin under an applied extensional force. On an **Expansion Tectonic** Earth this stretching is eventually followed by crustal rupture and complete failure once the ability of the crust to stretch is exceeded. This applied extensional force is a direct result of an increase in Earth surface area and change in surface curvature during an increase in Earth radius. As a simple example of the processes involved in stretching and rupture, when engineers want to test the strength of a metal bar they clamp the bar between two mechanical chucks and stretch it hydraulically until it breaks. What happens to the test piece under an applied stretching force is that, initially, the metal crystals are able to resist the force. As the applied force continues, the metal crystals begin to very slowly stretch and lengthen in the direction of the force. Ultimately, the metal crystals reach a point where they cannot stretch anymore and they then begin to rupture, tear, and fragment and eventually the metal bar breaks.

Unlike the metal bar, the Earth's outer crust can be visualised as a relatively thin skin or plastic shell where the thickness of the continental crust is known to be about 5 to 10 times thicker than the seafloor crust. This relatively thin continental crust, and similarly the even thinner seafloor crust, in turn covers a much thicker, hotter, and more ductile mantle. I reiterate that the Geological Map of the World used during the small Earth modelling studies presented here now shows that the seafloor volcanic crusts are actually quenched, cooled, and exposed mantle rocks; not drowned or *oceanised* continental rocks as was previously assumed by scientists.

For the Earth to increase its surface area during a progressive increase in radius, the outer continental crust must be able to distort, stretch, and ultimately rupture, break-up, and fragment, just like the metal bar example. The small Earth modelling completed so far shows precisely this and the continental crustal break-up and fragmentation history is what is now seen preserved in the seafloor crustal rocks. In contrast, the pre-break-up crustal stretching process is what is preserved in the geology of the continental crustal rocks. Only by understanding this stretching, rupture, and break-up process can the reader fully appreciate what the rocks are telling us about how this crustal stretching process works.

Researchers elsewhere have shown that the strength of the Earth's relatively thin outer crusts is controlled mainly by the ability of the crusts to deform, in particular by a process referred to as *plastic deformation*. This plastic deformation process is shown to be dependent on the prevailing temperature gradient existing within the crust and mantle, the composition of the rocks making up the particular crust, and also on how much geological time is available to perform the necessary crustal deformation. These observations were made elsewhere by studying heat-flow data from both active and inactive seismic regions of the Earth. Here, *rifts*—zones of continental crustal extension—were seen to be a common feature of the continents. Within these rift zones, volcanism and seismic activity were found to commonly precede crustal rifting by several million years. This then supported the idea that the crust is heated and weakened prior to rifting and stretching.

What all this means is that, on an **Expansion Tectonic** Earth, the microscopic amount of crustal stretching occurring each year throughout Palaeozoic and Precambrian times soon accumulated to many hundreds of kilometres of crustal stretching over billions of years of geological time. As will be shown later, throughout Precambrian times it is estimated that the total increase in circumference of the Earth amounted to much less than one millimetre per year, which was distributed around the entire circumference of the Earth. Under these conditions most rocks making up the Earth's crust would have plenty of time to slowly stretch and deform by atomic scale relaxation, plastic flow, or crystal regrowth. If not, local areas of crust may gradually accumulate excess stress and suddenly break during periods of earthquake activity that is more familiar to us.

In this context, the ability of the crust to both stretch during increases in Earth surface area and deform during changes in surface curvature depends on the amount of geological time available, as well as the softening effect that the warmth from the deeper crust and mantle provides. The various rock types that make up the continental crusts then determines how the crust will stretch and how much time is available determines how successfully they will deform. It will be shown later that a global network of continental sedimentary basins located on each of the small Earth models represents the primary focus for crustal stretching, which in turn may also be accompanied by jostling and deformation of adjoining continental crusts during on-going changes to surface curvature.

In the context of an **Expansion Tectonic** Earth, volumetric expansion of the Earth occurs deep within the mantle and results in what I refer to as *mantle swell*. Mantle swell is then transferred to the outer crust as crustal stretching, which is localised along zones of crustal weakness within the established global network of sedimentary basins. Within these zones of weakness crustal stretching is also accompanied by high heat flow, as currently demonstrated by seismic heat-flow data, and on the small Earth models this also coincides with the accumulation of sediments within a network of established sedimentary basins.

In contrast, within the seafloor crusts this stretching process is now occurring mainly along the mid-ocean-rift zones. This activity is accompanied by mantle-derived high heat flow and intrusion of volcanic lava along the full length of the mid-ocean-ridges. This then gives rise to the observed seafloor spreading and accumulation of new volcanic seafloor crusts, as discussed in previous chapters. Within the continents, crustal stretching may also be accompanied by intrusion or extrusion of igneous and volcanic rocks as well as on-going seismic activity.

The main processes and outcomes that affect crustal stretching during the progressive increase in Earth surface area are schematically summarised in Figure 6.1.

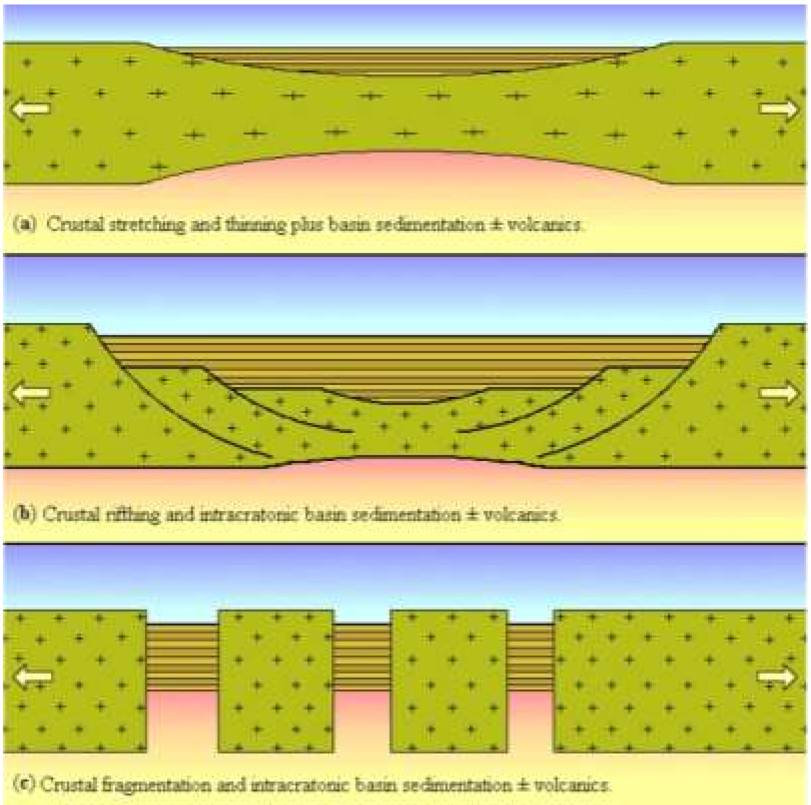

Figure 6.1 Primary mechanisms for crustal stretching during Earth expansion. Figure a) Simple crustal stretching; b) crustal rifting; c) crustal fragmentation. In each figure continental crust is shown as green, the mantle as pink shading and basin sediments are shown as horizontal stripes.

These processes and outcomes include:

1. **Simple crustal stretching:** This process occurs as stretching, thinning and down warping of the continental crust to form shallow sedimentary basins (Figure 6.1a). These basins are subsequently filled with sediment eroded from the surrounding elevated land surfaces. Continuation of this process eventually leads to crustal failure and may also be accompanied by localised crustal fragmentation at the point of rupture.

2. **Crustal rifting:** This process occurs mainly within the continental crustal regions as the crust starts to fragment and separate during tectonic activity (Figure 6.1b). The process forms what are referred to as *horst and graben* rift structures, with curved, *listric* faulting occurring along the margins of the rift zones. On the continents this process may then form a rift basin, which is in turn filled with sediment eroded from the surrounding elevated land surfaces plus intrusion of new volcanic lava. The East African rift zone and the Red Sea are good modern examples.

3. **Simple brittle fragmentation:** This process is a simple version of crustal rifting and may be more applicable to the ancient Precambrian granite crusts (Figure 6.1c). Here, the thick, brittle crust simply fractures, fragments, and separates and would again be accompanied by deposition of basin sediments as well as accumulation of intrusive and extrusive volcanic lava within any newly formed basins.

While schematic and simplistic, the examples shown in Figure 6.1 can be likened to a piece of toffee as simulating a fragment of continental crust. If the toffee is held with two fingers between both hands and pulled apart nothing much will happen. If we are strong enough, or the toffee brittle enough, we may then be able to break the toffee, as shown in Figure 6.1c. Alternatively, if we were able to apply and maintain a steady pull over an extended period of time we would eventually notice an atomic scale relaxation of the toffee molecules and after a while we would detect an atomic scale stretching of the toffee fabric. Over a prolonged period of time this stretching process would both accumulate and steadily increase and would eventually stretch and thin as in Figure 6.1a, in particular if the toffee is heated and softened from below. This atomic scale stretching is well known from testing metal products in civil engineering. Further stretching of this example will then eventually result in failure, initially as shown in Figure 6.1b and finally as complete rupture or fragmentation.

Rupture and fragmentation is here considered the primary mechanism for break-up and rifting of the continental crusts to form the modern continents.

By moving back in time, regardless of the toffee's current stretched or fragmented form, it is easy to comprehend and understand that the pieces of toffee in this hypothetical example must be returned to their original form, size, thickness, and shape, regardless of what the pieces look like after stretching. The analogy with Earth's continental crusts is identical. By moving back in time, in particular during the vastly more extended intervals of geological time available, the geological processes involved in stretching, deformation, faulting, fragmentation, as well as erosion of the continental crusts must be fully reversed and returned to their original pre-deformation states. These crusts must then be precisely reassembled into their pre-stretched, pre-deformed, pre-rifted, or pre-fragmented configuration.

Objections to crustal stretching mechanisms generally revolve around a long-standing misconception in geology that if we were to dig or drill deep enough into the Earth's crust we would eventually intersect much older bedrock. My reaction to this is, of course older bedrock will be intersected. In Figure 6.1a the age of the basement rocks will be as old as the surrounding crustal rocks that are being stretched. By digging or drilling through the overlying younger sediments the basin will be shown to be founded on a much more extensive area of ancient rocks than what is shown by the original surrounding rocks outcropping at surface. Similarly, for Figure 6.1b and Figure 6.1c the basement rocks will be as old as either the remnant ancient rocks or as old as the mantle rocks exposed at the time of crustal break-up. By moving back in time, the crusts are simply moved back to where they originated from by undoing the geological stretching processes that had acted on the crusts during this extended interval of time. This, of course, does not in any way contravene what is preserved in the geology.

On an **Expansion Tectonic** Earth, each of the examples of crustal thinning and rifting shown in Figure 6.1 may be accompanied by elevated heat flow originating from the mantle. This heat flow may also be accompanied by intrusion of mantle-derived igneous rocks in the form of granites or intrusive dykes or by volcanic eruptions at surface to form lava flows. Vast quantities of hot fluids and gases may also be involved, which would then accumulate in low-lying areas to form the ancient seas or rise to form the ancient atmosphere over time.

This heat flow is derived from deep within the mantle and on an **Expansion Tectonic** Earth its transfer to the surface occurred throughout an extensive global network of crustal weaknesses, which are the precursors to the modern mid-ocean-ridge spreading zones. This elevated heat flow also represents an important mechanism for the observed geological processes of *metasomatism*: the alteration of rocks by hot fluids, *metamorphism*: the alteration of rocks by heat and pressure, and *granitization*: the alteration of rocks by extremes in heat or pressure to form granites.

6.2 What is Continental Crust?

In contrast to the relatively simple seafloor crusts, continental crust is 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 *greenstone*—altered volcanic rocks—deformed and physically altered sediments eroded from the more ancient lands, intrusive and extrusive magmatic rocks, as well as multiple layers of overlying younger sediments deposited in past low-lying regions. These younger rocks in particular generally cover vast areas of older rocks (Figure 6.2, repeated).

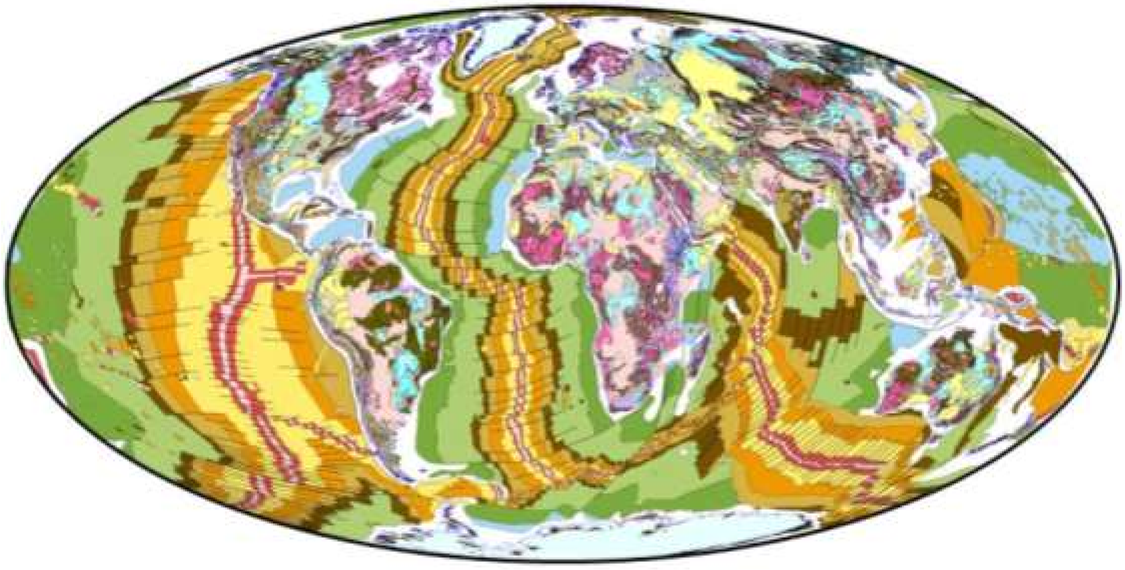

Figure 6.2 Geological Map of the World showing the distribution of the various ages of rocks occurring beneath the layer of surface soils.

Studies also show that the average composition of the continental crust is that of granite. In other words, rocks rich in silica and aluminium in the form of quartz and feldspar minerals. This contrasts with the seafloor crust which has an average composition of the volcanic lava called basalt—a lava rich in iron and magnesium. Average composition simply means that if all of the continental rocks were re-heated and melted their composition would approximate that of granite whereas the seafloor crustal rocks would be basalt, hence the big difference between continental crust and seafloor crust.

As has previously been discussed, the continental and seafloor crusts displayed in Figure 6.2 represent time-based bedrock geology. What this means is that this geology is not specific to any one rock type, but displays all rocks according to their ages. These rock ages can then be broadly correlated with the geological history, in particular for each of the areas of continental crust. The continental geology shown in this figure is further complicated by subsequent deposition of many layers of young sedimentary and volcanic rocks, which generally cover and overprint older crustal rocks lying below them. These in turn are complicated still further by many periods of metamorphism, folding, faulting, weathering, and erosion that may have occurred intermittently throughout Earth history.

In reality then, the Earth's continental crustal geology is far more complex than that depicted in Figure 6.2 and well beyond the needs of this explanation. Like the coloured seafloor crustal patterns, this map simply shows the ages of continental crustal growth and therefore the expansive growth history of the Earth's outer continental crustal skin. It should be further appreciated that very little of this geological information was available to early researchers during the 1950s and 1960s when Continental Drift, Plate Tectonic, and Earth Expansion theories were being developed, in particular, the global distribution of rocks shown in this map.

On this bedrock geological map the most ancient continental crustal rocks are shown as areas of pink and red colours, mainly occurring in Canada, Africa, the Baltic region and Australia. The distribution of these most ancient continental crustal rocks shown within the modern continents can be likened to islands of ancient rocks surrounded by younger sedimentary rocks—analogous to the remaining pieces of toffee in the stretched toffee analogy above. Like the modern seafloor lava, by progressively moving back in time, the eroded sediments shown on this map must be returned to these ancient rocks from where they originated and the sedimentary basins progressively closed. From an **Expansion Tectonic** perspective, these ancient crustal islands may then potentially represent remnant fragments of a more ancient and primordial Archaean supercontinent.

In Figure 6.2 these islands of ancient crustal rocks are in turn shown to be surrounded by deformed, less ancient and often metamorphosed sedimentary rocks shown as khaki to brown, blue, and yellow colours. These sedimentary rocks can be likened to the distribution of continental shelf sediments currently surrounding the modern continents. Just like the modern continental shelf sediments, when moving back in time the geological processes operating must be reversed and the sediments returned to the ancient lands where they originated from.

Put a different way, at the global scale shown in Figure 6.2, the continental rocks can be visualised as a mosaic of continental crustal fragments which are broadly made up of three dominant crustal types. In geology, these crustal types are referred to as *cratons, orogens,* and *basins.* These terms vary considerably in their usage and definition throughout the world and also within the published geological literature. To avoid confusion I will first define these terms so that all readers will understand what is being discussed.

- A **craton** is defined as a part of the Earth's crust that has attained relative crustal stability and the rocks have been little deformed for a prolonged period of time. By definition, cratons must have reached crustal stability by about 2,400 million years ago (the end of the Archaean Eon) and since then have undergone little deformation compared to adjacent parts of the crust.

- An **orogen** refers to a belt of rocks characterised by regional folding, metamorphism, and intrusion of magmatic rocks. The rocks of an orogen can include deformed, eroded, and reworked parts of older, early-formed cratons, as well as young volcanic and sedimentary rocks. A distinct tectonic phase of Earth movement, over a relatively short period of time, first establishes an orogen. It is also possible for an orogen to become re-activated during subsequent tectonic events and the belt normally remains as a permanent zone of relative weakness within the Earth's crust.

- A **basin** refers to an area that is underlain by a substantial thickness of sedimentary rocks. These rocks possess unifying characteristics of both sediment type and deformation history. Within a basin, sediments are deposited during a regionally restricted period of time, often extending for tens to hundreds of millions of years, during crustal depression or a related sequence of such events. The term basin is usually synonymous with the term *sedimentary basin* and it represents a regional topographical down-warp of the Earth's surface, generally filled with water.

From these definitions it should be appreciated that not all continental crusts are the same and not all rocks were formed by the same process or during the same interval of time. Cratons, for instance, are by definition the most ancient crustal rocks and are older than 2,400 million years. It is conceivable to imagine that an orogen may have started out as an ancient sedimentary basin, but later may have been deformed and metamorphosed and perhaps intruded by molten igneous rocks at any time during the subsequent Earth history. If older than 2,400 million years, these rocks may now be stable enough to be considered a craton.

During modelling of the continental crusts the physical characteristics of each of these various types of crust, as well as their distribution and tectonic histories, must be recognised and strictly adhered too. During model construction, the general shape and configuration of each of these crustal regions must also be retained throughout Earth history in strict accordance with their known distributions and ages.

It will be shown that:

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*Construction of **Expansion Tectonic** small Earth models, extending from the early-Jurassic Period back to the early-Archaean, involves the progressive removal of all younger basin sediments and magmatic rocks and simply returning these to the ancient lands or back to the mantle where they came from. Each basin is then restored to a pre-stretching or pre-rifting configuration on a smaller radius Earth.*

By moving back in time, adopting this process will enable us to progressively move the adjacent margins of each sedimentary basin closer together as part of one seamless ancient supercontinental crust, while still preserving the spatial integrity of the adjacent more ancient crusts.

This fundamental understanding of continental crusts is necessary to provide a mechanism for crustal modelling back in time in order to justify determination of an ancient primordial Earth radius during small Earth modelling studies.

6.3 Pre-Triassic Earth Radii

By measuring the surface area of seafloor crustal rocks from each of the oceans it was shown that this information can be used to derive ancient Earth radii for the various geological time intervals back to the early-Jurassic—about 200 million years ago. Similarly, by progressively removing young seafloor crust from each of the modern oceans and reducing the Earth radius accordingly, each of the remaining crustal plates can be reassembled precisely on small Earth models. These models demonstrate that the remaining seafloor crustal plates can be accurately reassembled together along their respective mid-ocean-ridge spreading axes, without the need to invoke pre-existing crusts, to remove crusts by subduction, or to arbitrarily fragment the continents.

The ultimate aim of this exercise though is to establish a radius for the most ancient primordial Earth and, similarly, to establish a formula for calculating an ancient Earth radius. This formula will then be used to calculate the radius of the ancient or future Earth at any moment back or forward in time.

The presence of ancient pink and red continental rocks shown in Figure 6.2 suggests that a primordial small Earth may have existed at the beginning of geological time when the oldest known rocks on Earth were first formed—around 4,000 million years ago. Since there were no, or very limited, volcanic seafloor crusts in existence during pre-Jurassic times evidence for this primordial Earth radius must then be established from the surface areas of ancient continental crusts found on each of the present-day continents.

Unlike volcanic rocks preserved on the seafloors, the continental crust is much more complex and generally much more ancient. Again, continental crust is a mixture of sedimentary, igneous, metamorphic, and volcanic rocks, which have been folded, faulted, eroded, and buried many times over throughout Earth history. In addition, young rocks generally cover the more ancient rocks and the presence of ancient rocks can often only be inferred from deep drilling or geophysical seismic surveys. Apart from surface or near-surface rock exposures, it is then extremely difficult to accurately measure the total surface area of each rock type existing on the present-day continents. This applies in particular to the buried bedrock crustal rocks that are used throughout this study and especially where the process of crustal stretching, as introduced previously, has been active.

A number of possible scenarios for establishing a radius of the most ancient primordial Earth from measured areas of continental crusts are graphically shown in Figure 6.3. These scenarios range across a whole spectrum of possibilities, ranging from adoption of the present total continental surface area (Curve A), through to an estimate of the total surface area of preserved Archaean crusts (Curve D). Additional constraints also include the approximate relationship between sedimentary rock age and amount of outcrop area on the present land surface (Curve C), plus an intermediary curve determined by removing areas of young sedimentary rocks from around the continental margins (Curve B).

Unfortunately, while each of these scenarios has some merit in constraining a primordial Earth radius, none of these can substantiate, with any degree confidence or accuracy, what a primordial Earth radius may have in fact been. The estimates shown in this figure vary from between 1,500 kilometres to 3,500 kilometres radius for the early-Precambrian and the wide variation of estimates shown make them very inconclusive.

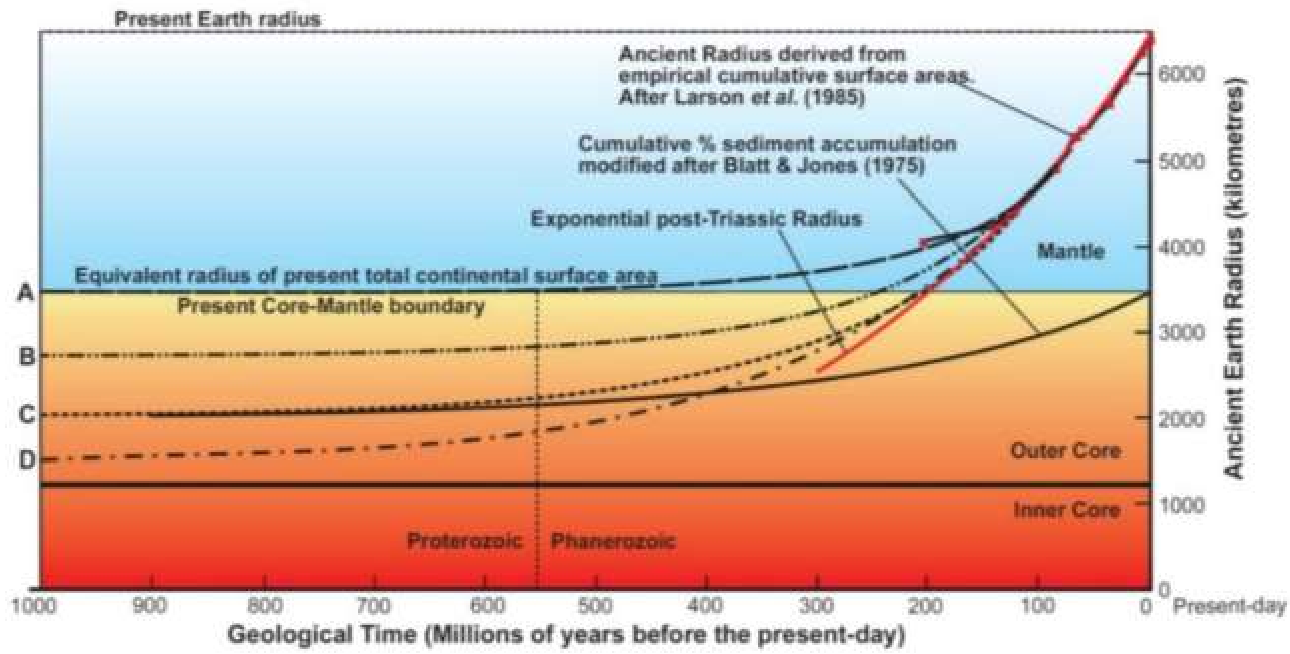

Figure 6.3 Constraints to determining a primordial Precambrian Earth radius. Curves depict Earth radius constrained by, Curve A: the present total continental surface area; Curve B: present total continental surface area less marginal basins; Curve C: published estimates of cumulative sediment areas and; Curve D: total estimated area of Archaean crust.

Because of this uncertainty, for the **Expansion Tectonic** small Earth modelling presented here, a primordial Earth radius was established during model construction by simple, empirical, trial and error. This may appear somewhat unscientific but, given the surface area data limitations outlined above, it was found to be the only viable means available with sufficient flexibility to constrain or to reasonably eliminate each of the four possible scenarios shown. I must also emphasise that:

Modelling continental crustal data back to the Archaean has never been done before, for any tectonic theory, and, as such, the modelling presented here represents the first time that this has ever been attempted.

The method adopted here to determine a potential primordial Earth radius is basically very simple. During model construction, by moving back in time the radius of each preceding model is progressively reduced in small, incremental stages. An equivalent area of the youngest sedimentary and magmatic rocks remaining is then removed from the primary bedrock geological base map. The global network of sedimentary basins is then progressively reduced in surface area until only the most ancient Precambrian continental crustal rocks remain.

This method is justifiable because the younger crustal rocks represent sedimentary and magmatic rocks that were deposited, intruded, or extruded after the older crustal rocks were first formed. During progressive removal of the younger rocks, each of the sedimentary basins and rift zones are then restored to a pre-stretching or pre-rift configuration and all sediments and magmatic rocks are simply returned to the exposed land surfaces or mantle where they originated from.

By using this rather subjective construction method an Archaean small Earth with a primordial Earth radius of about 1,700 kilometres can be readily constructed. This primordial small Earth is made up of an assemblage of the most ancient pink and red coloured Archaean crustal fragments, plus remnant khaki coloured early-Proterozoic crustal rocks (as shown in Figure 6.2). In this construction method all young sedimentary and igneous rocks are simply returned to their original crustal or mantle sources during a process of simple, step-wise reduction in Earth radius.

While this primordial Earth radius, which is very similar in radius to the present Moon—about 27 percent of the present-day Earth radius—is very difficult to comprehend, it is reiterated that the crustal reconstruction is readily achieved by using a very basic construction method. By using this reconstruction method, no fundamental physical law has been violated.

The primordial Archaean Earth simply comprises an assemblage of the most ancient crustal components, where all younger rocks have been returned to their places of origin.

This 1,700 kilometre Earth radius, while subjective, represents an approximate limiting radius for the most ancient primordial Earth. This primordial radius can then be used to establish a mathematical formula to calculate Earth radius at any moment back or forward in geological time. From this primordial small Earth radius, mathematical modelling studies of Archaean to present-day Earth radius shows that the change in Earth radius increases in accordance with an exponential rate of increase in Earth surface area.

For the mathematically minded the derived Earth radius formula is expressed as:

$$R_a = (R_0 - R_p)e^{kt} + R_p$$

Where: R_a = the ancient Earth radius at time t, R_0 = the present-day mean Earth radius, R_p = the primordial Earth radius = 1,700 kilometres, e = base of natural logarithm, k = a constant = 4.5366×10^{-9}/year.

The exponential increase in Earth's radius throughout geological time, as determined from empirical model studies, is graphically displayed in Figure 6.4.

The location of the Archaean to present-day **Expansion Tectonic** small Earth models used to constrain this graph are shown as red dots and squares, along with historical estimates of ancient Earth radius by others based on both geophysical methods and visual reconstructions of the continents. The radius curves determined by Koziar and Vogel are also shown for comparison. The curves of Koziar and Vogel coincide precisely with the estimates of ancient Earth radius established here to about 200 million years ago. Their curves were, however, limited to early versions of seafloor mapping data available at the time. They also used estimates of pre-Jurassic continental crustal areas only, without considering the potential for further continental crustal stretching.

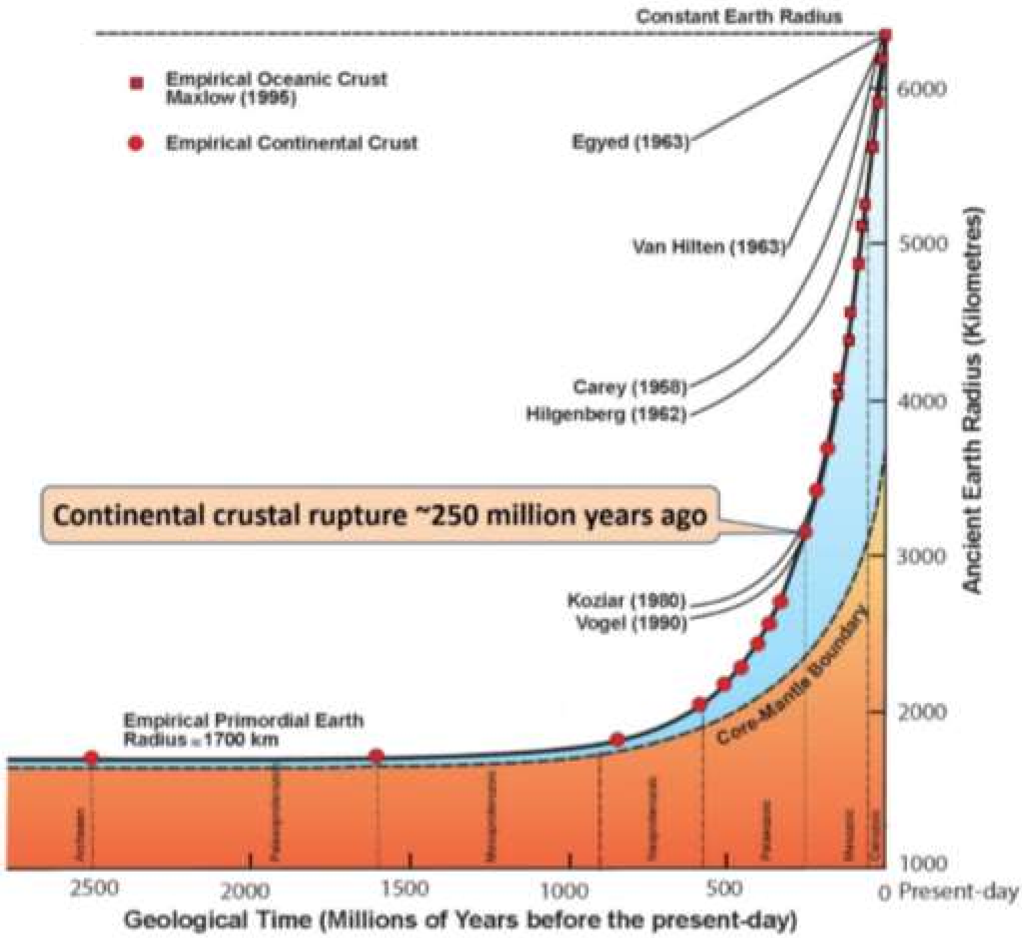

Figure 6.4 Exponential increases in Earth radius extending from the Archaean to present-day. Graph shows post-Triassic increase in radius derived from seafloor mapping and pre-Triassic change in radius derived from an Archaean primordial Earth radius of 1700 km. Small Earth models constructed are shown as red coloured circles and squares. A suggested core-mantle boundary remains speculative.

As can be seen in this figure, the available data has improved considerably since the early geophysical estimates of ancient Earth radius. It also shows that there is considerable agreement with previous estimates made using the seafloor surface area data back in time to at least 200 to 250 million years ago.

This graph, as it stands, suggests that during the early-Archaean to mid-Proterozoic times—extending from about 4,000 to 1,600 million years ago—the Earth's ancient radius remained relatively static, increasing in radius by approximately 60 kilometres during the entire 2,400 million years of ancient Earth history. From the mid-Proterozoic—about 1,600 million years ago—the Earth then underwent a steady to accelerating increase in radius to the present-day. This accelerating increase is now reflected in the break-up of the Pangaea supercontinental crust, the subsequent opening of the modern oceans, and the relatively recent development of modern seafloor crusts.

This is an interesting outcome. A civil or structural engineer testing the tensile strength of a particular metal or the compressive strength of concrete or rock would get a similar curve to that shown in Figure 6.4. The curve would then be discussed in detail with respect to the molecular-scale stretching or compression of the particular test product prior to molecular failure, final rupture, and breaking of the test piece. The only difference between the engineering scenario and the small Earth models is the scale difference between the test piece and the size of the Earth; as well as human comprehension.

The graph above suggests that, during Precambrian times, an increase in both radius and surface area of the Earth was accommodated for by molecular-scale redistribution and stretching of the crusts. This is evidenced in the rock-record by linear rock fabrics so often seen in the most ancient rocks exposed at surface today—such as schist and gneissic rocks. The ability for the continental crust to absorb this molecular-scale crustal stretching then began to rapidly decrease, resulting in an overall weakening and subsequent thinning of the crusts, until the ability to stretch was finally exceeded during late-Permian to Triassic times. During these times the continental crust then began to fail, rupture, and break apart to ultimately form the modern continents and open to form the modern oceans. By removing the inherent strength of the overlying continental crust, the Earth then underwent a rapid to accelerating increase in Earth radius to the present-day and by inference this process will continue well into the future.

Until more research effort is undertaken, it is acknowledged that this primordial Earth radius determination and Earth radius formula must remain speculative for the Palaeozoic and Precambrian times.

The ultimate test of the methodology behind determining an ancient primordial Earth radius though is in the ability for the continental crusts to assemble back in time. As was discussed in previous chapters on seafloor crustal modelling, if the mechanisms, and similarly the assumptions, behind this construction method are incorrect then ancient crustal fragments will fail to assemble. If they fail to assemble then consideration will have to be given to alternative methods, or even to abandoning the quest.

6.4 Important Assumptions

As was discussed during the seafloor crustal modelling studies, prior to carrying out model construction it is important to firstly acknowledge and define any adopted assumptions. Acknowledging these assumptions will then help understand the limitations of our knowledge. These assumptions will also help define the direction our current understanding of the process will potentially take the modelling. By understanding the limitations of these assumptions, subsequent quantification studies can also be better understood in the context of the adopted limitations.

In addition, to avoid confusion, the term subduction, when used, will be restricted here to its classical Plate Tectonic usage. In order to maintain a static radius Earth model, Plate Tectonic usage implies that thousands of square kilometres of excess seafloor crust must be disposed of beneath the continents.

Similarly, subsequent closure of oceans during continental drift gives rise to continental collision to form mountains. In contrast, subduction does not occur on an **Expansion Tectonic** Earth and observed subduction-related phenomena are basically related to crustal interaction processes during changing surface curvature.

For the reconstruction of continental crust on each of the Archaean to Triassic **Expansion Tectonic** small Earth models presented here it is assumed that, for an Earth undergoing an exponential increase in surface area and radius through time:

- Sediments deposited in continental sedimentary basins, as well as magmatic intrusions and volcanic eruptions, represent new crusts that accumulate primarily within down-warped areas of continental crust.

- These continental basin sediments, magmatic intrusions, and volcanic eruptions are not removed from the Earth's surface by subduction processes and, in conjunction with additional on-going geologic processes, are essentially preserved in the rock-record.

- Moving back in time, all younger sediments and intruded igneous rocks must be returned to their respective places of origin.

- Moving back in time, the surface area of sedimentary basins must be progressively reduced to their pre-rift, pre-stretching, or pre-break-up configurations.

What these **Expansion Tectonic** Earth assumptions mean is that, by moving back in time, all sediments must simply be returned back to the ancient lands where they were eroded from and similarly, all magmatic and volcanic rocks must be returned back to the mantle or lower crustal regions where they originally came from. After doing this, the surface area of each of the sedimentary basins or rift zones must then be reduced to simulate the return of the crust to a pre-stretching or pre-rifted state when moving back in time.

Once again, during model construction the only stipulation required during cutting and pasting of crustal information between each successive small Earth model is that:

- Continental crustal plates must undergo small vertical and surface area adjustments to allow for a progressive change in surface curvature of the Earth with time.

6.5 Pre-Triassic Model Construction

By now it should be well and truly appreciated that there are significant fundamental differences between the composition of the geologically relatively ancient continental and relatively modern seafloor crusts. Only by recognising this fact can the process of **Expansion Tectonic** small Earth modelling be extended back to the primitive Archaean Eon. What will now be done is to progressively remove continental crust from within the identified network of continental sedimentary basins and restore the remaining crusts to their pre-basin configuration on smaller radii Earth models.

The series of 24 small Earth models shown in Figure 6.5 represent the earlier seafloor crustal models—models younger than about 200 million years—recreated to include continental crustal geology, plus additional pre-Jurassic continental crustal models extending back in time to the early-Archaean. One model has also been extended to 5 million years into the future. Shown on these models is both seafloor and continental crustal time-based bedrock geology.

The models in this particular figure show the closure of the Indian Ocean after removing all seafloor crusts. These models also show the relative sizes of the ancient Earth through time after progressively removing seafloor volcanic rocks, igneous rocks, and eroded continental sediments and returning these rocks and sediments back to either the mantle or ancient lands where they originally came from.

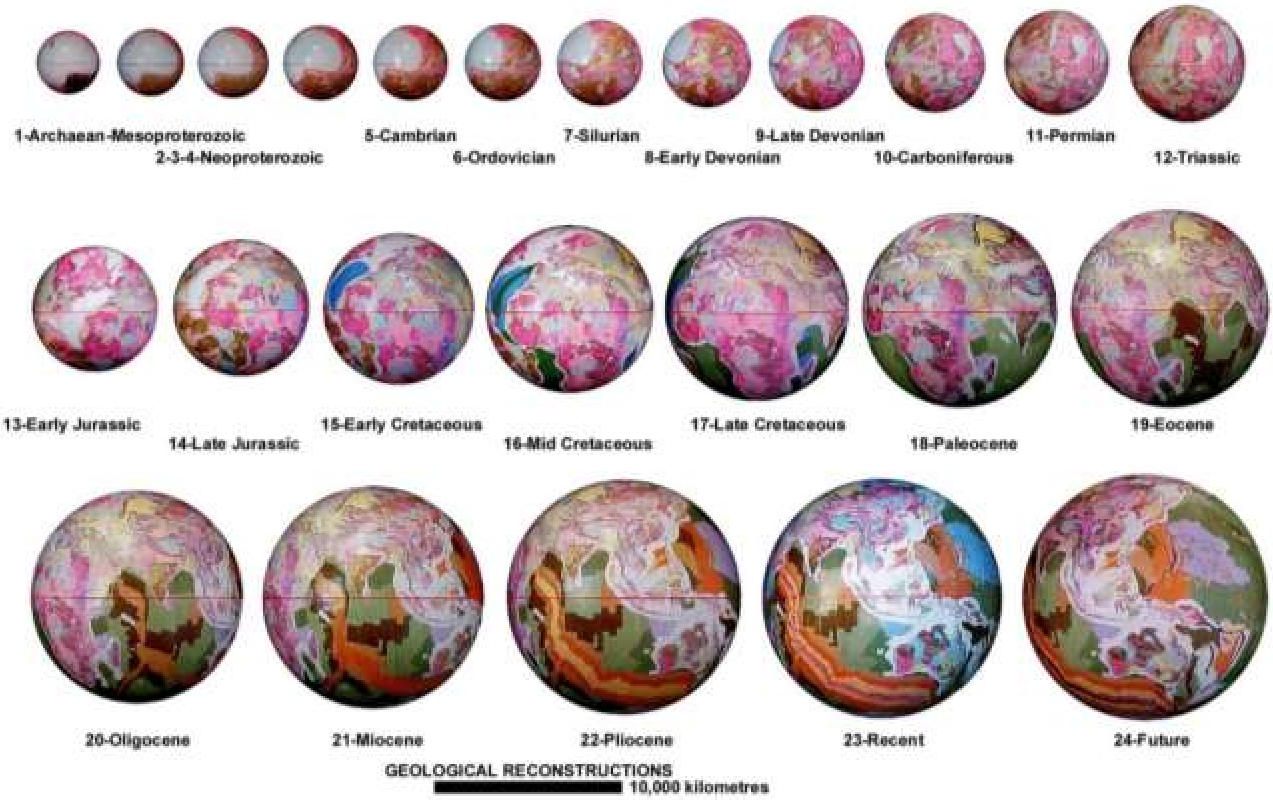

Figure 6.5 Spherical Archaean to future **Expansion Tectonic** small Earth geological models. Models show relative increase in Earth radii over time showing both continental and seafloor geology. Models range in age from the Archaean to present-day, plus one model projected 5 million years into the future.

The step-wise construction of the additional Jurassic to Archaean models presented here is continued back in time until removal of all seafloor volcanic and continental sedimentary basin sediments and magmatic rocks is complete. At that time the most ancient Archaean continental crustal rocks, along with any remnant Proterozoic basement rocks, are then assembled together as a complete, primordial, pan-global Archaean small Earth model. Modelling studies suggest that this primordial Archaean small Earth model had a radius of approximately 1,700 kilometres, which is about 27 percent of the present Earth's radius and of a similar size to the present Earth's Moon.

While not immediately evident at the scale shown, each of the Triassic to Archaean **Expansion Tectonic** small Earth models in Figure 6.5 show that crustal stretching, thinning, and rifting of continental crust occurred within a global network of crustal weakness. This global network coincides with the previously established network of sedimentary basins and is shown to surround each of the most ancient continental orogenic crustal rocks. This network of crustal weakness also represents the precursor to, and is exactly coincident with, the known early-Jurassic to present-day mid-ocean-rift zones. The presence of magmatic, intrusive, and extrusive volcanic rocks within these areas of crustal weakness, as well as the close proximity of Precambrian metamorphic rocks, also suggests that these zones were associated with high heat flows emanating from the mantle, as previously predicted. Again, this distribution is a reflection of and was a precursor to the modern mid-ocean-rift zones.

By moving forward in time from the primitive Archaean small Earth model, successive models in Figure 6.5 show that the distribution of ancient continental sedimentary basins, continental magmatic rocks, and zones of crustal weakness progressively evolve into the better established network of geologically more recent sedimentary basins. This demonstrates that the zones of crustal weakness, as represented by these basins and mobile zones, have been important sites for progressive crustal stretching, basin formation, and seawater accumulation throughout Earth's history.

These zones of crustal weakness eventually form the loci for continental crustal rupture, as well as complete continental break-up and opening of the modern ocean basins during late-Permian and younger times.

7 Origin of the Modern Continents

"...terrestrial expansion brought about the splitting and gradual dispersal of continents as they moved radially outwards during geological time." Vogel, 1983

On an **Expansion Tectonic** Earth the ancient supercontinents existed as a complete continental crustal shell encompassing the entire Earth for 94 percent of geologic history. This supercontinental phase lasted for some 3,750 million years and culminated with break-up of Pangaea about 250 million years ago. During this ancient time, continental crust covered the entire Earth with no intervening oceans.

The origin of the supercontinents simply involved a progressive, evolutionary crustal process during a prolonged period of crustal stretching and changes to both Earth surface area and surface curvature through time.

The outlines and configurations of the supercontinents were then controlled and dictated by changes to the ancient sea-levels and coastal shorelines.

In strong contrast:

The modern continents only existed in their current form after break-up of the ancient Pangaea supercontinental crust started some 250 million years ago.

These modern continents simply represent the fragmented remains of the ancient Pangaea supercontinental crustal shell. This fragmentation and break-up occurred because the ability of the supercontinental crusts to continue to stretch during on-going increases in Earth surface area was finally exceeded during late-Permian times. Once crustal stretching was exceeded the Pangaea supercontinental crust then ruptured, broke apart and fragmented to form the modern continents and opened to form the intervening modern oceans.

Discussion on the origin of the modern continents overlaps and follows on from the development of the more ancient supercontinents. During Precambrian and Palaeozoic times, ancient continental crusts making up the ancient supercontinents had already undergone a considerable amount of stretching and distortion during changes to both surface area and surface curvature. This stretching process originated from early-Archaean times where, once the ancient crust had cooled and stabilised, it started to crack and fracture during onset of Earth expansion. These fractures were focussed within a global network of crustal weakness and were also the loci for on-going intrusion of volcanic lava and formation of a network of low-lying sedimentary basins. On-going stretching and extension of the crust was then primarily focussed within this network of crustal weakness.

As will become apparent in the following figures, the modern continents often have a nucleus of most ancient crusts which are surrounded in turn by younger sedimentary basins or orogens. The orogens generally comprise older sedimentary basins that have been heated and folded. This global network of ancient sedimentary basins is analogous to the modern oceans whereby the network of crustal weakness contained within these basins represents the precursor to the modern mid-ocean-ridge spreading zones. Once rupture and separation of the supercontinents began, part of these sedimentary basins then remained attached to one continent and other parts remained attached to adjoining continents.

When describing the development and subsequent history of these modern continents geographical orientations relative to the ancient equator will be given in lower case, for example, the long axis of Australia was orientated **north-south** throughout the Precambrian—as distinct from its current **east-west** orientation. In contrast, current geographical descriptors and names of continents relative to the present-day equator will be given in upper case, for example **North** America.

7.1 Australia

The Australian continent, shown in Figure 7.1, has large areas of ancient crusts preserved throughout what is now Central, Northern, and Western Australia. The rest of present-day Australia is made up of relatively young sedimentary rocks which were originally linked to similar sedimentary basins now located in China and North and South America. The older parts of the Australian continent had their beginnings as part of the ancient Archaea supercontinental crustal assemblage. This ancient assemblage later extended in surface area as new sedimentary basins opened and extended around its margins.

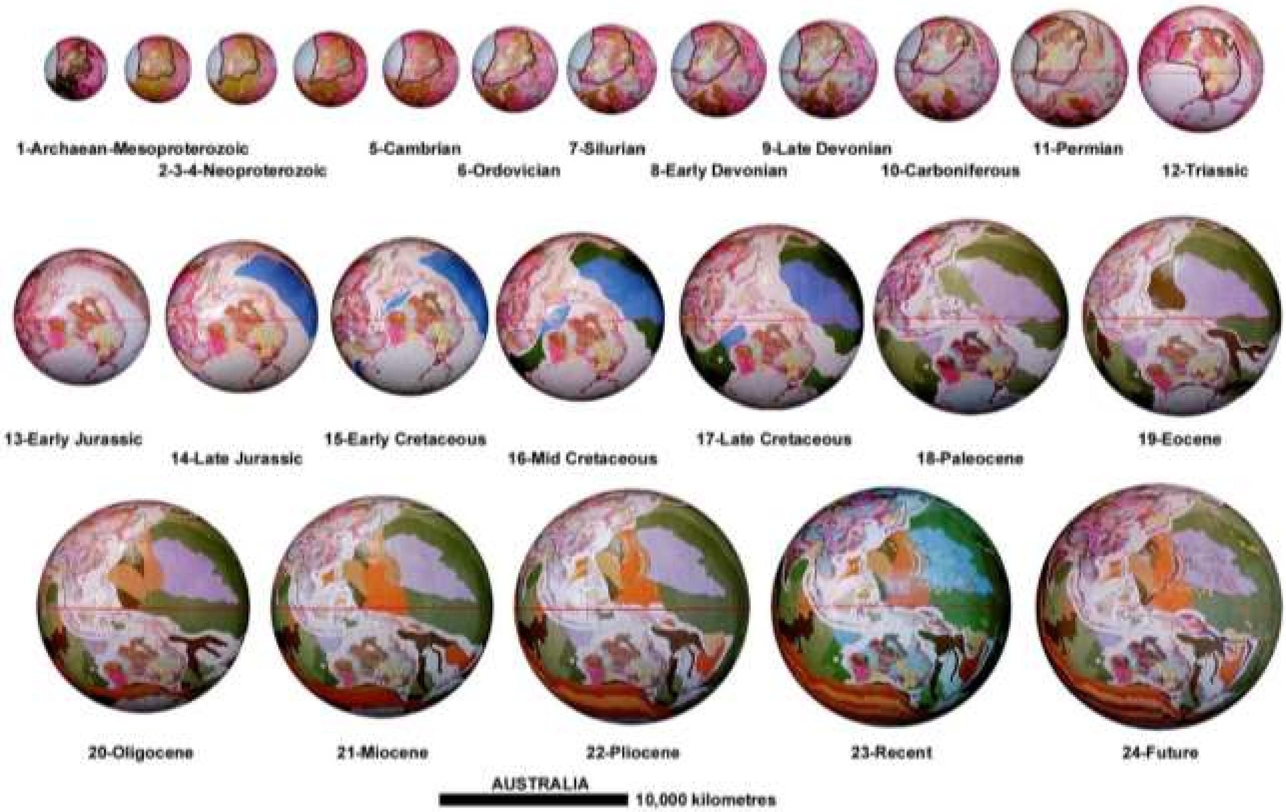

Figure 7.1 The continental crustal development of Australia. The outline of the pre-Jurassic Australian crust is shown as a black line. During the Precambrian to late-Palaeozoic times Australia was orientated north-south prior to rotating counter clockwise to the present east-west orientation. This occurred during opening of the modern Pacific Ocean. The horizontal red line represents the location of the ancient equator.

Throughout the various Precambrian and Palaeozoic Eras most of ancient Australia was located in the northern hemisphere and the long axis of the primitive Australian continent was orientated north-south relative to the ancient equator. Once the ancient Pangaea supercontinent started to break-up and the modern Pacific Ocean commenced opening during the Mesozoic Era, the newly formed Australian continent then rotated counter clockwise to its present east-west orientation and migrated south into its present location in the southern hemisphere.

During these ancient times the Australian crusts abutted directly against crusts from primitive China to the north, Canada and North America to the east, South America to the south, and East Antarctica to the west. At that time ancient Australia was located within mid- to high-northern latitudes relative to the ancient equator and the ancient equator passed through what is now Central and Northern Australia.

During this pre-break-up supercontinent time the Proterozoic sedimentary basins of Northern and Central Australia formed part of an extensive global network of sedimentary basins. These basins extended north into the Proterozoic basins of Alaska, Canada, Northern Russia, and Asia, and to the east and south these basins were also linked to the Proterozoic basins of North America, Central America, and South America. Deposition of sediments within these ancient Australian sedimentary basins was most active to the south—within what is now Eastern Australia—and this deposition extended into adjoining regions in primitive New Zealand, South America, North America, and Antarctica. Break-up of this extensive sedimentary basin occurred during Permian times during initial opening of the South Pacific Ocean. Remnants of this basin are now preserved in East Australia, New Zealand, Central and South America, North America, and Antarctica

Crustal movement during this time was accompanied by ancient mountain building events, mainly within the network of sedimentary basins in what is now Central and Eastern Australia. Remnants of these same mountain building events are also preserved as the Andean mountain events of South America, the Appalachian and Grenville Mountain events of Eastern North America, and the Cordilleran mountain event of Western North America and Canada. Events in Central and Northern Australia were also associated with periods of crustal movement and jostling of the various ancient crusts located between Australia and North America. This jostling occurred as each of the ancient crusts adjusted for changing surface curvature. The mechanism for this jostling process will be discussed in later chapters.

Continental crustal rupture to form the modern Australian continent first commenced during Permian times in areas located to the northeast of Australia, relative to the ancient equator, adjacent to what is now the Pilbara and Kimberley regions of Western Australia. Opening also occurred in the south, adjacent to Eastern Australia, separating Australia from New Zealand. The outline of the modern Australian continent then began to take shape in these areas once the North and South Pacific and similarly the Indian Ocean began to open.

After slowly opening during the Permian and Triassic Periods, the early North and South Pacific Oceans then started to rapidly open, separating Australia from North and South America, while initially retaining a brief land link between Queensland in East Australia and California in North America. These previously separate North and South Pacific Oceans then merged during the Jurassic Period, finally separating Australia and New Zealand from North and South America.

Similarly, the Indian Ocean commenced opening during the Jurassic Period and was located adjacent to what is now Northwest Australia. As a result, Australia separated from China and South East Asia as the Indian Ocean continued to open and extend southwards along the west coast of Western Australia. At that time lands connecting Australia with adjoining continents remained attached to South East Asia to the north and East Antarctica to the south allowing plant and animal species migration between each of these continents.

Rifting between Australia and East Antarctica commenced during the Paleocene—about 65 million years ago—during opening of the Southern Ocean. Australia and Antarctica are continuing to drift apart to the present-day leaving both continents as separate island continents. During this rifting process, Australia migrated south from mid-northern latitudes crossing the ancient equator into its present-day mid-southern latitude location. Bear in mind that migration is apparent and it is the opening of the oceans that causes this apparent migration.

Rocks exposed throughout Australia now reflect this geographic migration history, with extensive coral reef deposits located along the full length of Eastern Australia reflecting its original equatorial location throughout the Palaeozoic Era.

This was followed by a prolonged period of tropical weathering as Australia rotated and crossed the equator, which is marked by extensive deposits of *laterite* rocks—rocks that have undergone deep chemical weathering from tropical rains—throughout present-day West and Northeast Australia. This was then followed by a progressive drying and *desertification* of the landscape to the present-day as Australia continued to migrate south away from the equator. Once the Southern Ocean began to open, Australia then remained geographically isolated from its neighbouring continents and has continued to progressively migrate further south into low- and mid-southern latitudes.

This southern migration of Australia is at odds with Plate Tectonic studies whereby Australia is instead said to be migrating north, out of more temperate to polar climate zones, and is said to be colliding with South East Asia. This interpretation is based primarily on palaeomagnetic studies—more on this in later chapters—and this interpretation is in fact contrary to what the rock-record shows. Irrespective of what Plate Tectonics insists, coral reef deposits and tropical weathering simply cannot occur in high polar latitudes; they are diagnostic of equatorial latitudes.

7.2 Africa and Arabia

Africa and Arabia contain extensive areas of ancient Precambrian crusts. Both originated from the Archaea supercontinental crustal assemblage located adjacent to the Archaean and Proterozoic regions of primitive South America, North America, Central Europe, Scandinavia, India, and East Antarctica. This early continental crustal configuration, shown in Figure 7.2, has since remained spatially intact throughout Earth history relative to each of the surrounding continents.

Throughout Precambrian and Palaeozoic supercontinent times the ancient South Pole was located within what is now Central West Africa and during that time a south-polar ice-sheet extended from there into Arabia and South America. Once crustal break-up commenced, this ancient South Pole is shown to have made an apparent migration south along the present West African coastline during the Mesozoic Era as the African continent migrated north.

The crustal development of primitive Africa and Arabia during Precambrian and Palaeozoic supercontinent times involved extensive continental crustal stretching and formation of sedimentary basins. Each of these areas was, in turn, accompanied by crustal jostling between each of the South, East, and West African cratons during changing Earth surface curvature. Throughout North Africa, crustal stretching and deposition of sediments continued into the Palaeozoic and later eras in conjunction with similar crustal stretching and jostling within what are now the Mediterranean, Central European, and Asian Tethys regions.

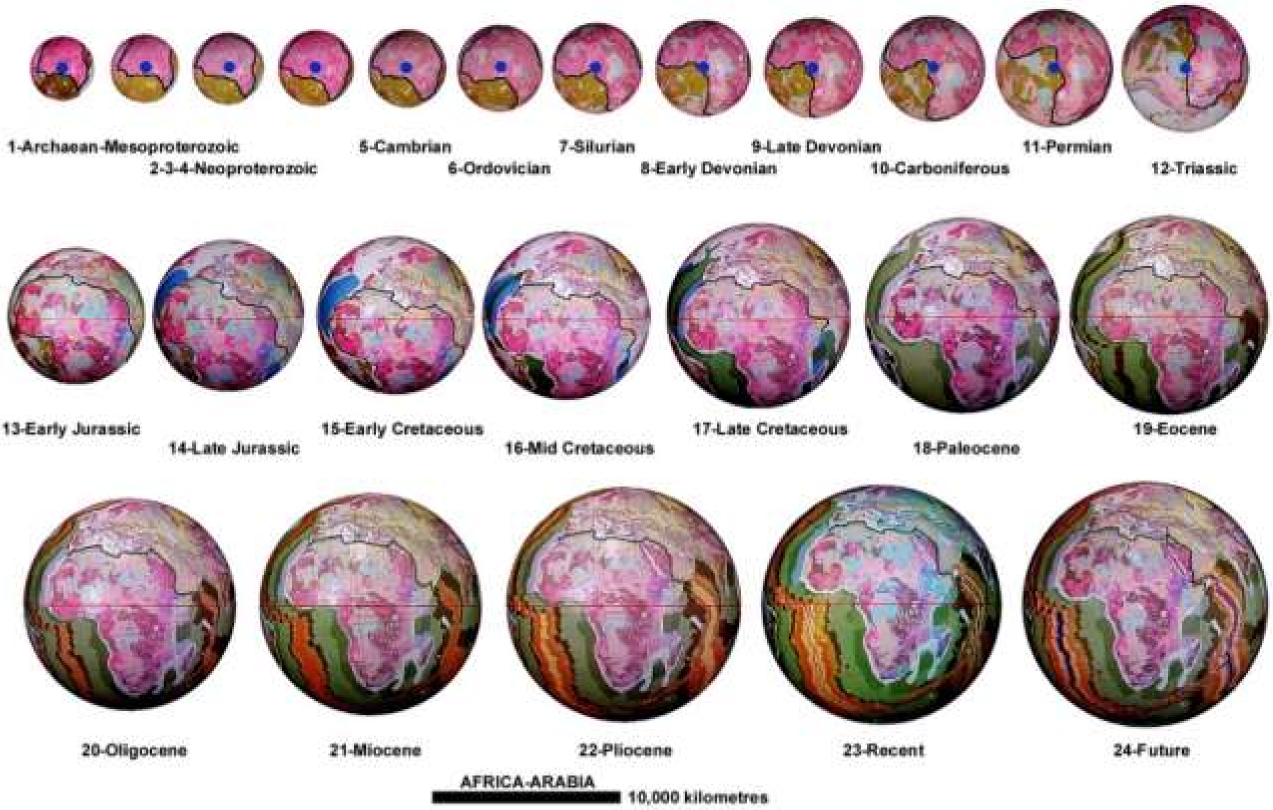

Figure 7.2 The continental crustal development of Africa and Arabia. In each of the Precambrian and Palaeozoic models North Africa is shown located south of the ancient equator and the South Pole is located in west Central Africa. The Archaean to Triassic models are centred on the South Pole (blue dots). The horizontal red line represents the location of the ancient equator and the black lines represent the African continental crustal outlines.

Precambrian and Palaeozoic crustal movements and mountain building occurred along what is now the present East African coast, associated with similar events in primitive Madagascar and India, as well as along the West African coast associated with the Grenville, Appalachian, and Hercynide Mountain events in Eastern North America and Europe. Remnants of events associated with the younger Alpine and Himalaya Mountain building episodes also occur within what is now North Africa.

Break-up of the ancient Pangaea supercontinent to form the modern African and Arabian continents was first initiated between West Africa and North America during the Permian and Triassic Periods during opening of the North Atlantic Ocean. Rifting and separation between South America and Africa, as well as between Africa, Antarctica, Madagascar, and India, commenced during the Jurassic adjacent to what is now South Africa. This rifting continued north, within the opening South Atlantic Ocean, to eventually join with the North Atlantic Ocean. Similarly, rifting continued north along the East coast of Africa during opening of the Indian Ocean which eventually gave rise to the modern African continental outline.

Rifting and separation of Africa from Arabia, and similarly Africa from the Mediterranean and Middle East regions, commenced during the Cretaceous Period during opening of the Mediterranean Sea and this rifting is continuing to the present-day within the opening Red Sea.

During the Mesozoic and Cenozoic Eras, Africa and Arabia continued to slowly migrate north, relative to the South Pole, in conjunction with opening of the Atlantic and Indian Oceans. From its central West Africa location throughout Precambrian to Palaeozoic times, the ancient South Pole is shown to have made an apparent migration south—due to the northward movement of Africa away from the southern polar region toward to equatorial region—along the west coast of South Africa. It then crossed the newly opening South Atlantic Ocean during the Mesozoic Era and continued onto the Antarctic continent during the later Cenozoic Era. This apparent polar migration severely disrupted existing plant and animal species development within Africa as the polar climate zone also experienced an apparent migration south across the land surface.

Once the ancient South Pole crossed the Atlantic Ocean, much of Africa and Arabia maintained a centrally-located equatorial position through to the present-day with the ancient equator experiencing a slow apparent migration from a North African position to its current Central African position.

It is interesting to note that on an **Expansion Tectonic** Earth:

A direct geographical connection across to Europe and Asia is maintained throughout Earth history and only relatively recently are the continents shown to be separating and rifting along what is now the Mediterranean and Red Seas.

This, of course, is again at odds with Plate Tectonic assemblages where Africa and Arabia are said to be migrating north and colliding with Europe and Asia to form the Alpine Mountain belt. This conventional migration and collision, however, cannot explain the opening of the Mediterranean Sea during the late-Cretaceous times without invoking subduction of pre-existing Tethyan crusts, nor can it explain the present opening of the Red Sea and rifting between Arabia and Africa.

7.3 Antarctica

The continental development of both East and West Antarctica is speculative because of the masking effect of the present-day ice-sheet coverage. This ice cover, as well as the ice-sheet covering Greenland, is part of the Bedrock Map of the World base map used to construct the small Earth models and could not be removed during model construction. The Antarctic icecap is known to be about 33 million years old, representing a considerable part of the Cenozoic Era. Reconstructions and limited published field evidence also indicates that the East Antarctica continent comprises mainly Precambrian crusts and this crust has remained relatively intact throughout Earth history.

The continental reconstruction of Antarctica is shown in Figure 7.3. This figure shows that, unlike present-day East Antarctica, during the Precambrian Eras West Antarctica was made up of small remnants of Proterozoic crusts. The reconstructions also show that during Precambrian and early-Palaeozoic times the primitive crusts making up both East and West Antarctica straddled the ancient equator. These continental crusts were located adjacent to primitive Australia, South America, South Africa, India, and Central and Southeast Asian crusts.

Ancient Proterozoic and Palaeozoic sedimentary basins located in what are now India, Central and Southeast Asia, Australia, and South America surrounded the ancient Antarctican continent and extended into West and East Antarctica beneath the present ice-sheet. At that time mountainous regions in West and East Antarctica also formed extensions of similar mountainous regions located in Eastern Australia, as well as the Andean regions of South America.

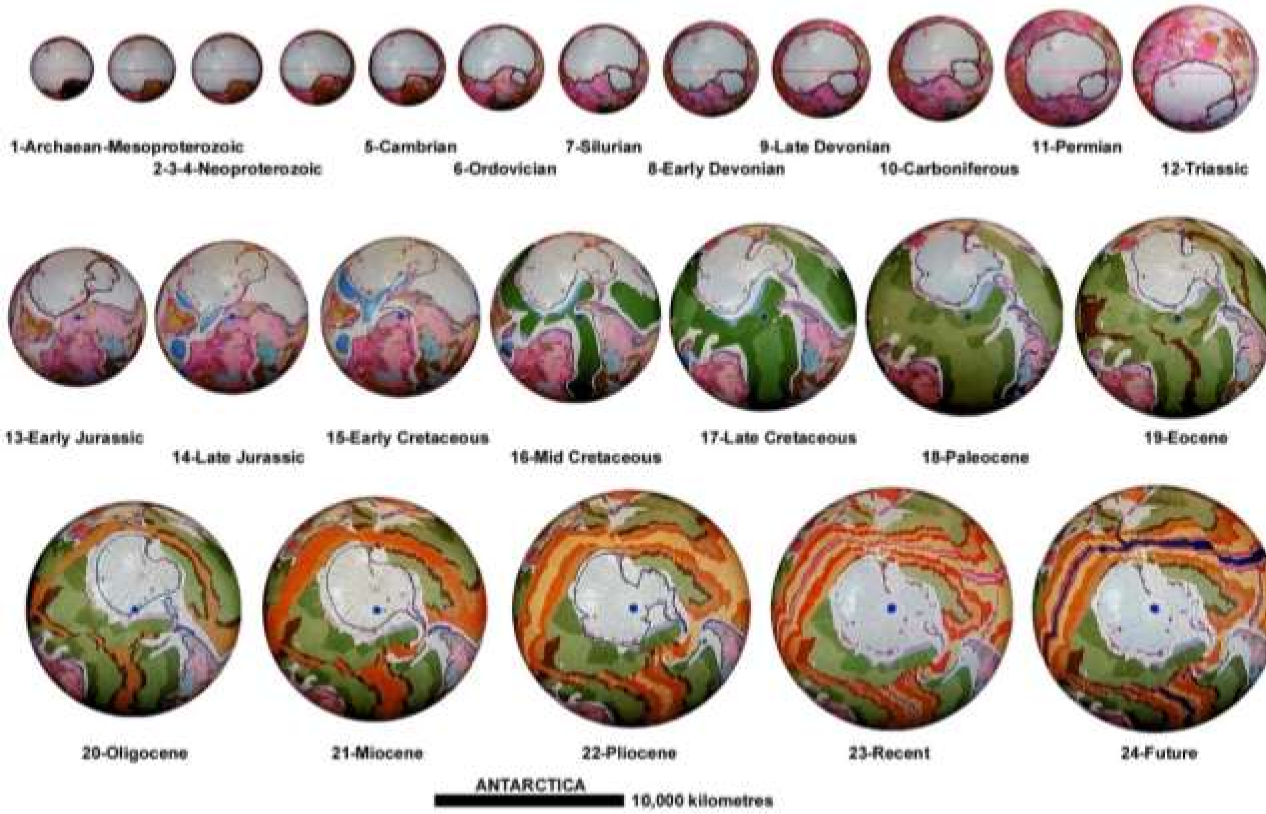

Figure 7.3 The continental crustal development of East and West Antarctica (shown as pale blue—the present-day south-polar ice shelf). During the Archaean to late-Palaeozoic Eras Antarctica straddled the ancient equator. The continent then rapidly migrated south, as the modern oceans opened, to its present location at the South Pole. The horizontal red line represents the location of the ancient equator and blue lines represent the ancient coastlines. Note: models 13 to 24 are centred on the South Pole (shown as blue dots).

Break-up of the former Pangaea supercontinent to form the modern Antarctican continent commenced during early-Permian times during a period of crustal rupture and opening of the South Pacific Ocean—the ancient South Panthalassa Sea. By the Late Jurassic, opening of the Indian and South Atlantic Oceans had also commenced leaving a land connection between Australia and East Antarctica and similarly between South America and West Antarctica. Final break-up, rifting, and separation of modern Antarctica from Australia and East Antarctica commenced during the Paleocene, some 65 million years ago.

On an **Expansion Tectonic** small Earth, the development of West Antarctica relative to East Antarctica was closely related to opening of the South Pacific Ocean. By the Late Cretaceous West Antarctica had separated from East

Antarctica and had begun to rotate clockwise, relative to East Antarctica, as the South Pacific Ocean continued to widen and open. During that time the West Antarctican Peninsular remained joined to the southern South American Peninsular. This peninsular continued to remain joined until separation and rifting between the two continents began during the Miocene leaving modern East and West Antarctica as separate and isolated continents through to the present-day.

Throughout Precambrian and Palaeozoic times the Antarctican continent straddled the ancient equator. Once break-up was initiated the combined East and West Antarctican continent is then shown to have commenced an apparent migration south, relative to the ancient South Pole. It then continued migrating further south to its present south-polar location throughout Mesozoic and Cenozoic times, establishing and preserving the present south-polar ice-sheet.

This reconstruction and migration history shows that Antarctica evolved throughout most of its history within a warm tropical environment prior to migrating south into high southern and then into south polar-regions. A close look at the various small Earth models also shows that Antarctica is currently not stationary over the South Pole, as convention suggests, but is continuing to migrate slowly across the south-polar region.

It is also important to note that:

Seafloor mapping shows that the surrounding Southern Ocean contains a single, continuous mid-ocean-rift zone. All of the surrounding continents are, in fact, migrating north away from Antarctica as new seafloor crust continues to be intruded along this mid-ocean-rift zone.

This is a fatal flaw in Plate Tectonic reconstructions, whereby a suitable explanation cannot be given to explain why there are no subduction zones available to absorb this huge amount of Southern Ocean seafloor crustal spreading surrounding Antarctica.

7.4 Europe, Russia and Asia

The European and Asian continent, inclusive of Russia, is a vast area and constitutes the largest land mass on Earth today. The continental crustal development of Europe and Asia is shown to be a complex and prolonged history of Precambrian to recent crustal stretching and extension, sedimentary basin formation, mountain building, and intrusion of magmatic rocks. Much of the present European and Asian continent now represents the uplifted and exposed seafloor of the former Tethys Sea region, with relatively minor areas of more ancient crusts.

In Plate Tectonic studies a large Tethys Ocean is depicted as being located between the fragmented remains of the present European and Asian continent and is inferred to have covered many small crustal plates, as well as Cretaceous *island-arcs* and small continents. Parts of Central and Eastern Europe are also said to have been covered by a northern branch of the Tethys Ocean. This branch was separated from the Tethys by the formation of the Alps, Carpathians, Dinarides, Taurus, and Elburz Mountains, before it gradually disappeared during the late Miocene Epoch, becoming an isolated inland sea.

In contrast, on an **Expansion Tectonic** Earth, during Archaean and early-Proterozoic times the European and Asian continent was largely made up of a network of Precambrian sedimentary basins—the early Tethys Sea basin in particular (Figure 7.4). It also included small fragments of Archaean crusts that are now dispersed throughout Europe, as well as the larger ancient Mongolian and Chinese crusts. These crusts were once united as part of the ancient Archaea supercontinent. After fragmenting during the Precambrian, these crusts now form small remnants embedded within the much larger Tethys sedimentary basins.

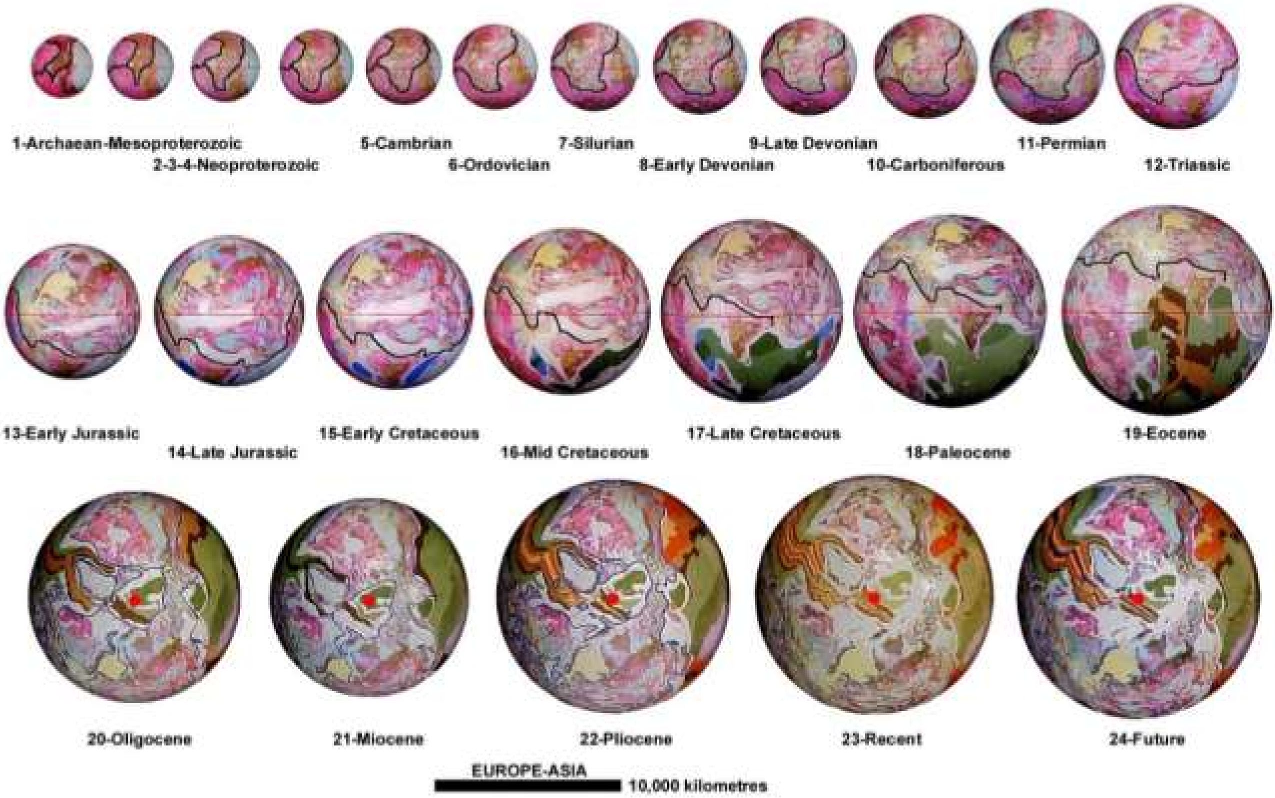

Figure 7.4 The continental crustal development of Europe and Asia. Models 20 to 24 are centred on the North Pole (shown as red dots). The horizontal red line represents the location of the ancient equator, blue lines represent the ancient coastlines, and the black line represents the outlines of the ancient European and Asian continent.

Throughout the Precambrian and into the following Palaeozoic times, the Northern Asian region of the ancient European and Asian Tethys Sea was centred over the ancient North Pole. Similarly the European region, in what is now the Mediterranean region, was centred on the ancient equator. East Antarctica was located along the eastern margin of this large continent, Australia was located to the north, Canada to the northwest, Greenland to the west, Scandinavia and Arabia to the southwest and India was located to the south (Figure 7.4).

During Precambrian and Palaeozoic times, sediments were being eroded from each of the exposed surrounding continental land surfaces and deposited within the extensive Tethys Sea. This north-south orientated Tethys Sea basin in turn formed part of a much more extensive global network of continental seas. In this context, the ancient Tethys Sea also included Precambrian sedimentary basins that are now exposed in Central Australia and India and further afield also included ancient basins located within South America.

Break-up of the Pangaea supercontinental crust first began in the ancient Arctic, North Atlantic, and North Pacific Oceans during the Permian which then initiated break-up and separation of the combined European and Asian continent. During that time, as each of the surrounding modern continents began to drift apart and the modern oceans began to open, the existing Tethys continental sea was then disrupted and began to progressively drain. During the Mesozoic, the ancient Tethys Sea gradually became exposed as dry lands as the waters slowly drained into the opening modern oceans. Deposition of sediments within the ancient Tethys Sea region was then disrupted and deposition of eroded sediments shifted into the newly formed marine basins, now located around the margins of the modern continents.

During that time the on-going development of Europe, Asia, and Russia was strongly influenced by ever changing sea levels and changing coastlines. The Tethys Sea was completely drained during the Cenozoic, exposing Europe, Asia, and Russia as the elevated continent it is today. Because of its large size, Europe and Asia straddled many climate zones, ranging from north-polar to equatorial, with parts extending into low southern latitudes. Today, the entire European and Asian continent is located in the northern hemisphere but still extends from the equator through to the North Pole.

Throughout Earth history, crustal stretching and mountain building associated with changes in Earth surface curvature played an important role in shaping the European and Asian continent. Precambrian and Palaeozoic events in Western Europe were associated with the ancient Grenville, Appalachian, and Hercynide Mountain building events now preserved within Eastern North America and Scandinavia. Similarly, during the Mesozoic and Cenozoic Eras, the Alpine and Himalaya Mountain belts were formed during opening of the Mediterranean Sea and were accompanied by renewed stretching and crustal extension between Europe and Asia relative to Africa.

This **Expansion Tectonic** continental crustal history differs markedly from Plate Tectonic reconstructions. On an **Expansion Tectonic** Earth fragmentation of former supercontinents and inclusion of an extensive ancient Tethys Ocean is not necessary in order to close off the North Atlantic Ocean to conform to seafloor bedrock mapping data.

7.5 India

The Indian continent is traditionally shown on Plate Tectonic reconstructions to be an island continent migrating north during the

Mesozoic Era, moving across a vast pre-existing Indian Ocean until it collided with Asia during the Cenozoic. Collision with Asia is then thought to have resulted in formation of the Himalaya Mountain belt.

In contrast, the crustal development of India on an **Expansion Tectonic** Earth is shown in Figure 7.5. During Precambrian times, the ancient Indian continent initially formed a southern extension of the European and Asian Tethys Sea basin. During that time, and extending into later Palaeozoic times, India was located adjacent to East Antarctica to the northeast, Madagascar and South Africa to the southwest, and Arabia to the west. The ancient crust making up the present Indian continent was originally located within mid-southern to equatorial latitudes throughout the Precambrian and Palaeozoic times.

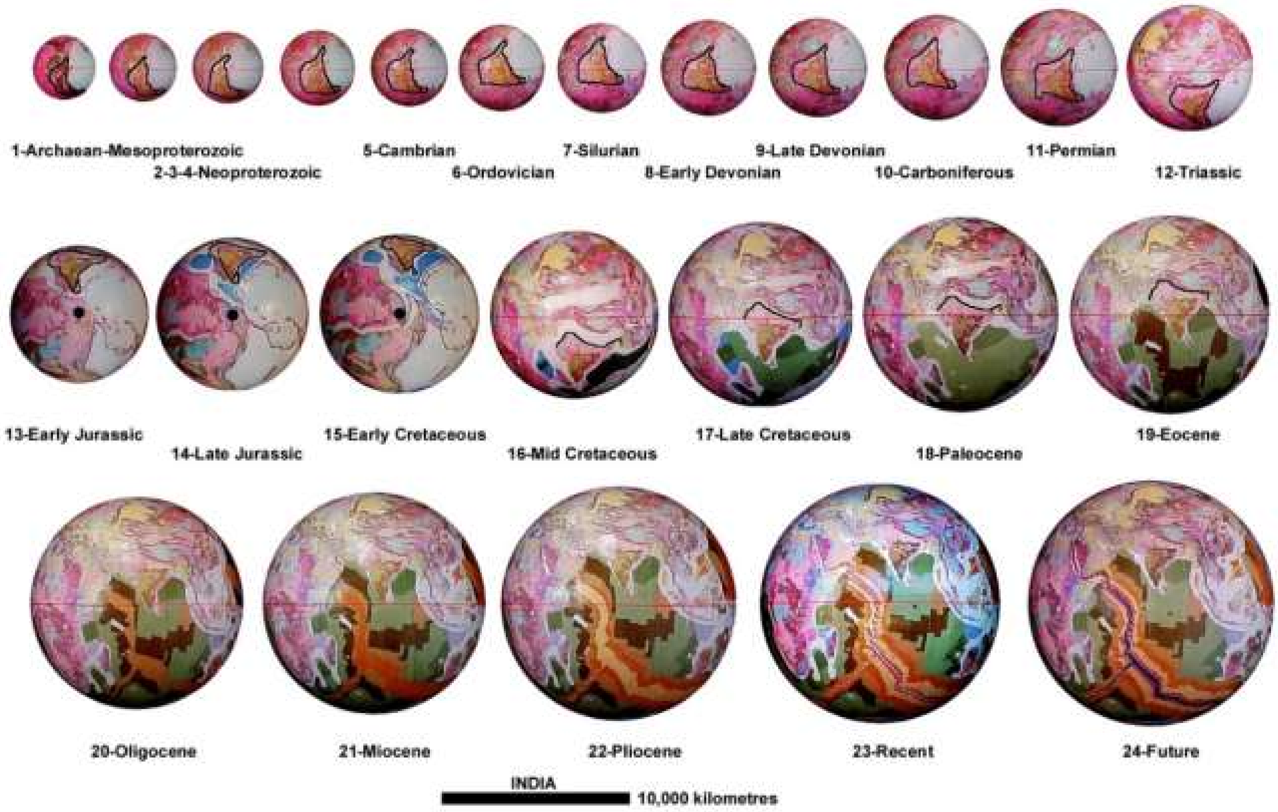

Figure 7.5 The continental crustal development of India. Each of the early-Jurassic to early-Cretaceous models are centred on the South Pole (shown as black dots). The horizontal red line represents the location of the ancient equator, blue lines represent the ancient coastlines, and the black line represents the Indian continental crustal outline.

During the Mesozoic, India briefly migrated into mid-southern latitudes before returning to equatorial and low-northern latitudes during the later Cenozoic Era. This apparent migration of India was related to its proximity to the rapidly extending European and Asian Tethys Sea basin. It was also influenced by the migration of adjoining continents away from the ancient South Pole, which was then located in central West Africa, and to the newly opening Indian Ocean.

Crustal extension between the ancient north and south Indian crustal regions occurred during the Proterozoic Eon in conjunction with related crustal development in the Tethys region. This period of crustal extension continued into the Mesozoic Era. Crustal movement and mountain building in India was associated with crustal motion relative to Antarctica, Madagascar, and Africa, as well as a number of Palaeozoic to Cenozoic mountain building events along the northern Himalaya contact with Europe and Asia. In this context the Himalaya Mountain chain was intimately associated with changes to surface curvature focussed along this northern Himalaya contact.

Continental separation and rifting of India, Madagascar, and Sri Lanka from Antarctica and Africa commenced in the Jurassic during initial opening of the Indian Ocean. Madagascar and Sri Lanka then began drifting away from India during the early- to mid-Cretaceous, with Sri Lanka continuing to remain in close proximity with India.

In contrast to Plate Tectonic reconstructions:

*On an **Expansion Tectonic** Earth the Indian continent has remained geologically attached to the Asian continent throughout all Earth history.*

Because of the proximity of India to the European and Asian Tethys Sea region, India was geographically, but not geologically, isolated from Asia for much of that time by the presence of shallow continental seas. As the European and Asian Tethys Sea progressively drained during the Cenozoic Era, India and Asia were then fully exposed as one continuous continental plate with no requirement for a separate Indian sub-continent or collision event.

7.6 North America

The development of the North American continent is shown in Figure 7.6 to be intimately related to the ancient Archaea supercontinent crustal assemblage and its ultimate break-up to form the ancient Canadian, Greenland, and Scandinavian crusts. This cluster of ancient continental crusts is discussed together and is here referred to as the North American cluster. On Plate Tectonic reconstructions this cluster is referred to as the Laurentia and Baltica supercontinents and these have been extensively studied and referenced throughout North American literature.

On the **Expansion Tectonic** small Earth models shown in Figure 7.6 the ancient North American cluster of crustal fragments remained intact throughout Palaeozoic and Precambrian times. This cluster is shown to straddle the ancient equator, extending from mid-southern to high-northern latitudes. The ancient cluster was, in turn, assembled against the European and Asian Tethys region to the north, the Australian Proterozoic basins to the west, South America to the southwest, and West Africa to the south and southeast, relative to the ancient equator. Small Precambrian crustal fragments now located within Europe were also clustered adjacent to and southeast of Greenland and Scandinavia.

In effect, this ancient North American cluster formed a nucleus for surrounding crustal development. The cluster represented exposed elevated lands throughout these ancient times and supplied eroded sediments to surrounding sedimentary basins. The Precambrian and Palaeozoic development of the North American cluster then involved crustal extension and basin sedimentation within a surrounding network of continental sedimentary basins. These basins included links to the Tethys Sea basin to the southeast, as well as basins linked to what is now Russia, China, Australia, and South America to the north, west, and southwest.

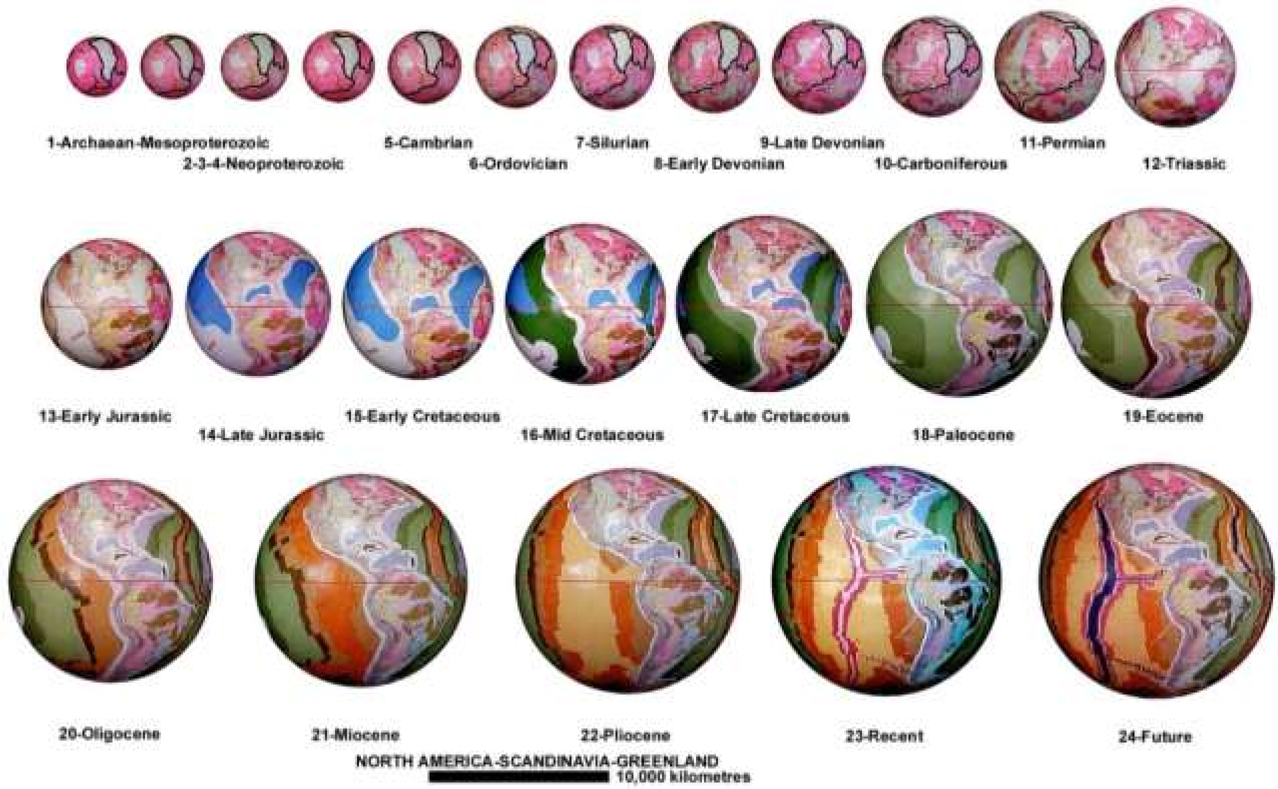

Figure 7.6 The continental crustal development of North America-Greenland-Scandinavia. The horizontal red line represents the location of the ancient equator and black lines represent the continental outlines.

This North American cluster remained intact throughout the Precambrian and Palaeozoic times until the Pangaea supercontinental break-up and opening of the North Atlantic Ocean commenced during the late-Permian Period. During opening of the North Atlantic Ocean, Scandinavia and the Baltic region were separated from North America and have since remained attached to Europe during further opening of the North Atlantic and Arctic Oceans.

Crustal jostling and mountain building events occurred during Precambrian and Palaeozoic times as a result of on-going changes to surface curvature. These events formed long linear mountain belts located around the margins of the North American cluster, forming the precursors to the Cordilleran, Grenville, and Hercynide Mountain belts.

Break-up and fragmentation of the ancient Pangaea supercontinent began during the late-Permian and by the Triassic the early Arctic, North Atlantic, and North Pacific Oceans had also commenced opening. This break-up and opening of the modern oceans then effectively defined the modern North American continental outline. By the early-Jurassic, break-up had continued to extend into the Arctic and North Atlantic Oceans and also into the Caribbean and Labrador Seas. Greenland was then separated from Canada and has remained in close proximity. Similarly, South America began an apparent drift away from North America. Fragmentation of the Northern Canadian Islands also occurred during the Jurassic Period, which was intimately related to rifting occurring between Canada and Greenland. Further rifting within the Northern Canadian region has continued to the present-day.

During break-up of Pangaea and opening of the Pacific, Atlantic, and Arctic Oceans, each of the established Precambrian, Palaeozoic, and Mesozoic mountain belts were then fragmented. Remnants of these mountain belts are now separated as far away as Australia, Africa, South America, Russia, and Europe. Much of the Grenville and Appalachian fold-mountain belts remained attached to Eastern North America and the Cordilleran Mountain belt remained attached to Western North America. The Hercynides remained attached to Europe, the Caledonides to Scandinavia, and the Mauritanides to West Africa. The northern extension of the Cordilleran Mountain belt continued via Alaska into Asia and continued as the Andean Mountain belt into South America. Fragments of this Andean belt also include the New England fold belt of Eastern Australia and remnants can also be seen in New Zealand.

Throughout late-Jurassic to Miocene times, north-south stretching of the Cordilleran and Andean Mountain belt maintained a continuous continental link extending from South America through to North America to Siberia. The Siberian connection was then severed during the Pliocene Epoch during opening of the Bering Strait and the Central American link still remains attached today.

From its original equatorial location, the North American continent and continental cluster then slowly rotated clockwise as a result of crustal break-up and opening of the Atlantic, Pacific, and Arctic Oceans. Each of the North American, Scandinavian, and Baltic continents has since migrated north into mid- and high-northern latitudes, relative to the ancient North Pole.

7.7 South America

The development of the South American continent is shown in Figure 7.7. This continent is closely associated with the development of Africa and the South America to Africa assemblage has long been recognised in Plate Tectonic reconstructions. The closing of the Atlantic Ocean and assemblage of the American and African plates forms the basis of the Gondwana supercontinental assemblage, as well as the basis for both Continental Drift and Plate Tectonic theory.

In **Expansion Tectonic** studies the South American crusts originally formed part of the ancient Archaea supercontinent, which in turn formed part of an extensive network of ancient Precambrian sedimentary basins. East Antarctica and Precambrian remnants of West Antarctica and New Zealand were located to the northwest, Australia was located to the north, North America to the northeast, and Africa to the east, south, and west. Subsequent development of South America involved an extended period of crustal extension and fragmentation of the ancient crusts during the Proterozoic Eon and Palaeozoic Era. This development occurred in conjunction with similar Pan-African events in South and West Africa and was also associated with events in ancient Australia and New Zealand.

During Precambrian and Palaeozoic times, the ancient South American continent extended from low equatorial to high south polar latitudes. During the late-Palaeozoic to mid-Cretaceous, as the Atlantic and Indian Oceans progressively opened, the South American continent then slowly migrated north, in conjunction with Africa, relative to the ancient South Pole. From its Precambrian and Palaeozoic southern hemisphere location, South America then rotated clockwise, in sympathy with opening of the Atlantic Ocean, and migrated north to straddle the present-day equator. During the Palaeozoic, crustal extension and basin formation also gave rise to extensive deposition of basin sediments located between what are now South America, Antarctica, Australia, New Zealand, and North America.

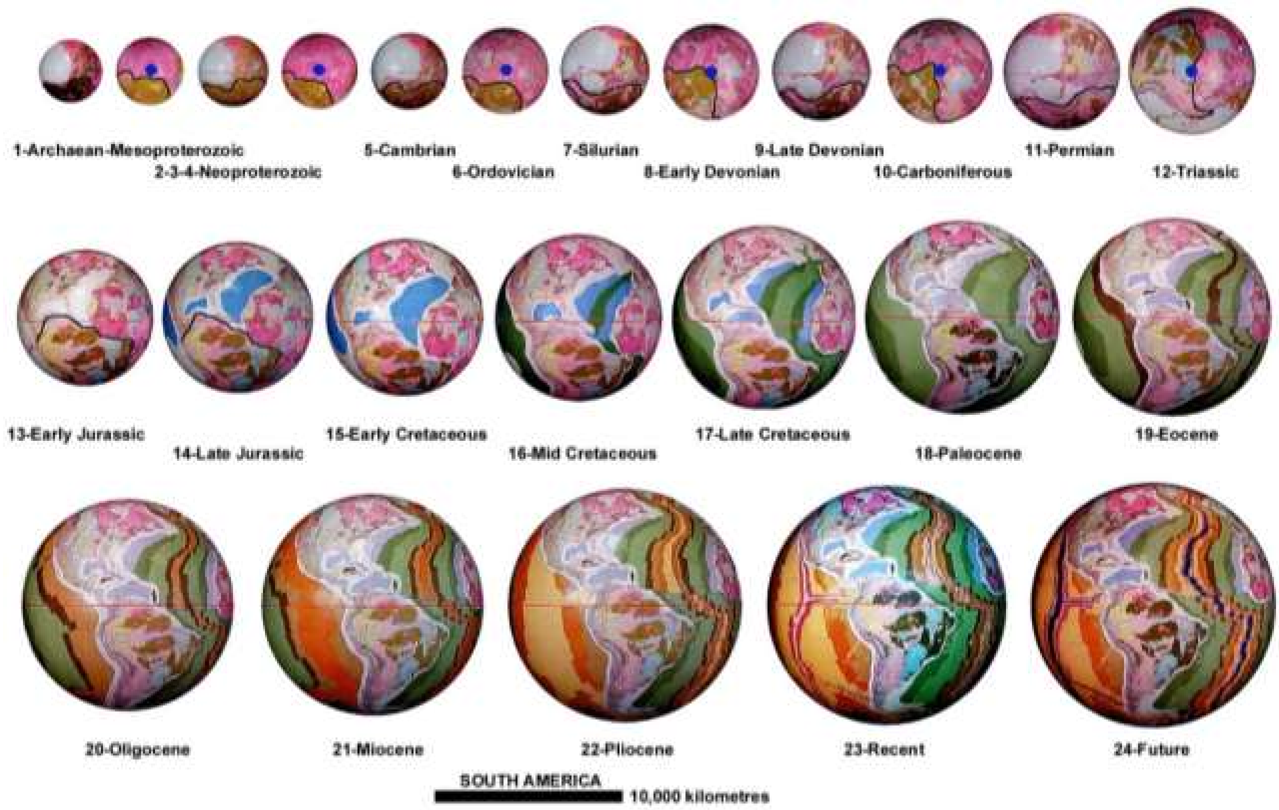

Figure 7.7 The continental crustal development of South America. The horizontal red line represents the location of the ancient equator, blue dots represent the South Pole, and black lines represent the South American continental outline.

Continental break-up between South America, New Zealand, Australia, and Antarctica commenced during late-Permian to Triassic times. This occurred in conjunction with opening of the South Pacific Ocean, with New Zealand retaining a brief link to Mexico. During the Jurassic, opening of the South Atlantic Ocean commenced in the south and this opening then migrated north to merge with the opening North Atlantic Ocean. During this time, South America separated from North America during opening of the North Atlantic Ocean and Caribbean Sea. A land connection with North America still remains along the South American and Central American peninsulas. A land connection between the West Antarctican Peninsular and southern South America also remained until final separation during the Miocene during opening of the Southern Ocean.

Mountains developed during the Mesozoic and Cenozoic as long linear belts along the West Coast of South America. This occurred in conjunction with further opening of the South Pacific Ocean and formed a Southern extension of the Cordilleran event in North America. Fragments of these mountain events also occur in New Zealand and Eastern Australia.

This crustal history of South America is in strong contrast with Plate Tectonic assemblages, whereby opening of the South Atlantic Ocean is compensated for by subduction of the South Pacific plate beneath the west coast of South America to form the Andean Mountain belt. As has been outlined previously:

Closing of the Pacific plates by subduction against the Americas is not required on an ***Expansion Tectonic*** *Earth.*

Instead, reconstruction of each of the oceans is shown to adhere with the seafloor crustal evidence preserved on the seafloors.

8 Into the Future

"All inferences from experience suppose...that the future will resemble the past." David Hume, 1777
"The result, therefore, of our present enquiry is that we find no vestige of a beginning, and...no prospect of an end." Hutton, 1788

In cosmological thinking it is a commonly held belief that the eventual demise of planet Earth will involve a fiery end, related to a steady expansion and decay of the Sun in the far distant future. As the Sun expands and decays scientists tell us that it will eventually envelop and consume each of the planets in turn to form a red giant star. This is certainly nothing for any of us, or future mankind to worry about as all life forms will have long since become extinct or evolved into something more adaptive by then.

From the continental and seafloor descriptions of Earth's past and present geological history discussed in the previous chapters, the concept of an **Expansion Tectonic** Earth can now be projected forward in time. From this, an account of what may eventually happen to not only the modern continents and oceans but also the Earth itself will be seen.

*On **Expansion Tectonic** small Earth models projection into the future is readily achieved by simply calculating a future Earth radius at any moment in time and extrapolating opening of the mid-ocean-rifting throughout all of the oceans.*

When the rate of increase in Earth radius established from the small Earth models is projected forward in time, both Earth surface area and radius is shown to increase to the size of the planets Jupiter and Saturn by about 500 million years into the future. For an **Expansion Tectonic** Earth, it is envisaged that one of two things may happen to the Earth during that time. Firstly, the Earth may fragment and disintegrate to form a second asteroid belt or, secondly, it may simply continue growing to become another giant gaseous planet. How this relates to an expansion of the Sun is uncertain, but again this does not concern the wellbeing of present mankind.

Because the present Earth is essentially a wet planet—because it has an atmosphere and hydrosphere—when compared to the dry inner rocky planets of the Solar System, to me the giant planet scenario seems the most likely outcome. As the Earth's mantle continues to swell, it is envisaged that more entrapped fluid and gas will continue to be expelled from the mantle to form a dense gaseous atmosphere in the far distant future. This may then extend in time to form planetary ring structures as lighter gases are progressively lost into space.

A reconstruction of an **Expansion Tectonic** Earth at five million years into the future is shown in Figure 8.1—which coincidently still looks very similar to the present Earth. Reconstructing crustal plates on this future small Earth model is readily done by simply calculating the predicted Earth radius from the established radius formula and then adding new seafloor crust along each of the mid-ocean-ridge axes—precisely as is happening today. Apart from the increased distances between the various continents and subtle changes to the coastlines, on this model the distribution of continents and oceans on the future Earth is shown to be essentially the same as it is today.

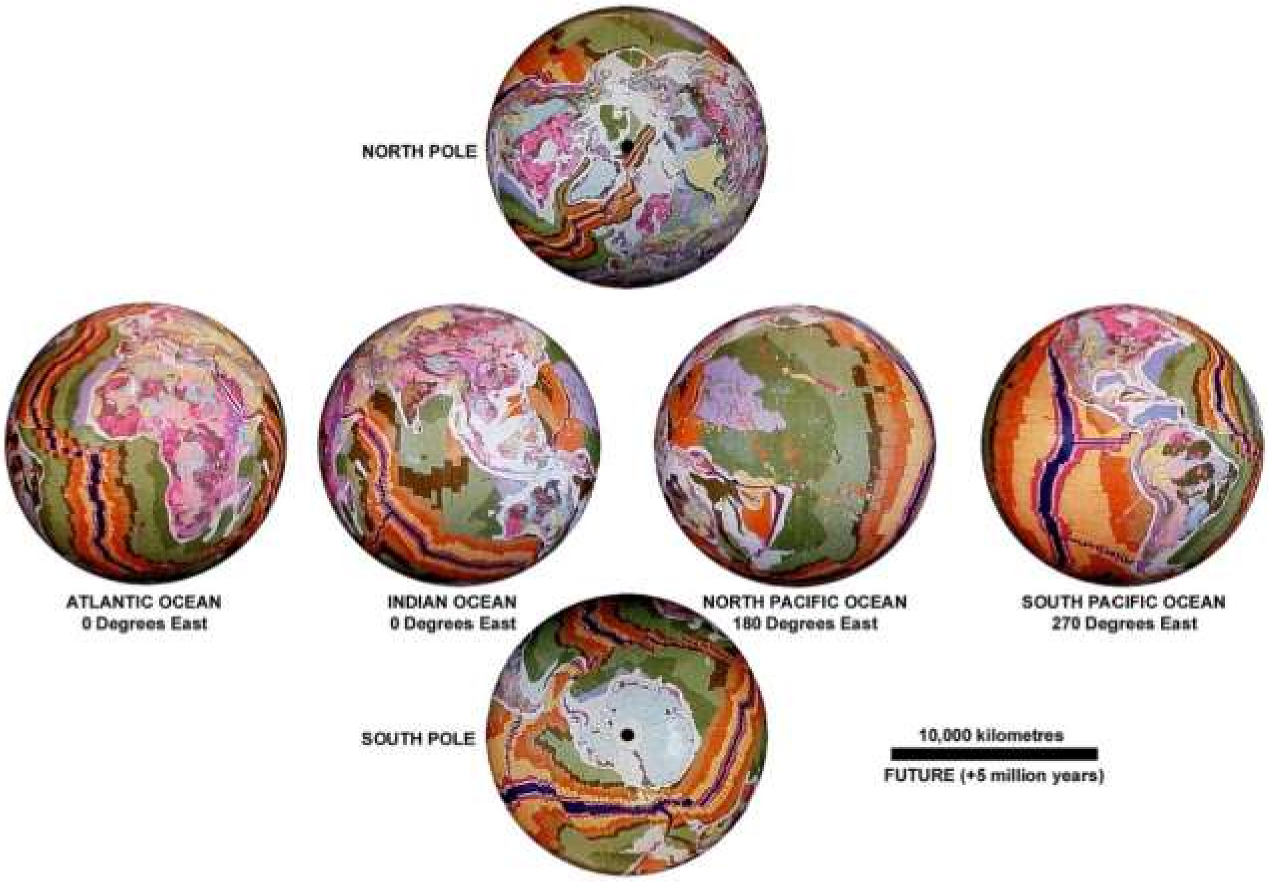

Figure 8.1 The **Expansion Tectonic** Earth projected to 5 million years into the future. The dark blue spreading ridge represents spreading along each of the mid-ocean-ridges for the next 5 million years. The model shows an extension of all mid-ocean-ridge axes into seismically active areas such as Turkey, Japan, California, and New Zealand.

During this geologically short interval of time, it is calculated that Earth radius will increase by 107 kilometres to 102 percent of the present radius. The series of images in Figure 8.1 show that the increase in Earth radius to 5 million years into the future is consistent with a continued increase in surface area of each of the oceans and lengthening of each of the present-day mid-ocean-ridge spreading axes. This process of lengthening of the mid-ocean-ridge spreading axes is a direct result of the increase in circumference of the Earth during an increase in Earth radius. The mid-ocean-ridge lengthening process then represents an important mechanism for future crustal development during on-going Earth expansion.

On an **Expansion Tectonic** Earth, as the mid-ocean-ridge spreading axes lengthen and the ridges open they can be visualised as being huge propagating cracks in the seafloor—which is precisely what they are. As the cracks propagate and lengthen they also continue to break-up the continental and seafloor plates into ever smaller fragments. This is currently occurring within each of the major earthquake prone areas of the world today. In these earthquake prone areas the seismic and earthquake activity occurs as a result tensional cracking and breaking apart of the crusts, not due to collision as portrayed in Plate Tectonics. This break-up is also accompanied by intrusion of volcanic lavas, elevated heat flow, and expulsion of new water and gases from the mantle.

Lengthening of the East Pacific mid-ocean-ridge spreading axis on an **Expansion Tectonic** Earth is currently occurring as a northward extension of the spreading ridge passing through the Gulf of California. This gulf will eventually rift and separate the Californian Peninsula from North America to form an island. A northward extension of the Red Sea Rift zone through the Gulf of Aqaba and Dead Sea region into Turkey will eventually result in the rifting and separation of the Sinai Peninsula from Arabia. A northern extension of the Marianas spreading ridge is shown to be continuing towards Japan and a southern extension of the Tongan spreading ridge is also continuing through New Zealand.

Elongation of the mid-ocean-ridge spreading zones within these areas contrasts strongly with the Plate Tectonic requirement for plate convergence, continental collision, and subduction of vast areas of oceanic crust. On an **Expansion Tectonic** Earth, an increase in surface area accompanied by elongation of the mid-ocean-ridges is considered to better represent the break-up and separation of the continents and opening of the existing oceans when moving into the future. These mid-ocean-ridge opening processes, as projected well into the future, also continues to comply with the established seafloor bedrock geological mapping.

9 Causal Mechanism

"...it may be fundamentally wrong to attempt to extrapolate the laws of physics as we know them today to times of the order of the age of the Earth and of the Universe." Creer, 1965

Discussion on the causal mechanism for **Expansion Tectonics** has been intentionally left until last, regardless of when this most fundamental of questions first arose. This was done to allow empirical evidence to be presented in a logical manner, without biasing outcomes of the evidence that needed to be presented.

Unfortunately, most humans instinctively want to know or at least comprehend a cause well before acknowledging any physical evidence.

This also touches on our innate and instinctive hesitation towards change where; *...it is better to err towards what we already know and are comfortable with rather than be seen to be different.*

It is acknowledged here that any proposal for a causal mechanism of an increase in Earth radius will open all sorts of controversial criticism and intellectual backlash. This is acceptable, as it is consistent with what Arthur Schopenhauer said about science in general:

"All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident."

This is all very well though, but at least an attempt must be made to assimilate the new ideas about **Expansion Tectonics** presented here into a working hypothesis, even if just to stimulate on-going research or intellectual backlash. Over time though *...true science insists that we must continually challenge new ideas until such time as the original concepts and ideas are indeed fully understood and they can be confidently accepted within the hypothesis as truth.* If time shows that these basic ideas are incorrect, true science also decrees that the particular reining hypothesis must be either modified, or rejected in favour of a hypothesis that better fits observation.

9.1 Historical Considerations

Concerning the physical cause of Earth expansion, in 1965 Creer maintained that *"...we should beware of rejecting the hypothesis of Earth* *expansion out of hand on grounds that no known sources of energy are adequate to explain the expansion process."* Creer further considered that *"...it may be fundamentally wrong to attempt to extrapolate the laws of physics as we know them today to times of the order of the age of the Earth and of the Universe."* This remains equally true today since historically, in the evolution of knowledge, empirical phenomena have often been recognized long before their cause or reason has been understood.

During the 1950s and 1960s there was active debate amongst many scientists, in particular centred on the new discoveries in seafloor crustal geology and how they relate to global tectonics. In 1963, Egyed summarized hypotheses proffered for the cause of Earth expansion since the theory of Earth expansion first gained recognition in the 1800s, and in 1973 Wesson gave a comprehensive review of the cosmological implications of an **Expansion Tectonic** Earth. Carey in 1983 also provided a comprehensive list of authors who have contributed to the causes of Earth expansion.

It should be appreciated, however, that most, if not all, of the following historical considerations were proffered many decades ago. Furthermore, it is important to appreciate that these considerations were made well before completion of the bedrock geological map of the oceans and continents, where:

Small Earth modelling studies presented here represent the first time that this mapping data has been used to accurately quantify and constrain an Earth expansion process.

Regardless of this, these early researchers recognized five main reoccurring themes for a causal mechanism of Earth expansion:

1. **A pulsating Earth:** This is where cyclical expansion of the Earth was considered to have opened the oceans and contractions formed the mountains. This proposal fails to satisfy an exponential increase in Earth expansion, and Carey considered the theme to have arisen from the *"false axiom"* that *"...orogenesis implies crustal contraction"* or collision to form mountains. Carey saw no compelling evidence for intermittent contractions of the Earth and this observation is now borne out by the symmetric seafloor spreading patterns as mapped in all of the modern oceans for the past 170 million years at least.

2. **Meteoric and asteroidal accretion:** This proposal was rejected by Carey as the primary cause of Earth expansion as the increase in Earth radius should decrease exponentially with time, not increase. Nor does this proposal explain the seafloor spreading patterns in each ocean. In order to maintain an increase in Earth radius of 22 millimetres per year this proposal would necessitate that the entire Earth, including both continents and oceans, be uniformly covered in meteoric dust and debris for many kilometres thick, which it clearly is not.

3. **Constant Earth mass, with phase changes to an originally super-dense core:** This was rejected by Carey as the main cause of Earth expansion because he considered the theme would imply too large a surface gravity throughout the Precambrian up until late in the Palaeozoic. Carey further considered that there is no evidence to suggest there was a large surface gravity in the past. Furthermore, the expansion of the Earth from an initial radius of 27 percent of its current radius to its current radius indicates a volume increase of the order 50 times the initial volume. Nowhere in the Solar System is a body with a mean density of this required magnitude, making it extremely unlikely there was ever a super-dense Earth.

4. **Secular reduction of the universal gravitation constant G:** Such a decline in G would cause expansion through the release of elastic compression energy throughout the entire Earth, resulting in physical changes in the minerals and rocks to lower densities. Carey again rejected this proposal as the main cause of expansion for three reasons; that formerly surface gravity would have been unacceptably high during the Precambrian; that the magnitude of expansion from this proposal would have probably been too small; and the arguments for such reduction in G were considered not to indicate an exponential rate of increase in Earth radius.

5. **A cosmological cause involving a secular increase in the mass of the Earth:** This remains the most acceptable causal mechanism, however, where the additional new matter comes from to increase Earth mass has not been forthcoming until now.

Carey in 1983 considered that each of these five proposals briefly summarised above are soundly based and may have contributed in part to some form of Earth expansion. He further considered that, "...because *of the limitations of surface gravity in the past there may be no alternative to an exponential increase of Earth mass with time."*

Because conventional science considers that the size of the Earth has remained essentially constant for all time, the question as to where any additional Earth mass may come from has never been required to be asked.

Because it has never been required to be asked, none of these historical proposals have been taken seriously. Moving in full circle, this is also why Earth expansion continues to be shunned and nothing has been successfully proffered to encourage conventional science to change its stance.

A lot of new science and global evidence has since been gathered over the past decades to seriously challenge conventional Plate Tectonics and to offer a plausible cause for Earth expansion. In addition to the five main themes above, new themes for a causal mechanism have recently been proposed, including:

6. **Ionic mass expansion:** Where the atoms of various elements gain additional mass which then doubles the radius of the Earth in about 500 million years. This theory is based on the ionization potentials of various elements, with an initial ionization beginning the mass accumulation process. The theory primarily differs from other theories in that the new mass accumulates within existing elemental atoms and not by the addition of new atoms.

7. **Matter transfer from the Sun:** Where electrons and protons ejected from the Sun enter the Earth and recombine within the 200 to 300 kilometres thick D" region, which is located at the base of the mantle directly above the core-mantle boundary.

With all of this in mind, a causal mechanism presented here is based on a suggestion put forward by John Eichler in 2011. Eichler posed the question, *"Does plasma from the Sun cause the Earth to expand?"* and by presenting a new argument based on known physical phenomena, he suggested that this might indeed be the case. Eichler elaborated with his statement that:

"To assume that the Earth is gaining matter and that this may be due to nucleosynthesis within the Earth seems to fly in the face of conventional wisdom—and it does. Based on empirical geologic evidence which strongly indicates that ***Expansion Tectonics*** *is indeed valid, the task confronted is to formulate a viable mechanism whereby this occurs. In a plasma universe, the Earth is under constant bombardment from space, with all the necessary components to reconstitute matter from its component parts deep within the Earth not requiring theoretical constructs which have never been experimentally observed. The Earth, having a magnetic field strong enough to interact with impinging particles, gathers more than sufficient fundamental particles, namely electrons and protons, to account for a slow increase in matter internally over hundreds of millions of years. There is therefore no lack of component particles to create new matter deep within the body of the Earth. The exact process by which this occurs is complex in nature and, like the interior of the Earth itself, involves speculation as to its dynamics. It is argued that the avenue of approach proposed here is plausible and warrants further serious scientific investigation. If new matter has been added to the interior of the Earth, there must be an answer to the riddle of the dynamics of the process."*

This proposal also incorporates the observations of Kremp who, in 1992, suggested that new geophysical evidence indicates that the Earth has been growing rapidly in the past 200 million years. Kremp indicated that seismologists have located the existence of a zone, about 200 to 300 kilometres thick, located at the base of the mantle directly above the core-mantle boundary, designated the D" region. Yuen and Peltier in 1980, as well as Boss and Sacks in 1985, earlier postulated the existence of a substantial flow of heat across this core-mantle boundary and concluded that if whole-mantle convection—a Plate Tectonic requirement for convection within the mantle—were to occur in the Earth's mantle, this D” region should be the lowest thermal boundary layer of the whole-mantle system. With the temperature of the outer core of the core-mantle boundary estimated to be about 800 degrees higher than the D” layer of the mantle, or perhaps even 1500 degrees higher, Kremp concluded that this thermal increase in the outer core may be a fairly recent process forcing a rapid expansion of the Earth.

With so much interstellar material impinging on the Earth, why hasn’t anyone taken the logical step and asked, where is all this material going to and what is it doing to the Earth itself?

9.2 Proposed Causal Mechanism

A proposed causal mechanism for an increase in Earth mass causing an exponential increase in Earth radius through time remains speculative, but is presented here in order to stimulate further discussion and research. What should be appreciated is that:

The Earth is now known to be constantly immersed in a solar wind, a rarefied flow of hot plasma emitted by the Sun in all directions, which is associated with the two-million-degree heat of the Sun’s outermost layer.

This solar wind usually reaches Earth with a velocity around 400 kilometres per second, with a density of around 5 ions per cubic centimetre. During magnetic storms, the flow of ions can be several times faster and the interplanetary magnetic field may also be much stronger.

The Earth’s magnetosphere has been shown to be full of trapped plasma as the solar wind passes the Earth. This flow of plasma into the magnetosphere increases with increase in solar wind density and speed, as well as with increases in turbulence in the solar wind. The flow pattern of magnetospheric plasma is from the magnetotail toward the Earth, around the Earth and back into the solar wind through the magnetopause. In addition to moving perpendicular to the Earth’s magnetic field, some magnetospheric plasma travels down along the Earth’s magnetic field lines where it loses energy to the atmosphere within the auroral zones.

New research now suggests that this process may be more common and possibly a constant means for the penetration of solar wind into the terrestrial magnetosphere.

Beyond the known observations about coronal mass ejection related plasma flow into the Earth, all else remains speculative once it enters the Earth. Again, as Eichler states, "*There is therefore no lack of component particles to create new matter deep within the body of the Earth. The exact process by which this occurs is complex in nature and, like the interior of the Earth itself, involves speculation as to its dynamics. It is argued that the avenue of approach proposed here is plausible and warrants further serious scientific investigation. If new matter has been added to the interior of the Earth, there must be an answer to the riddle of the dynamics of the process."*

At this stage it is envisaged that electrons and protons enter the Earth and recombine within the 200 to 300 kilometres thick D" region, located at the base of the mantle directly above the core-mantle boundary. Kremp concluded in 1992 that, "*...this thermal increase in the outer core may be a fairly recent process forcing a rapid expansion of the Earth."* New mass formation requires not only pure energy but the presence of both electrons and protons and science now knows that these are plentiful from the Sun. The recombination of charged electrons and protons within this D" region then provides a mechanism to form new matter. This matter in turn becomes the building blocks of all elements and mineral species present on and in the Earth including the new lava, water and gases now being expelled from the mid-ocean-ridge spreading centres in all of the ocean basins.

From an **Expansion Tectonic** perspective, this new matter accumulates within the D" region, located at the core-mantle interface. This increase in new matter results in an increase in Earth mass and volume which manifests itself as a swelling of the mantle. The increase in Earth volume and associated mantle swell is then transferred to the outer crust where it results in crustal extension, which is currently occurring as extension along the full length of the mid-ocean-rift zones. Extension within the mid-ocean-rift zones is accompanied by intrusion of new basaltic mantle-derived lava, along with expulsion of new water and gases. These in turn increase the surface area of all of the modern oceans in strict accordance with the seafloor mapping shown in the Geological Map of the World.

10 Concluding Remarks

"If 50 million believe in a fallacy, it is still a fallacy." Carey, pers. comm. 1995

In this summary document, heavy reliance has been made on the bedrock geological mapping of the oceans and continents to both measure the ancient radii of the Earth and to establish a formula to determine an ancient Earth radius at any moment in time. This bedrock mapping and measured ancient radius data was then used to construct small Earth models extending from the early-Archaean Era, some 4,000 million years ago, to the present-day plus one model extended to 5 million years into the future.

Throughout the Triassic to present-day times it was found that:

The seafloor crustal plates reassemble together on each small Earth model with a better than 99 percent global plate-fit without the need to fragment continents, subduct large amounts of seafloor crusts beneath the continents, or invoke pre-existing crusts in order to maintain a constant surface area Earth.

Similarly, when progressively older sediments and intruded magmatic rocks from continental sedimentary basins are returned to the ancient lands or mantle respectively, it was found that:

Remnants of the most ancient Precambrian continental crusts also reassemble together with a high degree of global fit-together on ancient small Earth models.

Throughout this extensive small Earth modelling study, the history of each of the ancient supercontinents and seas was also discussed, as well as the modern continents and oceans, in the context of an Earth progressively increasing its surface area through time. In order for the Earth to increase its surface area, it was stressed that the relatively thin outer continental and seafloor crusts must stretch and distort as the surface curvature of the Earth progressively flattens throughout history. It is considered that this distortion of the crusts during change in surface curvature has given rise to all of the known geological and geographical features that are now familiar to us on Earth today.

A side-line to this small Earth modelling exercise was to test the validity of past models of an **Expansion Tectonic** Earth, as previously constructed and published by Ott Hilgenberg in 1933, Klaus Vogel in 1983, and numerous others. Seafloor mapping was not available to Hilgenberg; hence his reliance on a visual fit-together of continental crustal fragments was far from convincing. This contrasts with the models of Vogel who had access to, and was able to use, early versions of the seafloor mapping data.

Completion of the Geological Map of the World in 1990 is therefore seen as a very important milestone towards quantifying **Expansion Tectonic**s. This bedrock geological mapping is now considered to be a valuable tool for anyone to accurately constrain plate assemblages on small Earth reconstructions, as well as a means to accurately measure the ancient Earth radius against time.

The conclusions of the various historical researchers regarding observations and impressions from their own modelling studies are worth briefly mentioning. Barnett in 1962 said, "*...it is difficult to believe that chance alone can explain this fitting together of the continental margins*." Creer in 1965 said, "*...the fit of the continents on a smaller earth appeared to be too good to be due to coincidence and requires explaining*," and Vogel was "*...continually amazed that the simplicity with which earth expansion answers so much of the earth's evolution has been so delayed in universal adoption.*" From their various works, these researchers concluded, "*...if all of the earth's continents were fitted together they would neatly envelope the earth with continental crust at approximately 55 to 60 percent of the present earth size.*" This led Hilgenberg to conclude "*Earth expansion resulted in the break-up and gradual dispersal of continents as they moved radially outwards during geological time.*" Similarly, Vogel suggested it was also "*...theoretically possible for the continents, without shelves, to fit together at approximately 40 percent of the present earth radius by considering that continental shelves were formed after the continental crust had fragmented.*" Vogel concluded from his modelling studies that, "*...the earth has expanded with time, from an early Pangaean configuration to the Recent, with continental separation caused by a radial expansion of the earth.*"

It is also worth mentioning again that during the 1950s, professor Carey, in researching and modelling the concept of continental drift, demonstrated "*...if all the continents were reassembled into a Pangaean configuration on a model representing the Earth's modern dimensions, the fit was reasonably precise at the centre of the reassembly and along the common margins of north-west Africa and the United States east coast embayment, but became progressively imperfect away from these areas.*" Carey concluded from this research that, "*...the fit of the Pangaean reassembly could be made much more precise in these areas if the diameter of the earth was smaller at the time of Pangaea.*"

It is unfortunate that:

Since acceptance of Plate Tectonics as the ruling tectonic theory during the 1960s, none of this alternative research is considered, acknowledged, or probably even known about today.

It is also unfortunate that the basic observations and conclusions of Vogel, Carey, and others continue to be totally ignored or simply discarded by mainstream science. Unbeknown to most Earth scientists today, these observations are in fact extremely important and valid in our modern understanding and perception of global tectonics. It is the little meme that is firmly embedded in the back of our minds—the constant Earth radius one—that is unfortunately still hindering geoscientific research today and the one that continues to get in the way of rational scientific thinking.

It is emphasised that, although Plate Tectonic reconstructions of individual regions on a constant sized Earth can achieve a high degree of fit-together, in most cases these reconstructions obscure the fact that crustal assemblage, development, and displacement in one region of the Earth globally affects all other areas. What this means is that problems of misfit in one area of the Earth on conventional reconstructions cannot, and must not, be conveniently transferred to an adjacent region and then simply ignored. Global tectonics is a holistic phenomenon, not a local phenomenon. Similarly, modern surface geological mapping also shows that the continents are not rigid plates, as is often portrayed in conventional tectonic studies, but are instead a complex array of crustal features each with their own equally complex crustal histories that must be taken into consideration when undertaking any modelling studies of the Earth.

In contrast, the modelling studies outlined in each of the previous chapters utilise the modern bedrock crustal mapping of the Commission for the Geological Map of the World and UNESCO (1990) to constrain plate assemblage on small Earth models of an **Expansion Tectonic** Earth. This mapping was not available to early researchers into Continental Drift, Plate Tectonics, or Earth Expansion. It is important to note that this map was originally commissioned and completed with the primary intent of quantifying the plate motion histories and prior plate assemblages on a Plate Tectonic Earth model. However, it is rarely used in Plate Tectonic studies today simply because it failed to achieve its intended aim—in other words, the factual data did not fit the preconceived static radius Plate Tectonic model.

By successively removing young seafloor crustal geology from along the mid-ocean-ridge spreading axes shown on this map and reuniting the remaining continental and seafloor crustal plates on small Earth models, the modelling studies of each of the Earth Expansion researchers mentioned above are indeed validated. In addition, the bedrock mapping demonstrates that all crustal plates do indeed assemble precisely, with one unique global fit-together on small Earth models. Again, as Creer so astutely noted, "*...the fit of the continents on a smaller Earth appeared to be too good to be due to coincidence and requires explaining.*"

The **Expansion Tectonic** modelling studies presented here demonstrate conclusively that the crustal plates, when reconstructed on small Earth models, coincide fully with the seafloor spreading and geological data and accord precisely with the derived ancient Earth radii for each model constructed. 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 seafloor crusts generated at spreading ridges is refuted. The small Earth modelling studies instead demonstrate that the mechanism of seafloor spreading, as highlighted by the seafloor mapping, provides a definitive means to accurately quantify an **Expansion Tectonic** Earth process.

It is emphasised that this bedrock geological mapping is factual empirical evidence and the **Expansion Tectonic** research undertaken can therefore be justly considered as empirical research. Empirical research, by definition, is a way of gaining knowledge by means of either direct or indirect observation. In **Expansion Tectonics**, this empirical evidence is the published seafloor and continental crustal mapping data preserved in each of the oceans and continents. This evidence was analysed here both quantitatively and qualitatively during model studies, without imposing prior premises or assumptions about Earth radius. By quantifying the seafloor mapping evidence and making sense of it in qualitative form, a number of empirical questions were then able to be asked in order to further knowledge and understanding within the bounds of the evidence available.

The most fundamental question considered during this modelling exercise was: ***Does the seafloor mapping really reflect an increase in Earth radius with time?*** This was dually answered and tested by measuring each of the seafloor surface areas in turn and from this, calculating ancient Earth radii for each time interval involved. The results were then further quantified by using the radii data to create small Earth models. These models were in turn used to test whether or not the remaining seafloor and continental crustal data will reassemble back in time to ultimately assemble as Pangaea and primordial Archaean small Earth models respectively. The construction of each of these small Earth models relied on the fundamental premise that seafloor volcanic lava intruded along the mid-ocean-ridge zones, as well as sediment deposited within marine and continental sedimentary basins, are cumulative with time. It was argued that, by moving back in time, both the lava and sediment must be returned to the mantle or ancient lands respectively, from where they originated.

By progressively removing seafloor volcanic lava from each of the small Earth models in turn it was shown that the plate fit-together along each mid-ocean-ridge plate margin achieved a better than 99% global fit for each model constructed.

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*This unique fit-together was considered to empirically demonstrate that a post-Triassic **Expansion Tectonic** Earth is indeed a viable process and therefore justified extending modelling studies back further to the Archaean.*

This experiment empirically demonstrated that all remaining continental crusts do indeed assemble as a complete Pangaea Earth at approximately 50 percent of the present Earth radius during the late-Permian. Similarly, by extending this philosophy back in time to the Precambrian times, remnant ancient Proterozoic and Archaean continental crusts were shown to assemble together as a primordial Earth at approximately 27 percent of the present Earth radius.

From this small Earth modelling exercise it was shown that, prior to the Triassic Period, the ancient supercontinents had existed as a complete continental crustal shell for 94 percent of early Earth history, lasting for some 3,750 million years. This supercontinental crust covered the entire Earth with no large intervening oceans. During that time large bodies of water were instead restricted to a network of relatively shallow continental seas. The evolution of the supercontinents during pre-Triassic times simply involved a progressive and evolutionary crustal process during a prolonged period of crustal stretching, accompanied by changes in both Earth surface area and surface curvature through time. The outlines and configurations of the supercontinents were then dictated by changes to the ancient sea-levels and coastal shorelines, primarily as a result of changes to the surface areas of each of the ancient seas.

In strong contrast, the modern continents simply represent the fragmented remains of the ancient Pangaea supercontinental crustal shell. This fragmentation and subsequent break-up occurred because the ability for the continental crusts to continue to stretch during on-going increases in Earth surface area was finally exceeded during the late-Permian Period. As a result, during the late-Permian the continental crust then ruptured and broke apart to form the modern continents. During that time the ancient continental seas were also disrupted and progressively drained from the continents into the newly opening modern oceans.

Quantification of an **Expansion Tectonic** Earth process back to the early-Archaean required an extension of the fundamental cumulative seafloor volcanic crust 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 achieve this, consideration was 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 then progressively restored to a pre-extension, pre-stretching, or pre-rift crustal configuration by simply removing young sedimentary and intruded magmatic rocks and reducing the surface areas of each of the sedimentary basins in turn, consistent with the empirical data shown on the Geological Map of the World. During this process, the spacial integrity of all existing ancient cratons and orogens was retained until restoration to a pre-orogenic configuration was required. By removing all basin sediments and magmatic rocks, as well as reducing the surface area of each sedimentary basin in turn, an ancient primordial small Earth with a radius of approximately 27 percent of the present Earth radius was then achieved during the early-Archaean.

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.

Mathematical modelling of both the seafloor and continental crustal surface area data demonstrate that the Earth is undergoing an exponential increase in surface area and radius, commencing from a primordial Earth of approximately 1,700 kilometres radius during the early-Archaean. From this, a current rate of increase in Earth radius is calculated to be 22 millimetres per year. Increase in Earth radius throughout the Archaean to mid-Proterozoic times was shown to increase by approximately 60 kilometres during 3 billion years of Earth history, prior to a steady to rapidly accelerating increase in Earth radius commencing during the late-Proterozoic and continuing to the present-day. Extrapolating this increase to the future demonstrates that expansion to 5 million years in the future is consistent with a continued spreading along all present-day mid-ocean-ridge axes.

Crustal assemblages on each of the small Earth models showed that large Panthalassa, Tethys, and Iapetus Oceans were not required during reconstruction. These oceans were instead replaced by continental Panthalassa, Iapetus, and Tethys Seas, which represent precursors to the modern Pacific and Atlantic Oceans as well as ancient sedimentary basins located on many of the present-day continents. Similarly, emergent land surfaces during the Precambrian and Palaeozoic Eras were shown to equate to the conventional Rodinia, Gondwana, and Pangaea supercontinents and smaller sub-continents.

On each Precambrian and Palaeozoic small Earth model, supercontinental development was shown to be progressive and evolutionary, with no requirement for random continental dispersion-amalgamation cycles.

Supercontinent configuration is shown to be related to progressive crustal extension within an established network of continental sedimentary basins, changes to Earth surface curvature, and changes to sea levels. Also, it is important to appreciate that on an **Expansion Tectonic** Earth the poles and equator remain stationary while the land masses make an apparent traverse across them.

While the extensive small Earth spherical model studies presented here empirically demonstrate that the concept of an **Expansion Tectonic** Earth is viable, the problem of where the excess Earth volume comes from and similarly where does it go to moving back in time remains a very real enigma. Despite this enigmatic origin for the excess volume required to quantify an **Expansion Tectonic** process, it is emphasised that the empirical evidence presented so far shows that:

The ability to globally reassemble Archaean to present-day crusts with such a high precision cannot be mere coincidence.

From this statement I maintain that scientists cannot continue to justify imposed ad-hoc premises or assumptions about Earth radius simply to maintain a perceived Plate Tectonic consensus of opinion. It is considered that:

This consensus of opinion, based on an untested static radius Earth meme, must therefore be rejected in order to allow true science to correctly consider and assess the empirical evidence presented here.

At this stage, the outcomes of this empirical crustal research are more than adequate to quantify the validity of an **Expansion Tectonic** Earth crustal process. However, in the eyes of many, it is still seen as largely subjective even though small Earth models were able to be readily constructed by simply assuming that the Earth's surface area is increasing with time as a direct result of an increase in Earth radius, with nil crustal consumption.

Readers interested in the extensive geological, geophysical, geographical, and biogeographical **Expansion Tectonic** research and data modelling studies now available are encouraged to visit my website at: www.expansiontectonics.com Publications available include: **On the Origin of Continents and Oceans** (2014), and **Terra non Firma Earth** (2005), both of which are available in hardcopy and eBook formats.