Paper 4: Modelling 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 increasing radius Earth the modern continents have only existed in their current form since breakup of the ancient Pangaean supercontinental crust commenced some 250 million years ago. The modern continents represent the fragmented remains of the ancient Pangaea supercontinental crustal shell. Fragmentation and breakup of Pangaea occurred because the ability of the supercontinental crusts to continue to stretch and extend during on-going increases in Earth surface area was exceeded during late-Permian times. Once crustal stretching was exceeded the Pangaean supercontinental crust then ruptured, broke apart and fragmented to form the modern continents and opened to form the intervening modern oceans, as well as initiating draining of waters from the ancient continental seas into the newly opening oceans.

During this post-Permian time, crustal extension was mainly confined to the modern oceans along well-defined mid-ocean-ridge spreading zones. Over time the increase in surface area and volcanic activity within the mid-ocean-ridge zones gradually exceeded the input of sediments from the continents. By the early-Jurassic Period the seafloor volcanic rocks were then exposed and preserved as modern seafloor crust within each of the oceans. Two sub-phases are recognised during this time, with each phase corresponding to the distribution of Mesozoic and Cenozoic seafloor crusts respectively.

Australia

The Australian continent (Figure 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 an ancient Precambrian supercontinental crustal assemblage. This ancient assemblage later extended in surface area as new sedimentary basins opened around the margins.

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 breakup 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.

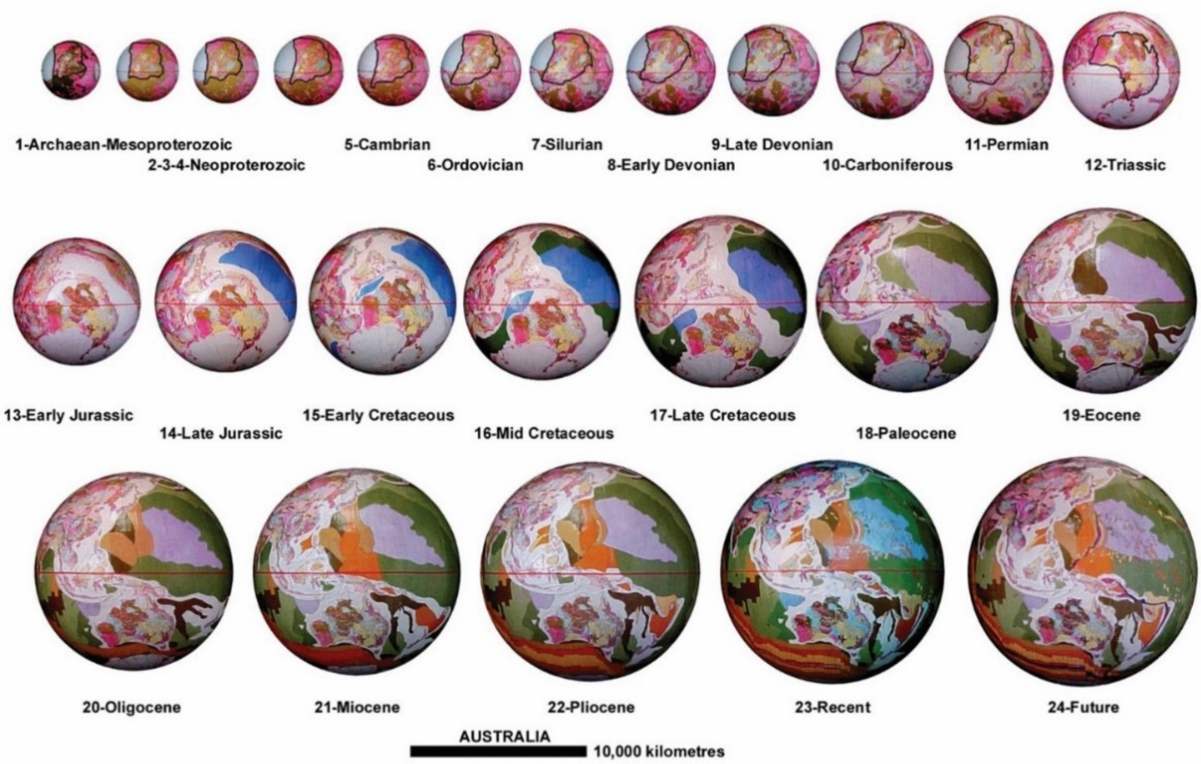

Figure 1 Continental crustal development of Australia. The outline of the pre-Jurassic Australian crust is shown as a black line. During the Precambrian to late-Palaeozoic Eras Australia was orientated north-south prior to rotating counter clockwise to the present east-west orientation. This occurred during opening of the modern Pacific Ocean. The horizontal red line represents the location of the ancient equator.

During this pre-breakup supercontinental 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. Breakup 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.

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 faunal and floral 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 migrate away from each other leaving both continents as separate island continents. During this rifting phase, Australia migrated south from mid-northern latitudes crossing the ancient equator into its present-day mid-southern latitude location.

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 conventional Plate Tectonic studies whereby Australia is instead said to be migrating north, out of more temperate to polar climate zones, to collide with South East Asia. This interpretation is based primarily on palaeomagnetic studies and cannot be reconciled on an increasing radius Earth.

Africa and Arabia

Africa and Arabia contain extensive areas of ancient Precambrian crusts. Both continents originated from an Archaean 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 (Figure 2) has since remained spatially intact throughout Earth history relative to each of the surrounding continents.

Throughout Precambrian and Palaeozoic supercontinental times the ancient South Pole was located within what is now Central West Africa and during that time a south-polar ice-sheet extended periodically from there into Arabia and South America. Once crustal breakup commenced, this ancient South Pole made an apparent migration south along the present West African coastline during the Mesozoic Era as the African continent migrated north (Figure 2).

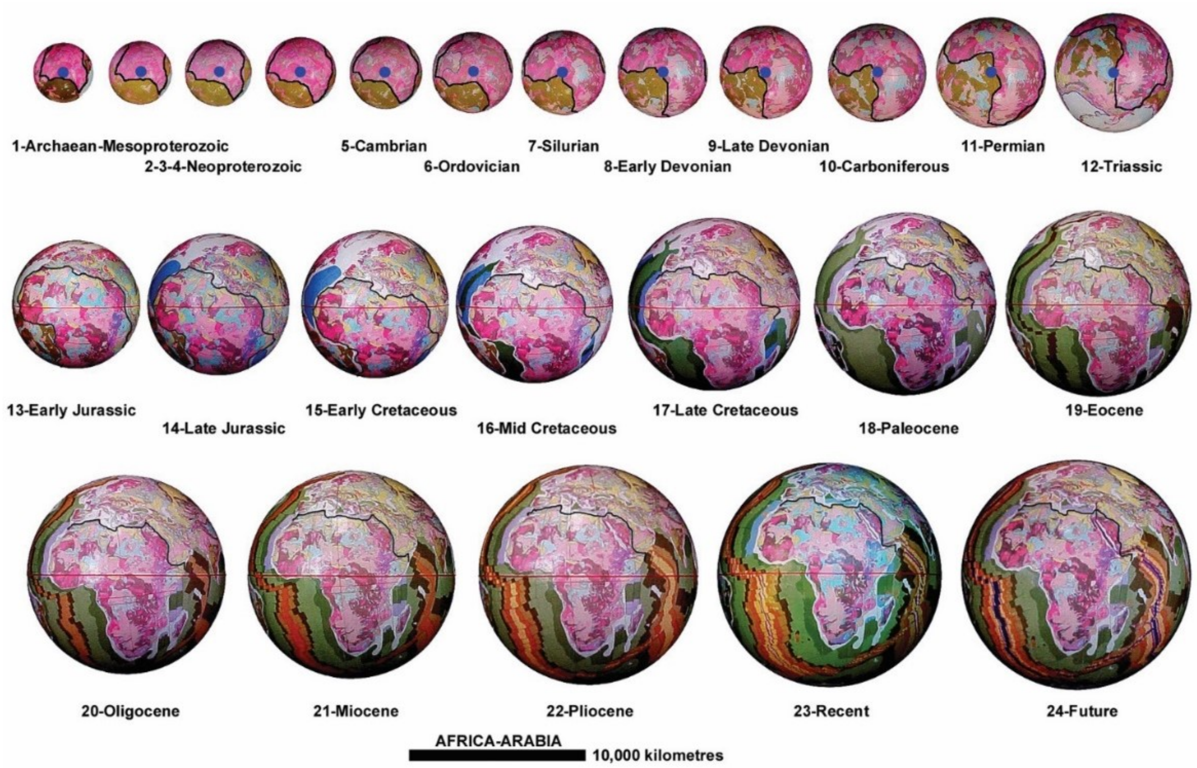

Figure 2 Continental crustal development of Africa and Arabia. In each of the Precambrian and Palaeozoic models North Africa is shown located south of the ancient equator and the South Pole is located in west Central Africa. The Archaean to Triassic models are centred on the South Pole (blue dots). The horizontal red line represents the location of the ancient equator and the black lines represent the African continental crustal outlines. Note: models 1 to 12 are centred over the South Pole and models 13 to 24 are centred on the equator.

The crustal development of primitive Africa and Arabia during Precambrian and Palaeozoic supercontinent times involved extensive continental crustal stretching and formation of intracratonic sedimentary basins. Each of these areas were, 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.

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 occurred within what is now North Africa.

Breakup of the ancient Gondwanan 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 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 latter 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 had 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.

On an increasing radius Earth a direct geographical connection between Europe and Asia is maintained throughout Earth history and only relatively recently are the continents shown to be separating and rifting within what are now the Mediterranean and Red Seas. This is again at odds with conventional 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.

Antarctica

The continental development of both East and West Antarctica is speculative because of the masking effect of present-day ice coverage. This ice-sheet, as well as the ice-sheet covering Greenland, is part of the Geological 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 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 (Figure 3) 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.

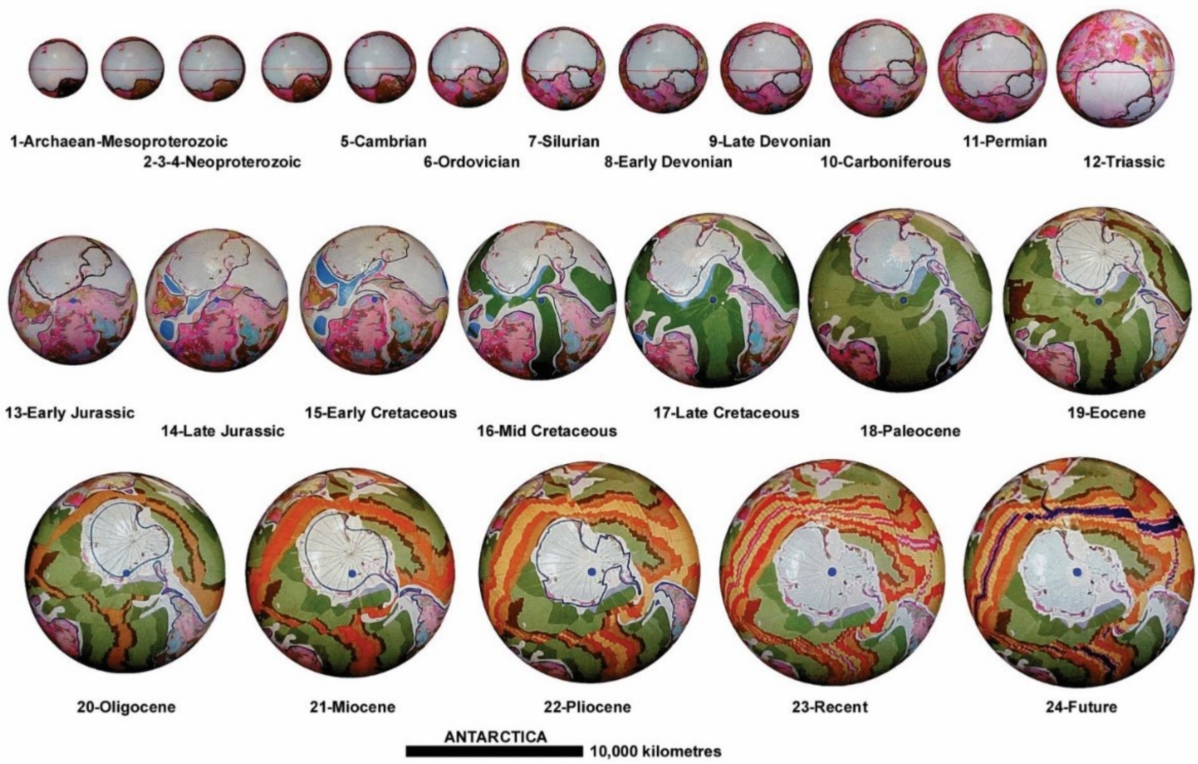

Figure 3 Continental crustal development of East and West Antarctica (shown as pale blue—the present-day south-polar ice shelf). During the Archaean to late-Palaeozoic Eras Antarctica straddled the ancient equator. The continent then rapidly migrated south, as the modern oceans opened, to its present 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).

Breakup of the former Gondwana 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 breakup, rifting, and separation of modern Antarctica from Australia and East Antarctica commenced during the Paleocene, some 65 million years ago.

On an increasing radius 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 breakup 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 by 33 million years ago.

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. The Oligocene to present-day small Earth models also show that Antarctica is currently not stationary over the South Pole, but is continuing to migrate slowly across the south-polar region. Seafloor mapping also shows that the surrounding Southern Ocean contains a single, continuous mid-ocean-rift zone. All of the surrounding continents are migrating north away from Antarctica as new seafloor crust continues to be intruded along this Southern Ocean mid-ocean-rift zone.

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 have 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 conventional Plate Tectonic studies a large Tethys Ocean is depicted as being located between 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 smaller 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 Period, becoming an isolated inland sea.

In contrast, on an increasing radius 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. 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 Archaean supercontinent. After fragmenting during the Precambrian, these Archaean crusts now form small remnants embedded within the much larger Tethys sedimentary basins.

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 over the ancient equator. East Antarctica was located along the eastern margin, 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 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 basin. 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.

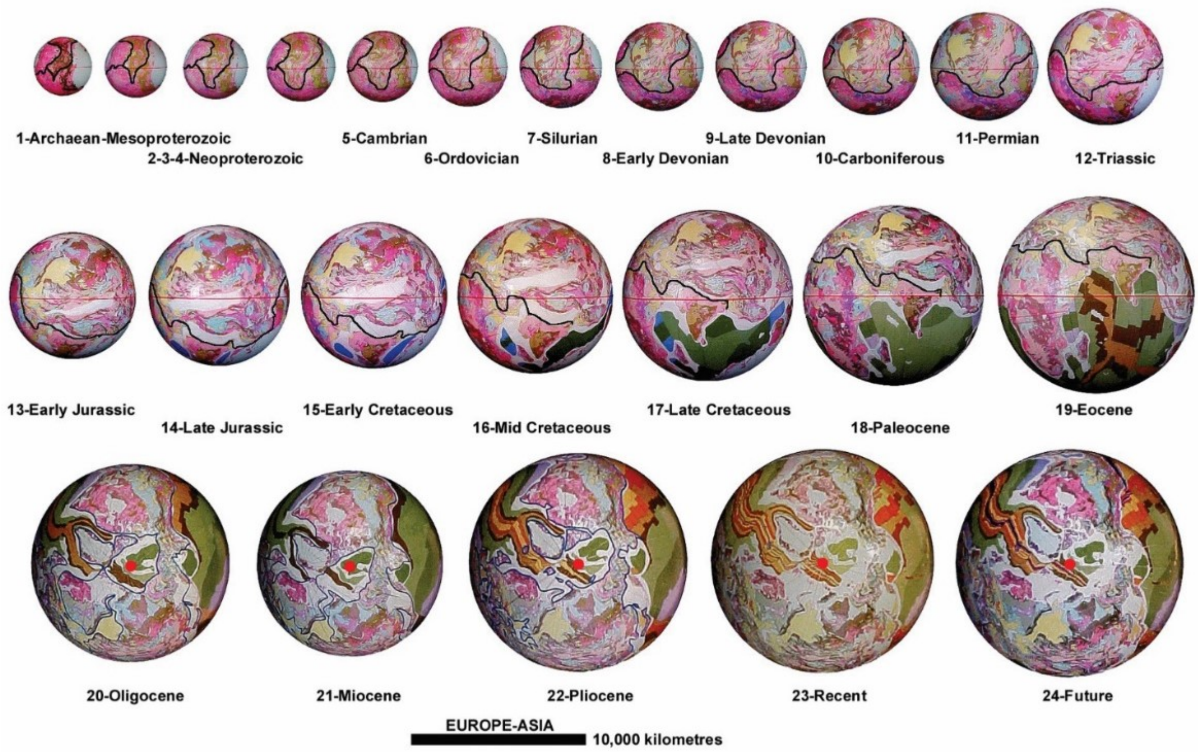

Figure 4 Continental crustal development of Europe and Asia. Models 20 to 24 are centred on the North Pole (shown as red dots). The horizontal red line represents the location of the ancient equator, blue lines represent the ancient coastlines, and the black line represents the outlines of the ancient European and Asian continent.

Breakup of the Pangaea supercontinental crust first began in the ancient Arctic, North Atlantic, and North Pacific Oceans during the late-Permian which then initiated breakup and separation of the combined European and Asian continent. During that time, as each of the surrounding modern continents began to rift 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 was then 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 many 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 Polar Region.

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 increasing radius continental crustal history differs markedly from conventional Plate Tectonic reconstructions. On an increasing radius 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 or to conform to seafloor bedrock mapping data.

India

The Indian continent is traditionally shown on conventional Plate Tectonic reconstructions to be an island continent migrating north during the Mesozoic Era, moving across a vast pre-existing Tethys Ocean until it collided with Asia during the Cenozoic. Collision with Asia is then said to have resulted in formation of the Himalaya Mountain belt.

In contrast, crustal development of the ancient Indian continent on an increasing radius Earth (Figure 5) during Precambrian times 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.

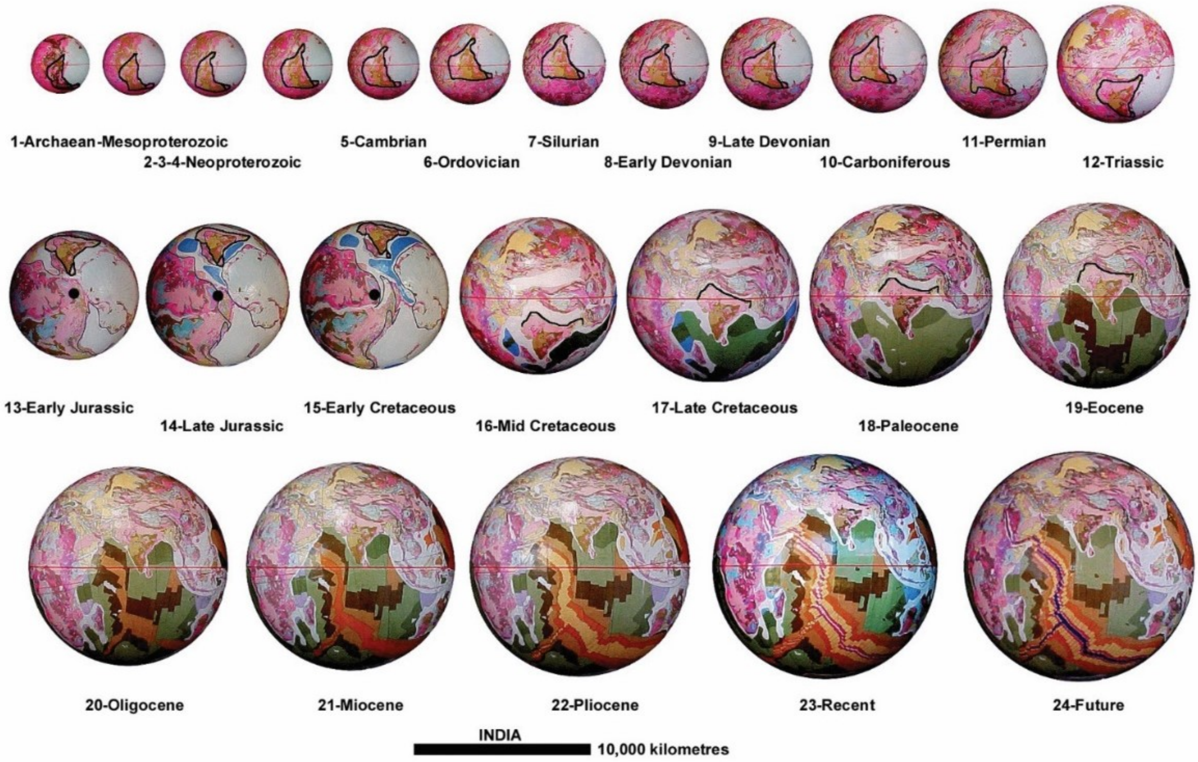

Figure 5 Continental crustal development of India. Each of the early-Jurassic to early-Cretaceous models (models 13 to 15) are centred over the South Pole (shown as black dots). The horizontal red line represents the location of the ancient equator, blue lines represent the ancient coastlines, and the 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 latter 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, as well as the newly opening Indian Ocean.

Crustal extension between the ancient north and south Indian crustal regions occurred during the Proterozoic Era 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 during the Jurassic with 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 to India.

In contrast to conventional Plate Tectonic reconstructions, on an increasing radius 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.

North America-Greenland-Scandinavia

The development of the North American continent on an increasing radius Earth (Figure 6) was intimately related to the ancient Archaean supercontinent crustal assemblage and its ultimate breakup 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 increasing radius small Earth models (Figure 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 are now Russia, China, Australia, and South America to the north, west, and southwest.

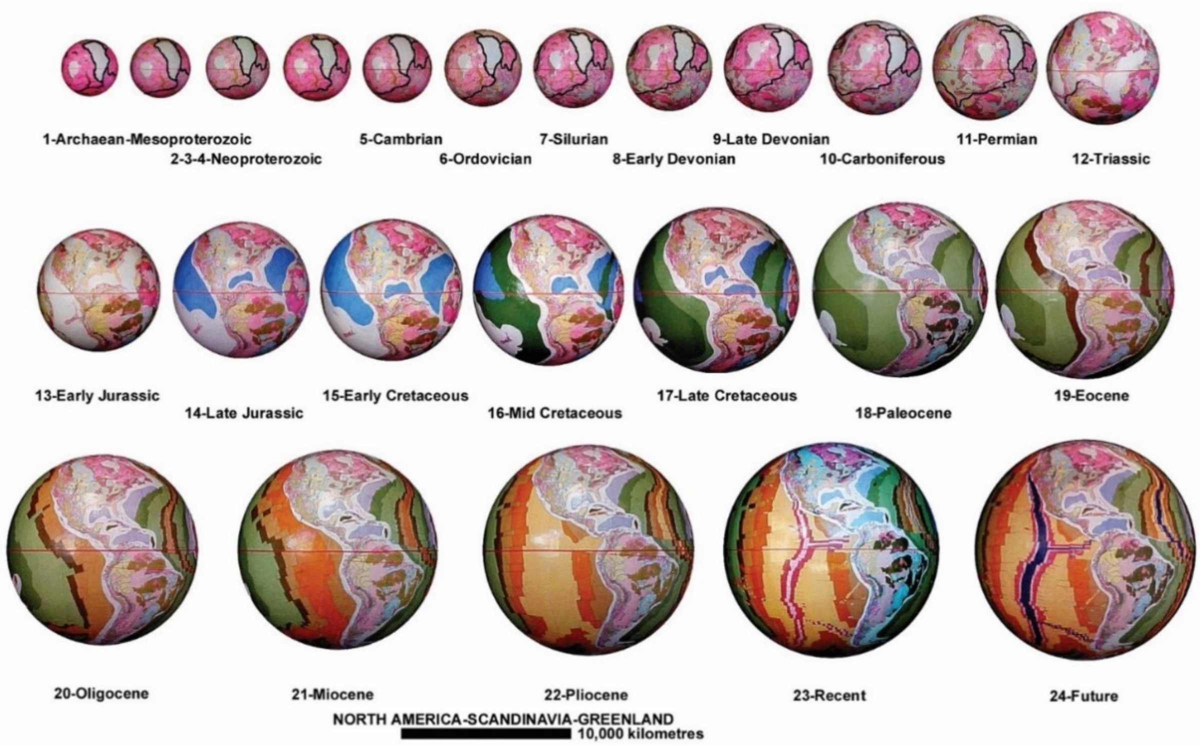

Figure 6 Continental crustal development of North America-Greenland-Scandinavia. The horizontal red line represents the location of the ancient equator and black lines represent the continental outlines.

This North American cluster remained intact throughout the Precambrian and Palaeozoic times until the Pangaea supercontinental breakup 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 resulted in long linear mountain belts located around the margins of the North American cluster, forming the precursors to the Cordilleran, Grenville, and Hercynide Mountain belts.

Breakup 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 breakup and opening of the modern oceans then effectively defined the modern North American continental outline. By the early-Jurassic, breakup 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 migration away from North America. Fragmentation of the Northern Canadian Islands also occurred during the Jurassic Period, which was intimately related to rifting between Canada and Greenland. Further rifting within the Northern Canadian region has continued to the present-day.

During breakup 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 slowly rotated clockwise as a result of crustal breakup 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.

1.1 South America

Development of the South American continent on an increasing radius Earth (Figure 7) is closely associated with the development of Africa. The South America to Africa assemblage has long been recognised in all Plate Tectonic reconstructions. Closing of the Atlantic Ocean and assemblage of the American and African plates also forms the basis of the Gondwana supercontinental assemblage, as well as the basis for both Continental Drift and conventional Plate Tectonic theory.

In increasing radius studies, the South American crusts originally formed part of an ancient Archaean 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.

Continental breakup 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 continued 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.

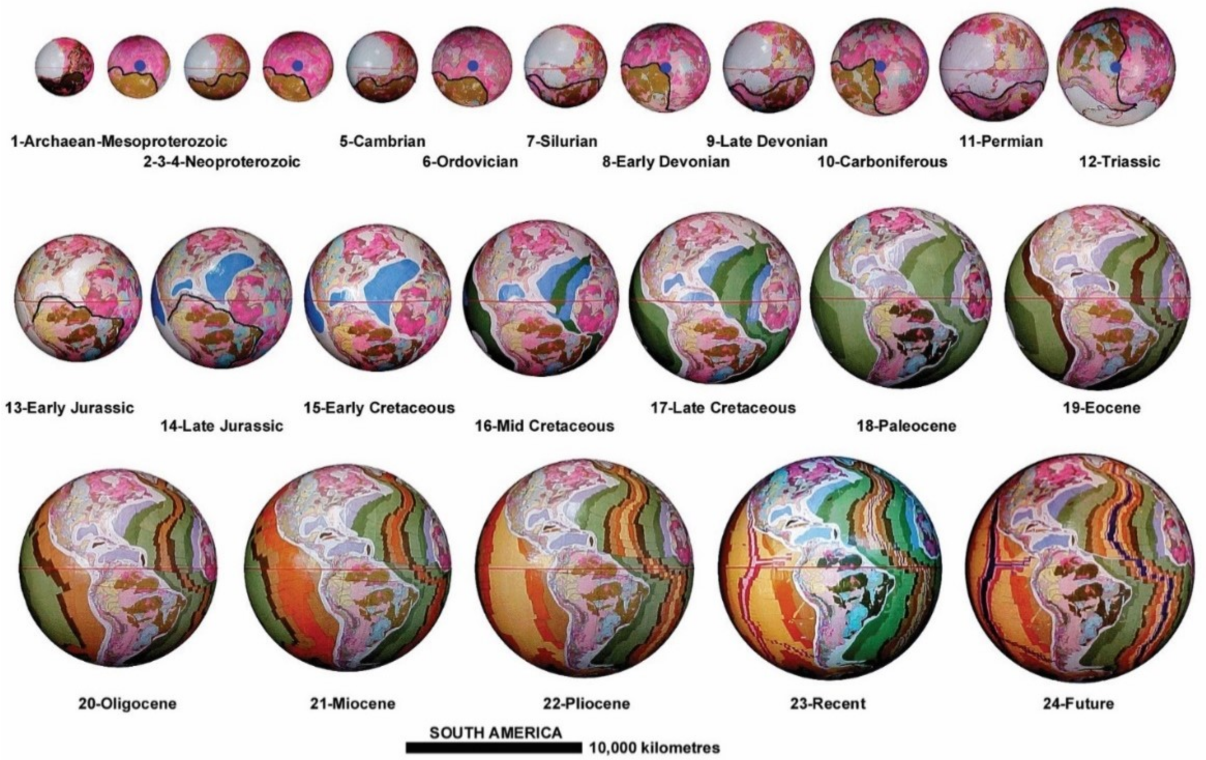

Figure 7 Continental crustal development of South America. The horizontal red line represents the location of the ancient equator, blue dots represent the South Pole, and black lines represent the South American continental outline.

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 conventional Plate Tectonic assemblages where 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. Closing of the Pacific plates by subduction against the Americas is not required on an increasing radius Earth.

The Future

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.

On increasing radius 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 increasing radius 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 increasing in size to become another giant gaseous planet.

Because the present Earth is essentially a wet planet when compared to the dry inner rocky planets of the Solar System, the giant planet scenario seems the most likely outcome. As the Earth's core-mantle continues to increase in size, it is envisaged that 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 increasing radius Earth at five million years into the future (Figure 8) is readily achieved 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. 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.

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 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 an increase in circumference of the Earth during increase in Earth radius. The mid-ocean-ridge lengthening process then represents an important mechanism for future crustal development during on-going increases in Earth radius.

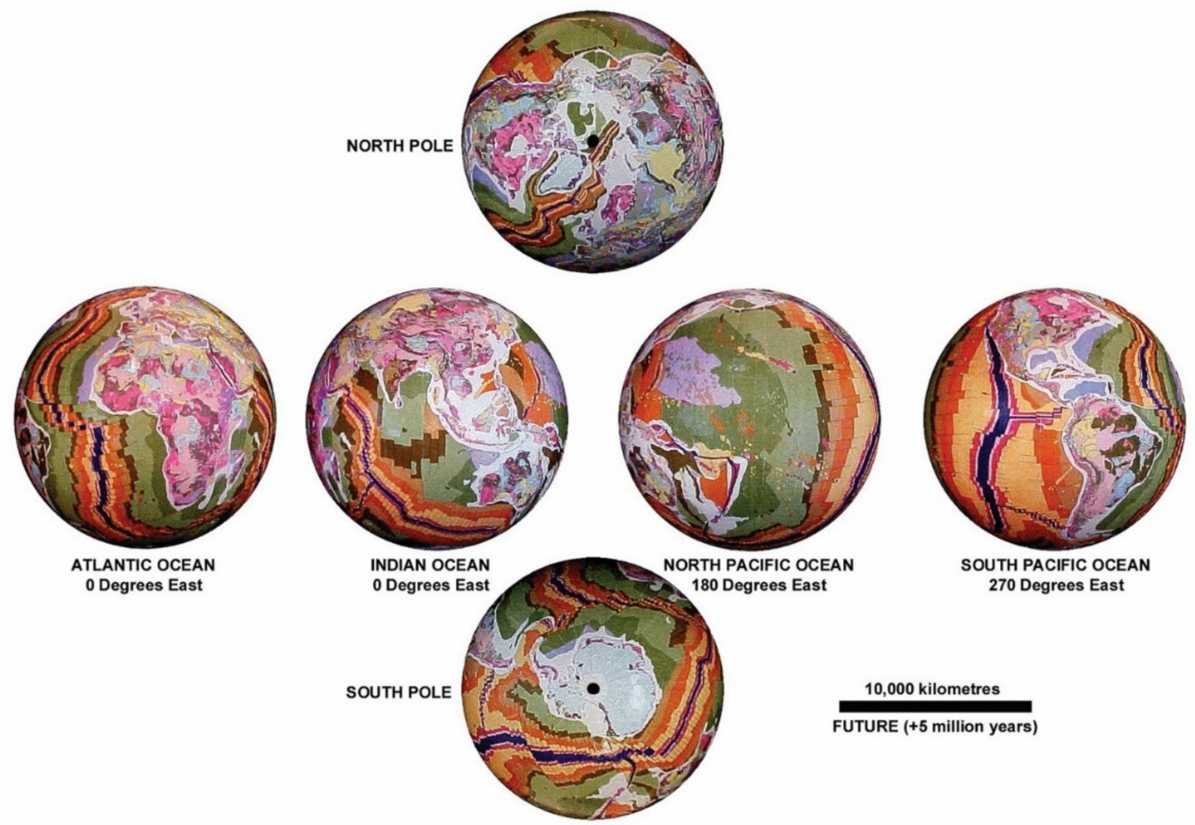

Figure 8 The increasing radius Earth projected to 5 million years into the future. The dark blue spreading ridge represents spreading along each of the mid-ocean-ridges for the next 5 million years. The model shows an extension of all mid-ocean-ridge spreading axes into seismically active areas such as Turkey, Japan, California, and New Zealand.

On an increasing radius Earth, as the mid-ocean-ridge spreading axes lengthen and the ridges open they can be visualised as being large propagating cracks in the seafloor—which is precisely what they are. As the cracks propagate and lengthen they 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 seismic and earthquake activity occurs as a result of tensional cracking and breaking apart of the crusts. This breakup is also accompanied by intrusion of volcanic lava, 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 increasing radius 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 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 conventional Plate Tectonic requirement for plate convergence, continental collision, and subduction of vast areas of oceanic crust. On an increasing radius Earth an increase in surface area accompanied by elongation of the mid-ocean-ridges is considered to better represent the breakup and separation of the continents and opening of the existing oceans when moving into the future. This mid-ocean-ridge opening process, as projected well into the future, also continues to comply with the established seafloor bedrock geological mapping as portrayed in the Geological Map of the World (CGMW & UNESCO, 1990).