Paper 6: Extinction Events

"A eustatic drop in sea level of 100 to 150 metres is a major physical consideration for the Maastrichtian [end-Cretaceous]. *At the very least, this event caused a major loss of stratigraphic resolution of extinction events; likely, it was a contributor to extinctions both in the sea and on land."* Dodson & Tatarinov, 1990

Published literature suggests that over 98 percent of all recorded species of life forms are now extinct. Based on the fossil record, the background rate of extinctions on Earth has also been estimated by others to be about two to five families of marine invertebrates and vertebrates every million years. This background rate of extinction represents the natural rate of dying out of species as they either evolve to replace pre-existing species or new species emerge to take their place. Since life began on Earth, several major mass extinction events have significantly exceeded this background extinction rate. In the past 540 million years there have been five major events, where over 50 percent of animal species existing at the time have died out.

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

End-Ordovician Extinction Event

An end-Ordovician extinction event occurred over a period of 10 million years at the Ordovician to Silurian transition, extending from 450 to 440 million years ago. Small Earth modelling shows that during the early-Palaeozoic times there was a single, on-going and well-established network of interconnected continental seas which collectively defined each of the surrounding supercontinents. Modelling demonstrates that, while the overall configuration of this ancient continental sea remained the same, there was a reduction in overall surface area between the Ordovician and Silurian small Earth models (Figure 1). This reduction in surface area gave rise to separation of the original network into at least two discrete seas which severely disrupted established coastal communities.

Extinction during the end-Ordovician, in particular over the 10 million year time-frame involved, is considered to have occurred as a result of increasing changes to surface curvature and elevation of the lands during initiation of Palaeozoic geosynclinal and orogenic activity. This activity deepened the seas and progressively drained waters from the shallow coastal shelf areas. These changes then disrupted the configuration of previously existing coastlines and the overall distribution of continental seas. Crustal changes in one area during changing surface curvature globally affected coastlines elsewhere by changing the overall sea-levels. This change in sea-levels then disrupted favoured continental shelf habitats as well as established migration routes.

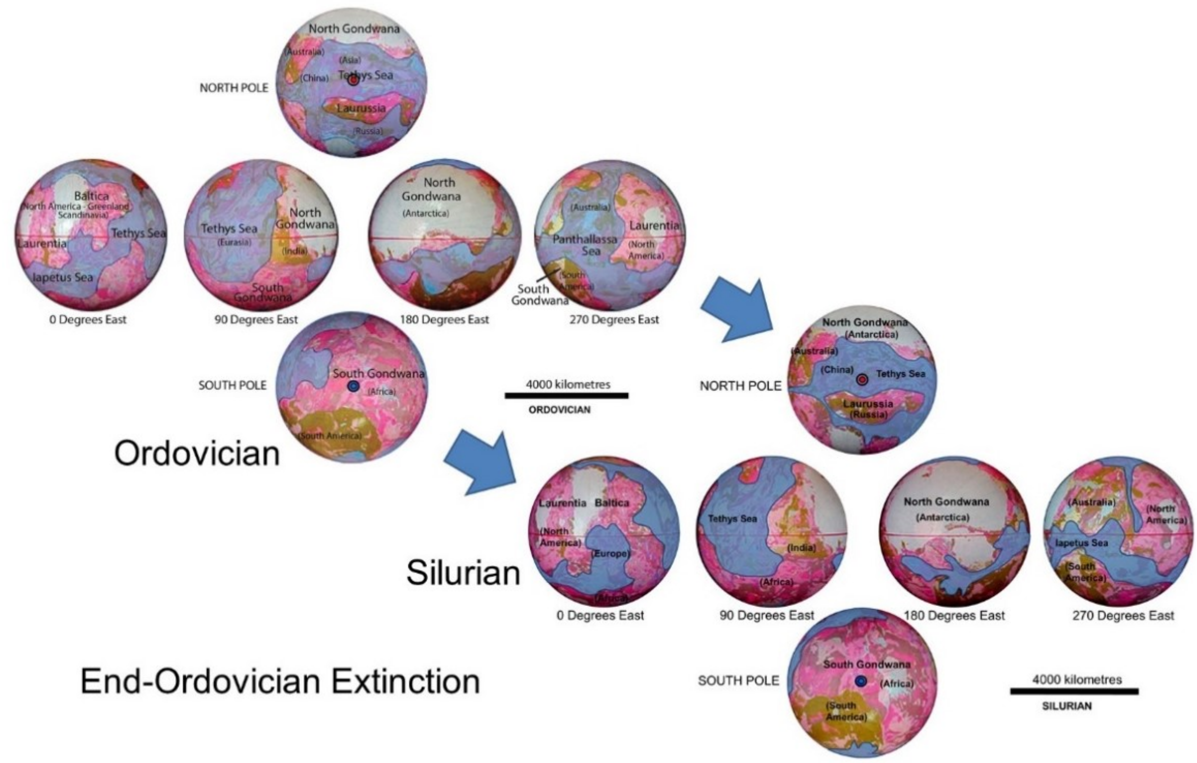

Figure 1 Ordovician and Silurian small Earth assemblages showing the distribution of ancient coastlines and seas (coastlines after Scotese, 1994, and Smith *et al.*, 1994) during the end-Ordovician extinction event. The ancient Tethys, Iapetus, and Panthalassa Seas form part of a global network of continental seas surrounding each of the exposed supercontinents.

Late-Devonian Extinction Event

A late-Devonian extinction event is known to have occurred over a period of 15 million years at the Devonian to Carboniferous transition, extending from 375 to 360 million years ago. On small Earth models (Figure 2) the timing of the late-Devonian extinction event places it within the latter part of the Gondwana supercontinental configuration. During that time the previously well-established network of interconnected continental seas was being subjected to ever-increasing adjustments to Earth surface curvature, geosynclinal activity, and orogenesis. During the Devonian times the ancient continental seas continued to further separate into a number of deep isolated seas. The geosynclinal and orogenic activity also provides substance for the series of extinction pulses occurring during this event, as noted by others.

On an increasing radius Earth it is considered that the late-Devonian extinction event primarily occurred during these Gondwanan times as a result of increasing changes to surface curvature, severe disruption to the configuration of the coastlines, and isolation of continental seas into a number of relatively deep and restricted seaways. This isolation again severely disrupted favoured continental shelf habitats and established terrestrial and marine migration routes. All of these changes then adversely affected species development and migration, promoting separate adaptive radiation of species within each of the isolated regions.

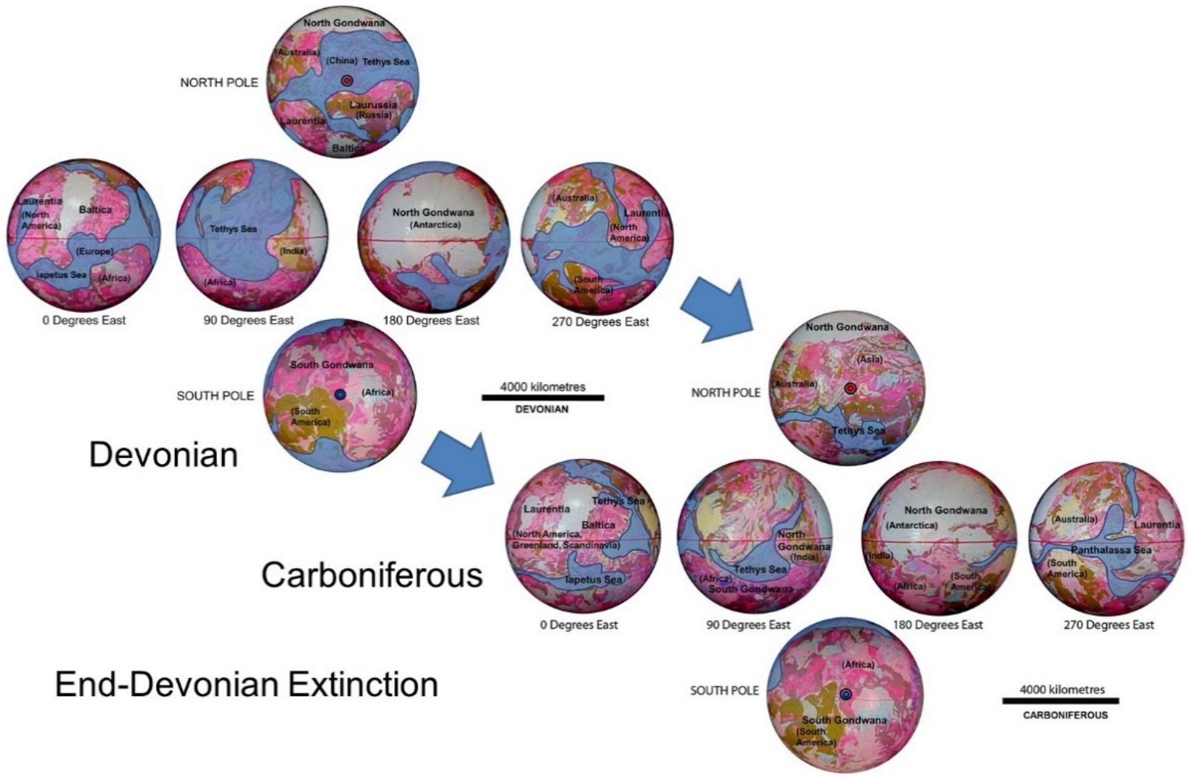

Figure 2 Devonian and Carboniferous small Earth assemblages showing the distribution of ancient coastlines and seas (coastlines after Scotese, 1994, and Smith *et al.*, 1994) during the end-Devonian extinction event. The ancient Tethys, Iapetus, and Panthalassa Seas form part of a disrupted global network of continental seaways surrounding each of the exposed supercontinents.

End-Permian Extinction Event

An end-Permian extinction event occurred around 250 million years ago at the Permian to Triassic transition. This event is considered by most researchers to have been the largest of the five major extinctions in Earth's history. Uncertainty exists in the literature regarding the overall duration of the end-Permian extinction event. Recent research shows that different groups of species became extinct at different times. An older theory, still supported in the literature, shows that there were two to three major extinction pulses 5 million years apart separated by periods of extinctions well above the background level. Research indicates that the long recovery time for this extinction event was due to successive waves of extinction as well as prolonged environmental stress to organisms, which inhibited recovery well into the following early-Triassic Period.

On an increasing radius Earth, the supercontinental crusts were previously shown to encompass the entire Earth as a single Pangaean supercontinent up to the late-Permian. During this extended period of time there were no modern oceans, only a network of continental seas covering low-lying parts of the supercontinental crusts. The transition from ancient seas to modern oceans came about when the ancient Pangaea supercontinental crust first started to rupture and breakup some 250 million years ago. The end-Permian extinction event is therefore significant as it coincides with breakup of the Pangaean supercontinent to form the modern continents and opening of the intervening modern oceans (Figure 3).

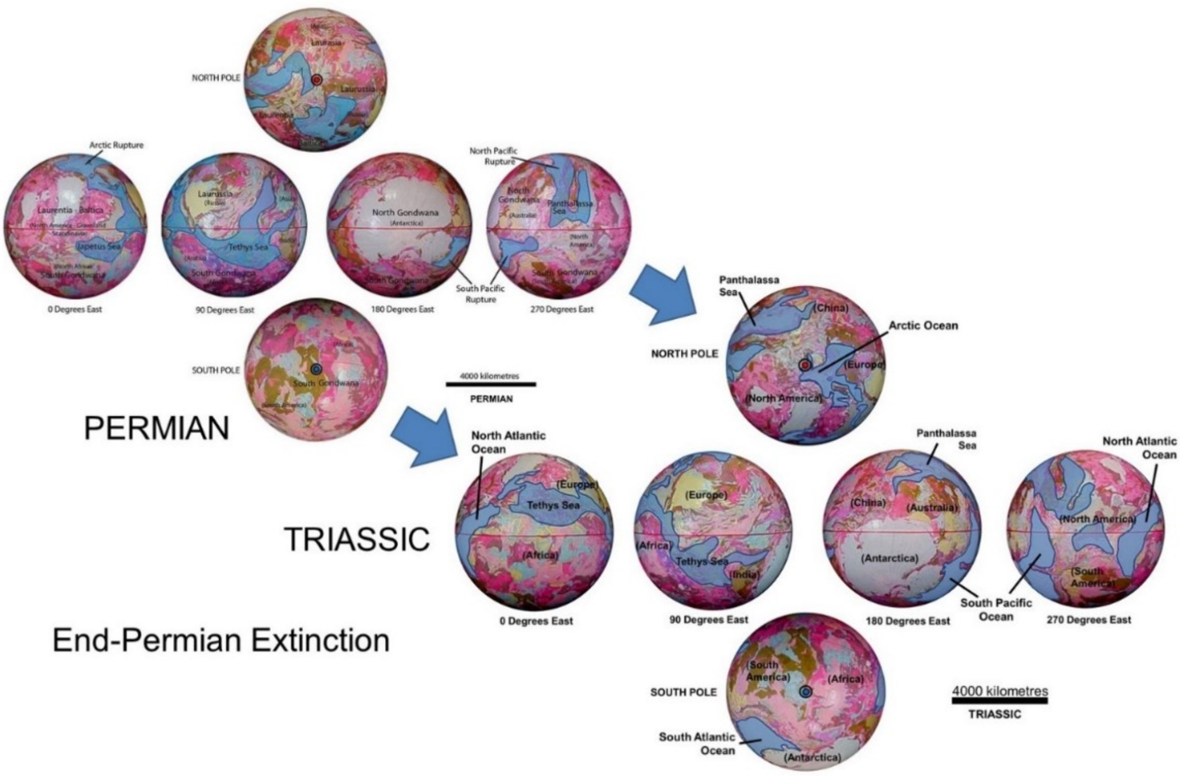

Figure 3 Permian and Triassic small Earth crustal assemblages showing the ancient coastline distribution as well as remnants of the ancient Pangaea supercontinent (coastlines after Scotese, 1994, and Smith *et al.*, 1994) during the end-Permian extinction event. The figure also shows the locations of Permian continental rupture commencing in the north and south Pacific and Arctic Ocean regions to form the modern oceans.

End-Triassic Extinction Event

An end-Triassic extinction event occurred some 200 million years ago at the Triassic to Jurassic transition. On an increasing radius Earth, by the end of the Triassic Period breakup of the Pangaean supercontinent and opening of the modern oceans was well established (Figure 4). Draining of the ancient continental seas into the modern ocean basins was also well advanced, with only remnant seas remaining within the Mediterranean to Middle Eastern Tethys Sea regions. As well as these remnant seas small Earth modelling shows that a number of modern oceans also remained isolated.

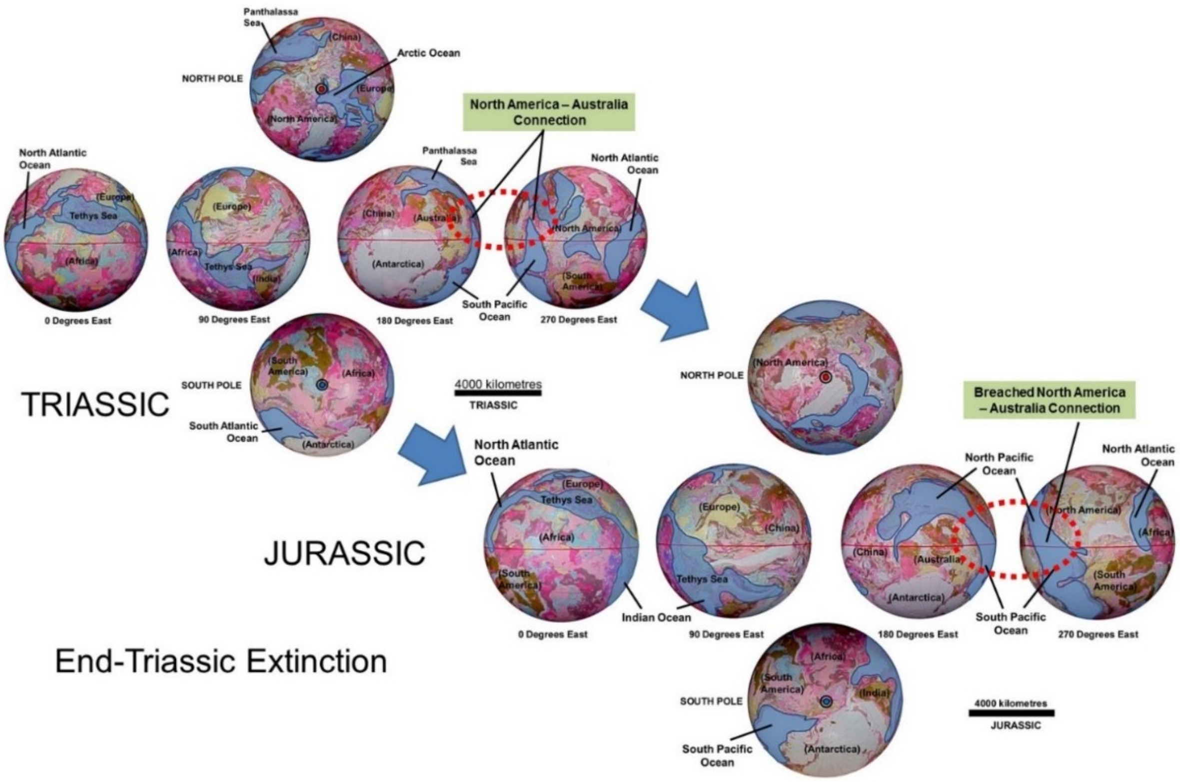

Figure 4 Triassic and Jurassic small Earth crustal assemblages showing the ancient coastline distribution as well as breakup of the ancient supercontinents to form the modern continents and oceans (coastlines after Scotese, 1994, and Smith *et al.*, 1994) during the end-Triassic extinction event. The figure highlights the location of continental breaching in the north and south Pacific to form the modern Pacific Ocean.

It is significant to note that the end-Triassic represents the period of time when previously separate North and South Pacific Oceans merged to form a single modern Pacific Ocean. This is highlighted in Figure 4 by comparing the Triassic and Jurassic small Earth models where a land connection between North America and Australia is shown to have been breached. Breaching and merging of these two separate oceans then resulted in drastic changes to global sea-levels, in particular the Western Interior Seaway, as the previously separate sea-levels equilibrated, disrupting the various habitats and established species migration routes. Merging of these oceans also allowed previously separate marine and terrestrial species to migrate and colonise new habitats, potentially displacing or eliminating less adaptive species.

End-Cretaceous Extinction Event

The end-Cretaceous extinction event—commonly referred to as the K-T event—is the most publicised and well known of all the extinction events, occurring around 65.5 million years ago at the Cretaceous to Paleogene transition. It is currently hypothesized that the end-Cretaceous extinction event was caused by one or more catastrophic events, including either an asteroid impact or an increase in terrestrial volcanic activity. Other researchers though consider the extinction event was more gradual, resulting instead from sea-level and climate changes already occurring during the late-Cretaceous, which may or may not have been aggravated by impact events or increased volcanic activity. Based on fossil evidence, the end-Cretaceous dinosaur extinction was considered by Dodson and Tatarinov in 1990 to have been a highly selective world-wide phenomenon, which lasted for approximately 8 million years.

On increasing radius small Earth models the end-Cretaceous extinction event coincides with breaching and opening of the Southern Ocean, located between Australia and Antarctica (Figure 5). During the late-Cretaceous the Australia to Antarctica assemblage had exposed land connections adjacent to Western and Eastern Australia with an isolated shallow sea located adjacent to Southern

Australia. These land connections were then partly breached along the Western Australian coastline, causing flooding of the Eucla Basin, prior to complete breaching and opening of the Southern Ocean during Paleocene to Eocene times—around 65 million years ago.

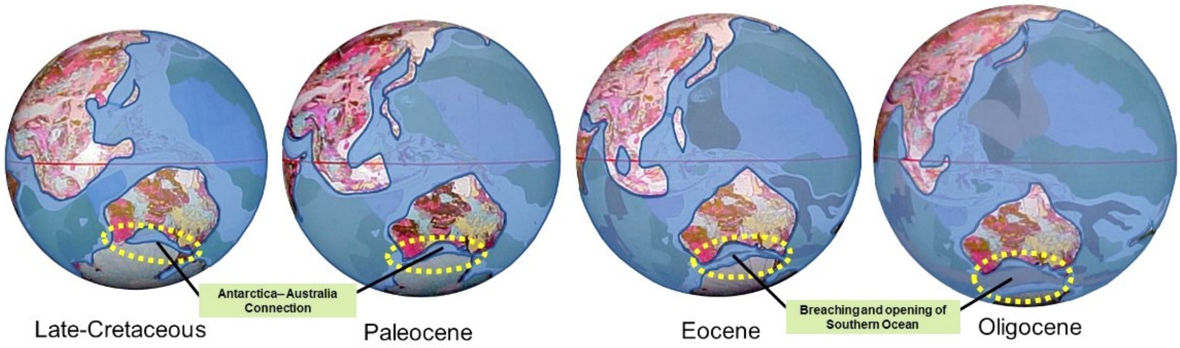

Figure 5 Late Cretaceous to Oligocene small Earth models showing land connections between Australia and Antarctica, prior to breaching during the Paleocene to form the Southern Ocean (coastlines after Scotese, 1994, and Smith *et al.*, 1994).

The significance of this breaching event is highlighted in Figure 6 showing the continued decline in surficial area of the Western Interior Seaway of North America during the late-Cretaceous and Palaeocene times. The Western Interior Seaway is an important area for dinosaur study and has provided a large amount of data for interpretation of the end-Cretaceous extinction event. It is significant to note that the considerable regression of the Western Interior Seaway into the Gulf of Mexico coincides with the extended duration of the end-Cretaceous extinction event, as noted by Dodson and Tatarinov.

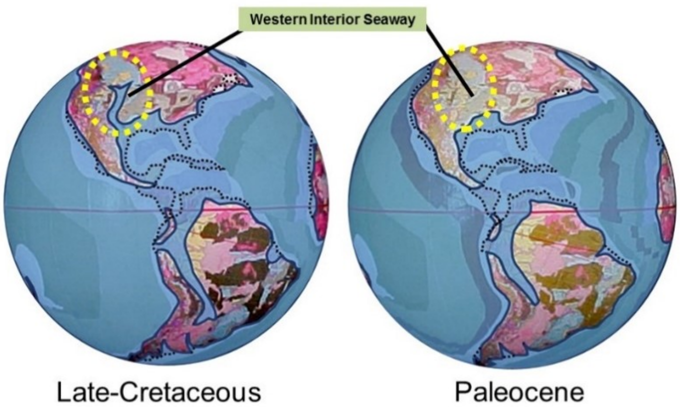

Figure 6 Late Cretaceous and Palaeocene small Earth models showing regression of seas within the Western Interior Seaway of North America (coastlines after Scotese, 1994, and Smith *et al.*, 1994).

On an increasing radius Earth it is considered that breaching between Australia and Antarctica during initiation and opening of the Southern Ocean resulted in a period of disruptive sea-level change. This continental breaching and sea-level change coincided precisely with the end-Cretaceous extinction event. These observations support the conclusions of others where the extinction event was more gradual, resulting from drastic sea-level changes already occurring during the late-Cretaceous, extending over a period of approximately 8 million years.