A Quick Look at the Jurassic World

David Lillis – 16 July 2020
e-mail: sigma@outlook.co.nz

The Extent of the Jurassic
The Jurassic Period spanned approximately 54.1 million years, beginning about 199.6 million years ago and ending about 145.5 million years ago. It followed straight after the Triassic Period, beginning with the Triassic–Jurassic extinction event. During this event, some 20% – 35% of Triassic marine genera vanished, while most terrestrial reptiles (except crocodilians, pterosaurs and dinosaurs) also became extinct. These extinctions opened new opportunities for diversification and radiation of new species during the Jurassic.

The Jurassic comprises three epochs, as follows: the Early Jurassic (about 199.6 million to about 174.1 million years ago), the Middle Jurassic (about 174.1 million to about 163.5 million years ago), and the Late Jurassic (about 163.5 million to about 145 million years ago).

The Jurassic lies within the Mesozoic Era - the age of dinosaurs. The Mesozoic encompassed the Triassic, Jurassic and Cretaceous periods, and lasted for almost 180 million years. In turn, the Mesozoic era lies within the Phanerozoic eon, the expanse of time since the beginning of the Cambrian Period to now (about 541 million years in total) and that is characterised by life on Earth. This eon comprises the Palaeozoic, Mesozoic and Cenozoic eras. The Jurassic was followed by the Cretaceous Period, lasting to approximately 66 million years ago.

The Jurassic Ages
The Jurassic is divided into eleven ages that are used internationally to date Jurassic rocks. Each age is characterised by the presence of particular species of bivalves, ammonites or other fossils. These ages average about 4.92 million years in duration, and each is characterised by its own geologic, climatic and evolutionary changes. Figure 1 gives the time frames of the eleven Jurassic ages.

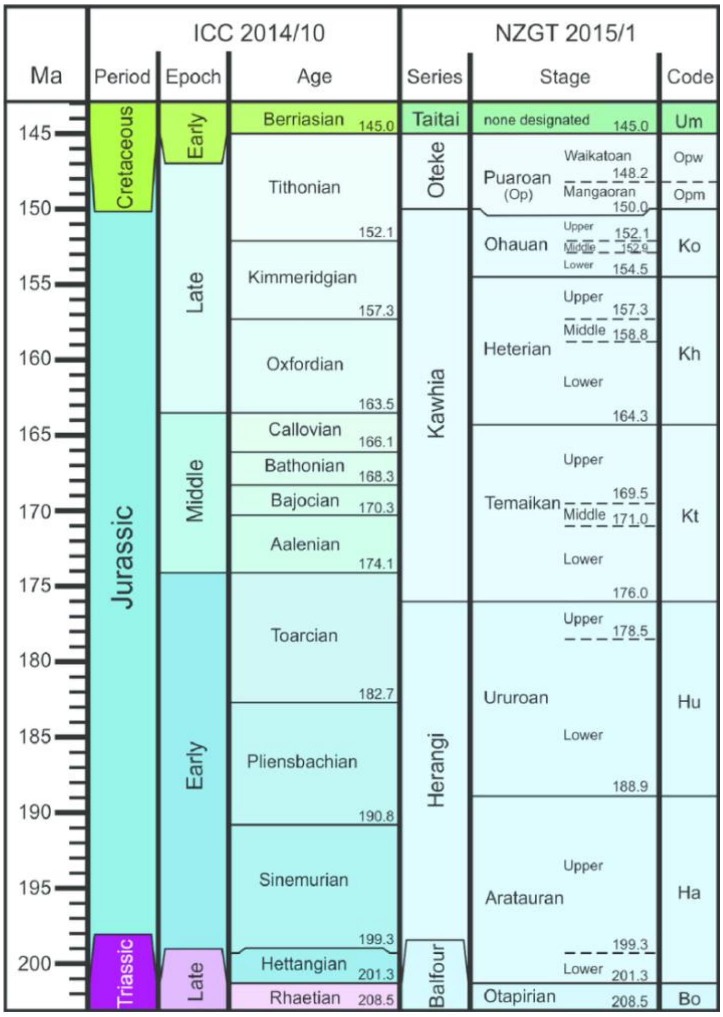

Figure 1: The Jurassic and its eleven ages

The Toarcian age had the greatest duration, at about 8.6 million years; while the shortest age was the Bajocian, at about two million years. In addition to the eleven Jurassic ages, the New Zealand geological record is subdivided into six stages, each based on the presence of particular fossils around New Zealand.

The Cretaceous is the only Phanerozoic system that has not yet been ascribed a global boundary definition. Issues in assigning a global Jurassic-Cretaceous boundary include the absence of major faunal changes between the Late Jurassic and Early Cretaceous, and disagreement on stratigraphic markers that might provide global correlation levels.

One marker for the base of the Bajocian is the earliest occurrence of the ammonite *Hyperlioceras*. Figure 2 shows a fossil *Hyperlioceras* from Bradford Abbas, Dorset (England), dated at early Bajocian, about 170.3 million years ago.

Figure 2: A *Hyperlioceras* fossil, about 170.3 million years old

Hyperlioceras was a fast-moving marine carnivorous ammonite for which we have fossils dating from about 171.6 million years to about 168.4 million years ago.

Jurassic Land and Sea
Figure 3 shows the configuration of Earth's land and oceans in the Late Jurassic (152 million years ago).

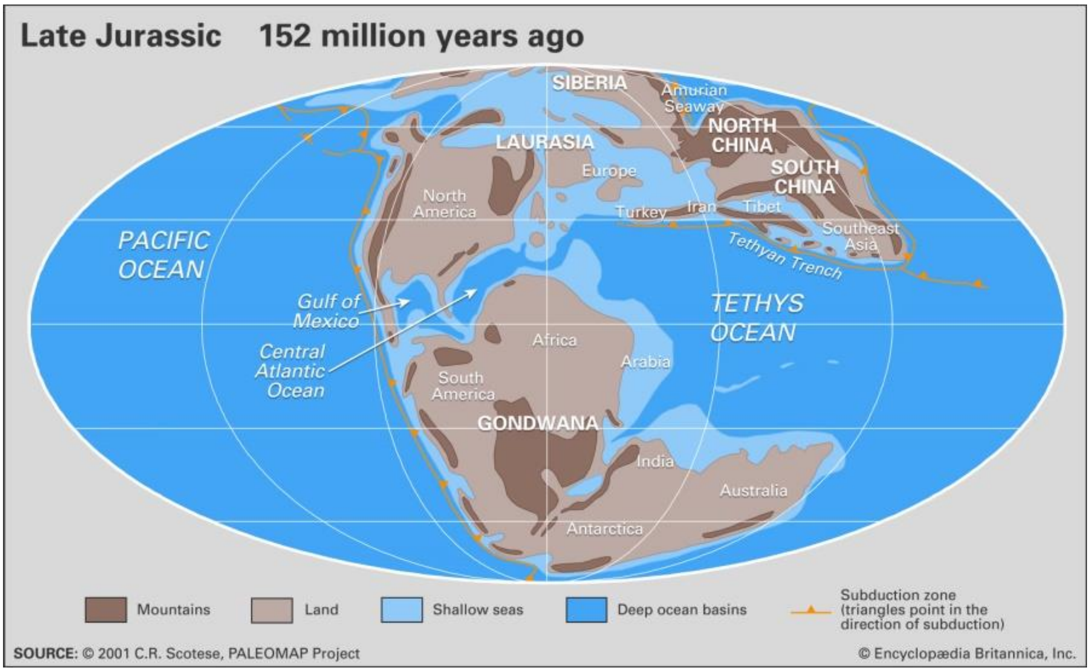

Figure 3: The configuration of Earth's land and oceans in the Late Jurassic

We see that Africa, South America and Antarctica were very close, closer than they were in the Cretaceous and much closer than they are today. Europe and North America were very close too.

During the Jurassic Period the continent Pangea broke up, eventually giving rise to the central Atlantic Ocean and the Gulf of Mexico, Antarctica, Madagascar, India and Australia, and eventually Africa and South America. The Jurassic was a time of considerable plate tectonic movement, volcanic activity and creation of mountain ranges. Shallow seas covered the continents and, today, Jurassic rocks yield oil, gold, coal and other natural resources. In fact, Late Jurassic shales (about 163.5 million to about 145 million years ago) provide almost half of the world's oil and gas source rocks.

Jurassic Sea Levels

The biostratigraphic record, including data on ammonites and microfossils, suggests a general rise in sea level throughout the Jurassic, beginning with a mean sea level similar to or below that of the present-day. The sea level rose to a high between about 153 million and about 151 million years ago, and stabilized in the Early Cretaceous to approximately 110 metres above the present day mean sea level. Our understanding of oceanic crustal production rates for the Jurassic (variations in the mean age of the oceanic lithosphere, variations in production rates at mid-ocean ridges, duration of seamounts, and large igneous beds on the seafloor) is more limited than that of the Cretaceous because much of the Jurassic seafloor has been subducted and destroyed.

Earth's Magnetism

Jurassic geomagnetism is usually investigated through marine magnetic anomalies. These anomalies show that reversals of the Earth's magnetic field were common, except during the Jurassic Quiet Zone, which occurred before about 157 million years ago. The Jurassic was characterised by apparently weak magnetism and indistinct reversals. Younger seafloor (about 155 million - 160 million years old) suggests that the Earth's magnetic field was relatively weak, experiencing rapidly changing polarization during the Jurassic Quiet Zone. Possibly, a weak signature could result from poor quality records of the geomagnetic signature in very old rocks but the Jurassic Quiet Zone could also have been a time in which the geomagnetic field was unstable and possibly not dipolar. However, the apparent dearth of polarity reversals in the Jurassic may in fact be due to the great age of the rocks and the extensive tectonic activity that they have experienced since their creation within mid-ocean ridges.

Jurassic Seasons and Climate

During the Jurassic the continents drifted farther from each other. Additional land and new coastlines were formed, the oceans widened and sea levels rose. Higher sea levels resulted in increased humidity and the Jurassic climate was warmer, wetter and more humid than in the preceding Triassic Period. Though not as warm as the succeeding Cretaceous, much of the Earth's land was covered in vegetation similar to that of a modern rainforest, enhancing carbon dioxide emissions and further warming the atmosphere.

Oxygen isotope analyses of marine fossils show that the Jurassic was generally warm and we have no evidence of glaciation or polar ice caps. Mean global temperatures were at their lowest in the Middle Jurassic and it was warmest during the Late Jurassic. The Jurassic-Cretaceous boundary was characterised by a reduction in temperature, though later the Cretaceous became even warmer. High levels of volcanic activity and seafloor-spreading led to the emission of additional carbon dioxide and therefore to high temperatures. Ocean currents were probably weaker than those of today because of the warm temperatures, low ocean density gradients and weaker winds.

Fossils of plants that tend to thrive in relatively warm environments are found up to 60° N and 60° S palaeo-latitude (i.e. latitudes of the Jurassic), indicating a larger tropical zone than exists today. Beyond these palaeo-latitudes (i.e. further north and further south), various frost-sensitive plants (e.g. ferns) suggest a smaller temperature difference between the Equator and the poles than today. Despite a smaller temperature gradient, there was a marked difference in marine invertebrate populations from northern higher latitudes and the tropical environment of the Tethys Ocean. Decreased latitudinal temperature gradients probably led to weaker winds and therefore weaker oceanic currents than we have today.

Jurassic Carbon Cycles and Climate Change

The climate of the Late Jurassic was characterized by high atmospheric carbon dioxide concentrations and monsoonal rainfall patterns. A comparison of the Late Jurassic carbonate carbon isotope curve with organic-rich sediments suggests that not only fluctuations in organic carbon burial, but also in carbonate carbon burial, had an impact on the C-isotope record. A Late Jurassic event (the Oxfordian C-isotope excursion) appears to correspond to a time of enhanced organic carbon burial, triggered by high nutrient transfer from continents to oceans during a phase of rising sea level.

Jurassic Land Animals

Both continental drift and warm climates led to the diversification and radiation of many creatures, especially dinosaurs. In addition, a greater diversity of plant species than before provided food for many genera of dinosaur. Such dinosaurs include carnivorous theropods (some of them related to modern birds), armoured herbivores, including ankylosaurs, stegosaurs and large herbivorous sauropods such as the brachiosaurs. Many giant sauropods lived during the late Jurassic period. The first known mammals had appeared in the Late Triassic and, during the Jurassic, mammals (usually smaller than a rat) were diversifying.

Figure 4 shows an Early Jurassic fossil lacewing, *Oregramma illecebrosa*.

Figure 4: A Jurassic fossil lacewing, *Oregramma illecebrosa,* and a modern owl butterfly

The fossil *Oregramma illecebrosa* is shown on the left and the modern owl butterfly, *Calico memnon,* is shown on the right for comparison. This lacewing existed during the Jurassic, probably sipping nectar and pollinating plants. It could have looked and behaved similarly to a modern butterfly, but in fact existed 40 million - 85 million years before the earliest butterflies appeared. The two insects have large wings, each with a spot that looks like an eye. *Oregramma illecebrosa* may have pollinated distant relatives of modern pine trees and cycads, while feeding on nectar. Though the two insects look similar, the lacewings are more closely related to insects such as snakeflies and mayflies.

Figure 5 shows a fossil dragonfly, *Stenophlebia*, from the Late Jurassic, Tithonian age.

Figure 5: A Jurassic fossil dragonfly, *Stenophlebia*

This dragonfly was found at the Solnhofen Formation located in Bavaria, Germany, and is dated to between 152 and 145 million years ago.

Figure 6 shows a Jurassic spider *Nephila jurassica,* dated at more than 130 million years ago.

Figure 6: A spider, *Nephila jurassica*, from at least 130 million years ago

Found at Daohugou, China, this male spider is considered to be intermediate between primitive types of true spider and today's orbweaver spiders. It is the largest known fossil spider.

Powered flight is believed to have evolved independently in vertebrates, especially among the pterosaurs, birds and bats. These forms display different configurations of the bony elements and epidermal structures that form the wings. Figure 7 shows a Jurassic bird, *Aurornis xui*; from about 150 million to 160 million years ago from China.

Figure 7: A Jurassic bird, *Aurornis xui*

Aurornis xui is the oldest bird known to science. It lived about 150 – 160 million years ago, was approximately 50 centimetres in length and probably was able to run very quickly. Its small teeth suggest that it may have hunted and consumed insects. Found in sedimentary rock, this fossil displays traces of feathers along the tail, neck and chest. However, it has no large feathers, so that it may not have been able to fly.

Figure 8 shows a Jurassic feathered dinosaur, *Ambopteryx longibrachium*, from about 163 million years ago from north-eastern China.

Figure 8: A Jurassic feathered dinosaur, *Ambopteryx longibrachium*

We see an artist's rendition of its probable appearance when alive and the two dark images in the middle of Figure 8 show microstructure of the wing membrane. *Ambopteryx longibrachium* was a feathered dinosaur (about 32 cm long and about 300 grams in body mass), and had bat-like feathered wings. *Ambopteryx longibrachium* is only the second feathered dinosaur known with membranes on its wings. It flew with wings made of skin, supported by a long, pointed wrist bone. With wings resembling those of pterosaurs (flying reptiles) and modern bats, its mode of flight was very different from that of birds. Researchers believe that it was capable of gliding but are unsure of whether it was capable of powered flight. Probably it was omnivorous and lived in forests.

Jurassic Fish and Marine Reptiles

Figure 9 shows a ray-finned fish, *Gyrodus hexagonus*, from the Late Jurassic of Solnhofen, Bavaria, Germany.

Figure 9: A Jurassic fish, *Gyrodus hexagonus*

Gyrodus was a genus of ray-finned fish that lived from the Late Triassic (about 227 million – 201 million years ago) to the Mid-Cretaceous (about 94 to 100 million years ago).

Figure 10 shows a fossil shark, *Palaeocarcharias stromeri*, of the Middle Jurassic, about 150 million years ago, from the Solnhofen Plattenkalks of South Germany.

Figure 10: A mid-Jurassic shark, *Palaeocarcharias stromeri*

Palaeocarcharias stromeri did not resemble today's mackerel sharks (that include today's great white shark). *Palaeocarcharias* was a slow-moving bottom-dwelling shark, approximately one metre in length. Probably it lived in shallow waters. Its body shape is similar to that of today's carpet shark, but its teeth are similar to those of mackerel sharks. In particular, their tooth microstructure is similar in composition to that of modern great white sharks. Thus, *Palaeocarcharias* may have evolved much later into the Megalodon and the great white.

Jurassic seas were dominated by large reptilian predators such as the pliosaurs, plesiosaurs and ichthyosaurs. Figure 11 shows a fossil of *Dearcmhara*.

Figure 11: A fossil *Dearcmhara*

Dearcmhara swam in the seas around Scotland, and the specimen above swam around the Isle of Skye. It was a marine reptile, an ichthyosaur, and lived about 170 million years ago. *Dearcmhara* had a long, thin snout and this specimen measures 4.3 metres in length.

Figure 12 shows a fossil ichtyosaur from the Jurassic.

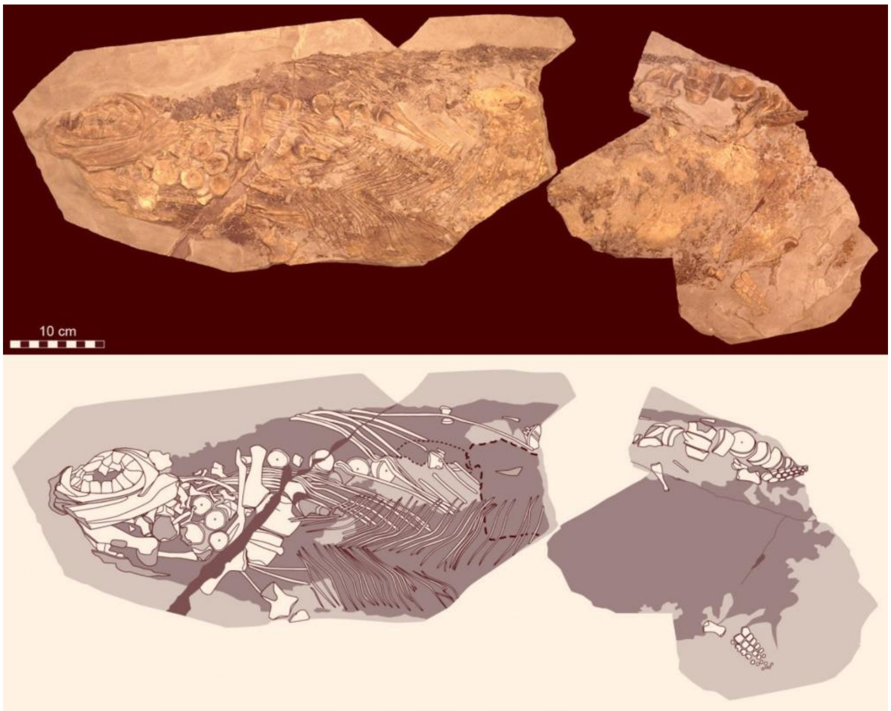

Figure 12: A fossil ichtyosaur

This *Stenopterygius* ichthyosaur dates from around 180 million years ago, in the Early Jurassic. Its soft-tissues still retain a degree of flexibility. Analysis of its molecular and microstructural morphology indicates that it was warm-blooded, had blubber (possibly for insulation) and may have used coloration as camouflage from predators. It lived in today's southern Germany. At that time, the two-metre reptile swam in a huge ocean that covered large parts of present-day Europe. Both the body outline and remnants of internal organs are clearly visible. It is so well-preserved that individual cellular layers within its skin are evident.

Figure 13 shows the teeth of a fossil pliosaur.

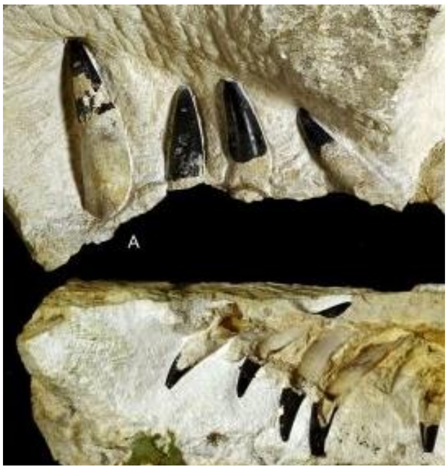

Figure 13: Fossil pliosaur teeth

Pliosaurs were the largest of the Jurassic seas' predatory reptiles. The animal that owned the teeth above lived between 145 million and 163 million years ago. This fossil was found in a cornfield in the Polish village of Krzyżanowice.

Figure 14 shows a fossilised turtle, found on a farm in southwest China's Chongqing municipality.

Figure 14: Fossil turtle from China

This specimen is a snake-necked turtle from about 150 million years ago.

Molluscs and Small Marine Life-forms

Figure 15 shows a fossil ammonite from the Late Jurassic of Sakaraha, Madagascar. It is between about 163.5 million and 157.0 million years old. In this particular fossil, sutures between shell sections remain visible.

Figure 15: A Jurassic fossil ammonite from Madagascar

Ammonites are extinct marine molluscs, related to today's squid, cuttlefish and octopuses. Ammonites are particularly common fossils of the Jurassic. They were predators that moved by jet-propulsion. A tube (called the siphuncle) filled the chambers of the shell with gas and water to control buoyancy. Ammonites sucked water through their mouths, pumped it over their gills, and squirted it out from a tube close to the tentacles. This squirting produced a jet action that moved the ammonite backwards though the water.

Though more closely related to the octopus, their shells resemble those of the nautilus. They first appeared in the fossil record about 240 million years ago and survived several extinction events. They disappeared about 66 million years ago, at the end of the Cretaceous.

Many ammonite species evolved over Mesozoic time, and their fossils are used to identify the relative age of rock formations (zone fossils). Most species evolved quickly but survived for only about 250,000 years before evolving further, making them highly reliable biomarkers for dating rocks.

Figure 16 shows a New Zealand fossil ammonite, *Aulacosphinctoides brownei.* The white bar represents one centimetre.

Figure 16: New Zealand Jurassic fossil ammonite, *Aulacosphinctoides brownei*

This specimen is very well preserved. It is from the Late Jurassic, about 148 million years old. It was found at Puti Point, Kawhia Harbour, in the North Island of New Zealand.

Figure 17 shows fossil *Aucklandirhynchia sexagesimae*, a brachiopod species first found in 1992. The white bar represents one centimetre.

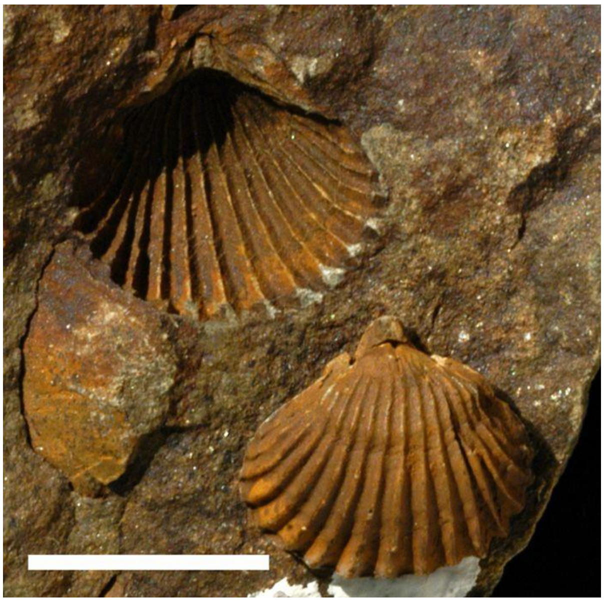

Figure 17: Fossil *Aucklandirhynchia sexagesimae* shells

Aucklandirhynchia sexagesimae appears in the known fossil record of New Zealand and New Caledonia in the early Jurassic, around 191 million years ago, and its last appearance was around 170 million years ago in the mid Jurassic.

Jurassic Plants

Conifers (including close relatives of living redwoods, cypresses, pines and yews) dominated the landscape, but neither flowering plants nor palms had yet evolved.

Figure 18 shows a Jurassic fern, *Cladophlebis*, from New Zealand. The white bar represents five centimetres.

Figure 18: A New Zealand Jurassic fern, *Cladophlebis*

Cladophlebis is thought to be the most common plant fossil of the Jurassic in New Zealand. It is found in nearly all plant sites of the Jurassic and has been characterized as the 'Mesozoic weed'. The *Cladophlebis* species of New Zealand Jurassic are also found in Patagonia and in Hope Bay, Antarctica.

Figure 19 shows a Jurassic fossil cycad, *Ptilophyllum acutifolium,* also from New Zealand. The white bar represents five centimetres.

Figure 19: A fossil cycad, *Ptilophyllum acutifolium*

Ptilophyllum is found in many parts of the world. They first appear in the known fossil record in the Late Triassic, around 237 million years ago and disappear from the known record in the Oligocene, around 28 million years ago. Thus, they lived over a vast expanse of time.

Figure 20 shows fossilised wood of Jurassic New Zealand. The white bar represents five centimetres.

Figure 20: Fossilised wood from a New Zealand Jurassic tree

Minor Extinction at the End of the Jurassic

A minor extinction took place toward the end of the Jurassic. Many of the stegosaurs and large sauropod dinosaurs vanished, as did many ammonites, marine reptiles and bivalves. The reasons for these extinctions are not well understood. However, many forms survived into the Cretaceous. For example, Ophthalmosaurid ichthyosaurs from the European Lower Cretaceous demonstrate ichthyosaur survival across the Jurassic – Cretaceous Boundary. Of course, mammals survived too and persisted through the next 80 million years of the Cretaceous, eventually giving rise to the age of mammals – the Cenozoic.

Acknowledgements

I wish to thank both Dr. Alan Beu and Marianna Terezow of GNS Science for their very helpful comments and for the photographs of the New Zealand fossils shown in this article.

References to Figures

Figure 1: retrieved from https://www.britannica.com/science/Jurassic-Period/Major-subdivisions-of-the-Jurassic-System

Figure 2: retrieved from http://www.thefossilforum.com/index.php?/gallery/image/45288-hyperlioceras-toxolioceras-politum-buckman-1902/

Figure 3: retrieved from https://www.britannica.com/science/Jurassic-Period

Figure 4: retrieved from https://www.smithsonianmag.com/smart-news/jurassic-era-insect-looks-just-modern-butterflies-180958040/

Figure 5: retrieved from: https://www.pinterest.cl/pin/386042999282021872/

Figure 6: retrieved from https://earthsky.org/earth/this-is-the-biggest-fossil-spider-ever-found

Figure 7: retrieved from http://www.sci-news.com/paleontology/article01143-aurornis-xui-first-bird.html

Figure 8: retrieved from http://www.trickhatmedia.com/163-mn-yr-old-fossils-reveal-new-bat-wing-dinosaur-species/

Figure 9: retrieved https://www.pinterest.nz/pin/666180969852252401/

Figure 10: retrieved from https://www.eurekalert.org/pub_releases/2019-07/uov-tao070419.php

Figure 11: retrieved from http://www.christianitydaily.com/articles/1575/20150112/new-marine-reptile-species-from-jurassic-period-identified.htm

Figure 12: retrieved from http://cdn.sci-news.com/images/enlarge5/image_6703_2e-Stenopterygius-Ichthyosaur.jpg

Figure 13: retrieved from https://www.livescience.com/ancient-sea-monster-pliosaur-fossils.html

Figure 14: retrieved from https://news.am/eng/news/458260.html

Figure 15: retrieved from https://www.fossilera.com/fossils/11-jurassic-ammonite-fossil-with-stand-sakaraha-madagascar

Figures 16 - 20: Marianna Terezow pers comm