

April 11, 2022

News and views

Before going on to a look at the events of the Triassic Period, here are some news items that I thought were interesting.

Geopolitics

Ukraine War

The war in Ukraine continues. Keeping in mind that the first casualty in war is truth, here are a few interesting sites and articles on the conflict:

- Daily updates at the [Institute for the Study of War](#), they are a bunch of [neo-conservative](#) consultants ([beltway bandits](#)), but their views can be useful.
- [Updates from the French Ministère des Armées](#), in French, but some browsers have a translation option.
- [Ukraine invasion's impacts on the world of science: Live updates.](#)
- More from Shirvan Neftchi of the Caspian Report: [The Ukraine War From Russia's Perspective.](#)
- From Gonzalo Lira, an [interview with Scott Ritter](#), retired intelligence officer.

Other Geopolitics

- Here's an interesting take on resources politics: [The Coming Resource Wars by Michael Lind.](#)

Research

- [New Geology articles published online ahead of print in March.](#)
- Plate tectonics of Africa (behind paywall): [Assembly of the basal mantle structure beneath Africa](#); summary and commentary on the article [here](#).
- Sedimentary geology: [Exposed sediments reveal decades of Lake Powell history](#); original research article [here](#).
- Groundwater quality: [Mapping aquifer salinity gradients and effects of oil field produced water disposal using geophysical logs: Elk Hills, Buena Vista and Coles Levee Oil Fields, San Joaquin Valley, California.](#)
- Geology of South America: [A Puzzle Mat for Assembling Colombia's Geologic History.](#)
- Holocene geology: [Holocene relative sea-level changes in the eastern part of Pomeranian Bay and the Szczecin Lagoon, Southern Baltic Sea](#); (behind paywall).

Climate Research

- Holocene climate change: [Arctic glaciers and ice caps through the Holocene: a circumpolar synthesis of lake-based reconstructions](#).
- Research into thermo-haline ocean circulation: [Freshwater forcing of the Atlantic Meridional Overturning Circulation revisited](#).
- [Chronicling the Hottest, Coldest, Windiest, and Rainiest Weather](#); the climate change may be more extreme weather events.
- Ancient climate change: [Oligocene moisture variations as evidenced by an aeolian dust sequence in Inner Mongolia, China](#).
- Really ancient climate research: [Lightning Had Difficulty Forming in Early Earth's Atmosphere](#).
- Improving climate modeling: [Impact of increased resolution on long-standing biases in HighResMIP-PRIMAVERA climate models](#); opening quote " Climate models do not fully reproduce observations".

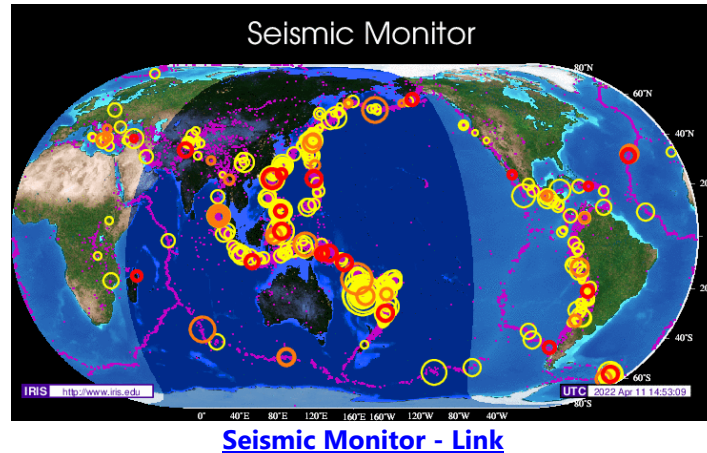
Paleontology Research

- An injured dinosaur left footprints: [A theropod trackway providing evidence of a pathological foot from the exceptional locality of Las Hoyas \(upper Barremian, Serranía de Cuenca, Spain\)](#).
- More injured dinosaurs: [Histological and chemical diagnosis of a combat lesion in Triceratops](#). summary [here](#).
- This is related to today's post on the Triassic Period: [Early Triassic ichthyopterygian fossils from the Russian Far East](#); article is on the early evolution of marine reptiles.
- Soft tissue preservation in fossils: [Perfectly Preserved 310-Million-Year-Old Fossilized Brain Found](#).
- Research into conchs: [Age and growth of one of the world's largest carnivorous gastropods, the Florida Horse Conch, Triplofusus giganteus \(Kiener, 1840\), a target of unregulated, intense harvest](#).
- Killer trilobites: [World's oldest known case of cannibalism revealed in trilobite fossils](#).
- [Dinosaur leg might be from the day the asteroid struck, scientists claim](#); The specimen has not yet been described in a peer-reviewed scientific journal; [related story](#).
- With friends like that, you don't need enemies: [Why tyrannosaurid forelimbs were so short: An integrative hypothesis](#); summary [here](#).
- From Australia: [New Research Sheds Light on Origins of Monotremes](#).

Fossil Tourism

- [Geology Rocks: Grand Canyon Fossils](#)

Volcanoes, Earthquakes and Geohazards



- [Exploring Subduction Zone Geohazards on Land and at Sea.](#)
- [Worldwide Volcano News and Updates.](#)
- Geohazard research, falling rocks: [Experimental and numerical studies of the impact breakage of granite with high ejection velocities.](#)
- Geohazards in history: [Did a 3800-year-old Mw ~9.5 earthquake trigger major social disruption in the Atacama Desert?](#)

Energy and Mining

- First [nickel](#) and now zinc: [Warning bells sound in London Metal Exchange zinc market](#); is it a free market or a racket?
- From the United States Energy Information Administration (USEIA): [In 2020, 27% of U.S. households had difficulty meeting their energy needs.](#)
- Ore formation research: [Fluocerite as a precursor to rare earth element fractionation in ore-forming systems](#) (behind pay wall).
- British energy policy: [UK energy strategy to 'breathe new life' into North Sea and Net Zero.](#)
- Long term trends: [220-year chart shows "no evidence" green energy transition is underway.](#)
- China needs energy: [China coal hub approves mega-mine that can produce for 97 years.](#)
- [Is It Time To Revisit The Keystone XL Pipeline?](#) The simple answer is yes. For Canadians, we should process **all** the crude oil produced in Canada and only export finished product (fuels, petrochemicals) surplus to its own needs to create maximum value for Canadians.
- [Philippines approves revival of nuclear power](#); related [Is it time to consider deep boreholes for nuclear waste disposal?](#)
- Webcast for gold bugs: [Galantas Gold to Present on Geology and District-Scale Potential of the Omagh Gold Project in a Webcast on April 21, 2022.](#)

April 11, 2022

The Triassic Period, Part 1: Events

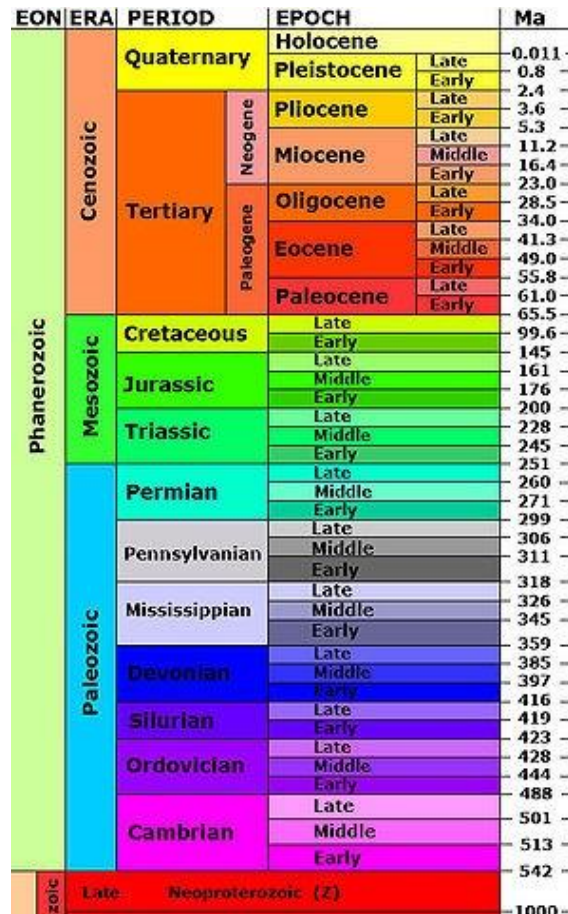


Figure 1 - Phanerozoic Time Scale

Credit: Modified from File: [Geologic time scale.jpg](#), United States Geological Survey, public domain

The [Triassic Period](#) lasted from the end of the [Permian Period](#), 251.9 million years ago (Mya) to the beginning of the [Jurassic Period](#), 201.4 Mya. The Triassic marks the end of the [Paleozoic Era](#) and the beginning of the [Mesozoic Era](#). It is bracketed by two mass extinction events: the [End Permian Mass Extinction](#), 251.9 Mya, and the [End Triassic Mass Extinction](#), 201.4 Mya. There's lots more that happened during the Triassic.

In this week's web log, we'll look at the paleogeography, orogenies, climate, and subdivisions of the Triassic. We'll also examine the [Manicouagan Impact](#) and finish up with the End Triassic Mass Extinction. In the following weeks, we'll look at terrestrial and aquatic life during the Period.

[Friedrich von Alberti](#) named the Triassic in 1834. He noticed a consistent array of three distinct

rock formations in southern Germany: the [Buntsandstein](#) sandstone, the [Muschelkalk](#) limestone and the [Keuper](#) clay. From this consistent grouping of three formation he proposed they formed a geological period that he called the Triassic after the Greek name for three, [triás](#).

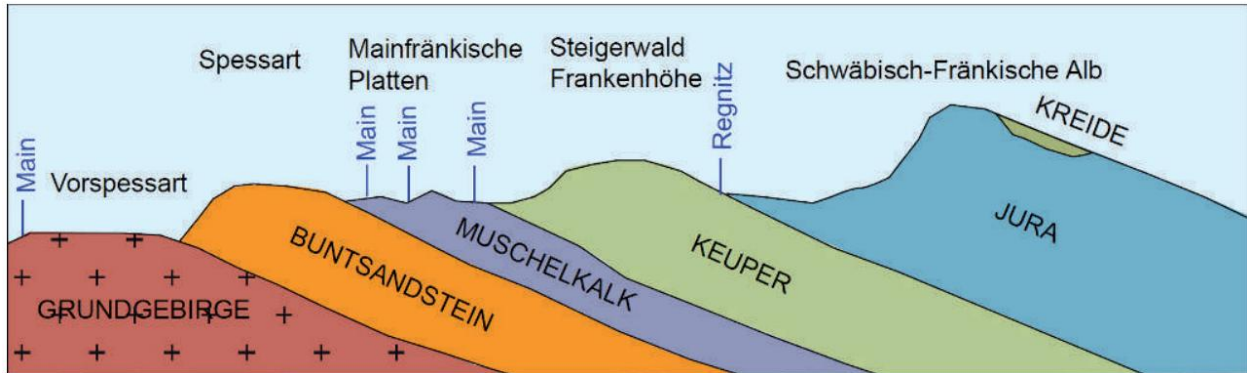


Figure 2 - Geological Cross Section, [Franconia](#), Germany
Credit: [Archäologisches Spessart-Projekt e.V](#)

Triassic Paleogeography

During the Triassic, much of the continental [cratons](#) were concentrated into the supercontinent, [Pangaea](#).

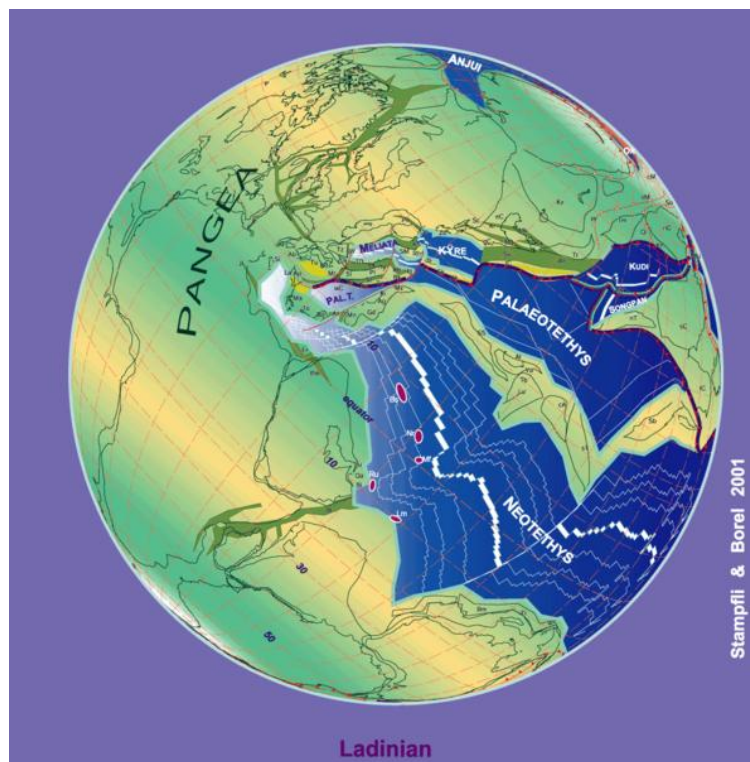


Figure 3 - The World of 230 Mya
Credit: [Stampfli & Borel 2002](#), [Tethyan Plate Tectonic Home Page](#)

Outside Pangaea, the rest of the world was covered by the [Panthalassa](#) together with the [Paleotethys](#) and [Neotethys](#) seas. Pangaea began to break up through the process of tectonic [rifting](#), one effect was the growth of Neotethys and the closing off of the Paleotethys sea.

Rifting also began between during the Late Triassic in what is now North America and Africa. This rifting process that would eventually lead to the formation of the Atlantic Ocean later in the Mesozoic. The rifting resulted in the deposition of the flood basalts of the [Central Atlantic Magmatic Province](#). This initial rifting is also shown in the sediments of the [Newark Supergroup](#) on the east coast of North America.



Figure 4 - Cow Branch Formation, Newark Supergroup, near Eden, North Carolina
Credit: [James St. John, Creative Commons Attribution 2.0 Generic](#) license

Triassic Orogenies

Major mountain building (orogenies) that occurred during the Triassic included:

- The [Cimmerian](#) orogeny built mountain ranges in Central Asian during the Late Triassic. The [Cimmerian](#) terrane rifted from the southern part of Pangaea, [Gondwana](#) and [accreted](#) onto the northern portion of Pangaea onto the [Kazakhstania](#) terrane as well as what is now north and south China.
- Also occurring in what is now Asia during the Triassic, the [Dabie-Sulu Orogeny](#). The Dabie-Sulu Orogen extends from the [Tanlu Fault Zone](#) between Shanghai and Wuhan in

modern-day China to the [Qaidam Basin](#) north of the Tibetan Plateau.

- The [Sonoma Orogeny](#) occurred in western North America during the transition from the Permian to the Triassic period. It was a series of accretionary events whereby the [Sonomia island arc](#) moved onto the rest of North America in what is now Nevada.
- Beginning in the Permian and ending in the Triassic Period, the [Hunter-Bowen Orogeny](#) happened in what is now the East coastal regions of Australia, creating the [New England Fold Belt](#).

Climate During the Triassic



Figure 5 - Triassic Sandstone, Maria Island, Tasmania, Australia

Credit: [cprevot](#), [Creative Commons Attribution-Share Alike 3.0 Unported](#) license

We have a fair amount of evidence for [climate during the Triassic](#). A lot of the deposits from the Triassic Period are [red bed sandstones](#) and [evaporites](#), which indicates that much of the continental interior of Pangaea was hot and dry, some of it was probably desert. There are no [glacial deposits](#) from the Triassic, the deposits from the polar regions indicate a moist and temperate climate. Deposits associated with the Neotethys Sea also suggest tropical and subtropical climates associated with the land around that sea. Given the size of Pangaea, much of the land must have had a continental climate with monsoons. Also noting that climate is not a static thing, one of the climate events uncovered through study of the period is the [Carnian Pluvial Event](#).

Major Divisions of the Triassic

Period	Epoch	Age/Stage	Substage (informal)	Mag	GSSPs	
Jurassic	Early	Hettangian			FAD of <i>Psiloceras spele</i> (ammonoid)	
Triassic	Late	Rhaetian				
		Norian	Sevastian			FAD of <i>Misikella posthernsteini</i> (conodont) - working def.
			Alaunian			
			Lacian			
	Carnian	Tuvalian			FAD of <i>Metapolygnathus echinatus</i> (conodont) - working def.	
		Julian				
	Middle	Ladinian	Longobardian			FAD of <i>Daxatina canadensis</i> (ammonoid)
			Fassanian			FAD of <i>Eoprotrochyceras curionii</i> (ammonoid)
		Anisian	Illyrian			
			Pelsonian			
Early	Olenekian	Bithynian			FAD of <i>Chiosella timorensis</i> (conodont) - working def.	
		Aegean				
		Spathian				
Induan	Induan	Smithian			FAD of <i>Neospathodus waageni</i> s.l. (conodont) - working def.	
		Dienerian				
		Griesbachian			FAD of <i>Hindeodus parvus</i> (conodont)	
Permian	Loping.	Changhsing.				

Figure 6 - Triassic Timescale

Credit: from [Ogg, J., C. Huang, & L. Hinnov. 2014](#)

The Triassic Period is typically divided into (surprise!) three epochs: the [Early](#), the [Middle](#) and the [Late](#) Triassic. These epochs are in turn divided into stages; let's look at these.

The Early Triassic

Originally corresponding to the Buntsandstein Formation, as per the original definition of the Triassic by Friedrich von Alberti, the Early Triassic lasted from 251.9 Mya to 247.2 Mya. The Early Triassic is further subdivided into the [Induan](#) and [Olenekian](#) Stages.

The Induan Stage(251.9 - 251.2 Mya) begins with the first appearance in the fossil record of the [conodont](#) species [Hindeodus parvus](#) which also marks the end of the Permian Period and the beginning of the Triassic. The [global reference profile](#) (GSSP) of the base of the Induan is situated in Meishan, [Changxing County](#), China. The Induan Stage is further informally subdivided into [Griesbachian and the Dienerian](#) subages or substages.

The top of the Induan Stage and the beginning of the Olenekian Stage (251.2 - 247.2 Mya) is marked by the first appearance of ammonite species [Meekoceras gracilitatis](#). No GSSP has been established for the base of the Olenekian Stage which is informally divided into the [Smithian and the Spathian](#) subages or substages.

The important events of the Early Triassic are the recovery of life after the End Permian Mass Extinction. There was a minor extinction event at the [Smithian-Spathian boundary event](#).

The Middle Triassic

Spanning the time between 247.2 Mya and 237 Mya, the Middle Triassic corresponds to the time when the Muschelkalk limestone was deposited, as per the original definition of the Triassic by Friedrich von Alberti. The Middle Triassic is subdivided into the [Anisian](#) and [Ladinian](#) stages.

The Anisian Stage (247.2 - 242 Mya) is defined by first appearance of conodont species [Chiosella timorensis](#) in the stratigraphic record. The original [type locality](#) for the Anisian Stage was near the village of [Großreifling](#) in the Austrian state of Styria but no GSSP for the base of the stage has been established. The Anisian Stage is itself further subdivided into the Aegean, Bithynian, Pelsonian, Illyrian substages.

The top of the Anisian and the base of the Ladinian (242 - 237 Mya) is marked by first appearance of ammonite species [Eoprotrachyceras curionii](#), the ammonite family [Trachyceratidae](#) as well as the conodont species [Neogondolella praehungarica](#) and [Budurovignathus praehungaricus](#). The GSSP for the base of the Ladinian is an outcrop in the river bed of the [Caffaro](#) river at [Bagolino](#), in the province of [Brescia](#), northern Italy.

Important events during the Middle Triassic include further development of new forms of life. During the Middle Triassic, woody trees flourished again and modern [Scleractinia](#) hard corals first appeared.

The Late Triassic

The longest epoch of the Triassic, the Late Triassic lasted from 237 Mya to 201.4 Mya and corresponds to the Keuper clay in Friedrich von Alberti's original definition of the Period. The Late Triassic is subdivided into the [Carnian](#), [Norian](#) and [Rhaetian](#) Stages.

The base of Carnian Stage (237 to 227 Mya) is defined by the first appearance in the stratigraphic record of the ammonite species [Daxatina canadensis](#). The GSSP for the base of the Carnian Stage is near [Badia](#) in the [Val Badia](#) in the region of South Tyrol, Italy. The Carnian is informally subdivided into the Julian and Tuvanian substages.

The top of the Carnian Stage and the beginning of the Norian Stage (227 - 208.5 Mya) is marked

by the appearance of the ammonites [Klamathites macrolobatus](#) and [Stikinoceras kerrias](#) well as the first appearance of the conodonts [Metapolygnathus communisti](#) and [Metapolygnathus primitius](#). No GSSP for the base of the stage has been established. The Norian Stage is further subdivided informally into the Lacion, Alaunian, and Sevatian substages.

The top of the Norian Stage and the beginning of the Rhaetian Stage (208.5 - 201.4 Mya) is defined by the first appearance of the marine conodont [Misikella posthernsteini](#). The Rhaetian does not yet have an official GSSP and has not been divided into the substages.

The end of the Rhaetian Stage is also the end of the Late Triassic Epoch, the last epoch in the Triassic Period. It is marked by the End Triassic Mass Extinction. Other events in the Late Triassic include the development of the first dinosaurs and the Manicouagan Impact. We'll discuss the dinosaurs in the next week's web log on terrestrial life during the Triassic.

The Manicouagan Impact



Figure 7 - Lake Manicouagan

Credit: [Copernicus Sentinel-2, ESA, Creative Commons Attribution-Share Alike 3.0 IGO license](#)

During the Late Triassic, about 214 Mya, the Earth had one of its occasional really bad days. In this case, an asteroid approximately 5 km wide crashed into North American craton in what is now the Province of Quebec. The [Manicouagan Impact Structure](#), severely eroded over the past

214 Mya, today forms a circular lake with a central peak called Mount Babel, which has been interpreted as being the result of post-impact uplift.

As if a single big impact was not enough, there is some [evidence](#) to suggest that the Manicouagan Impact Structure is part of multiple impact event that includes the impact structures at [Rochechouart](#) crater in France, the [Lake Saint Martin](#) crater in Manitoba, the [Obolon'](#) crater in Ukraine, and the [Red Wing](#) crater in North Dakota. However, for all the trouble that the impacts must have caused, there is no evidence to suggest that they contributed to the End Triassic Mass Extinction that occurred some 12 million years later.

The End Triassic Mass Extinction or Life is Hard

After the massive destruction of life at the end of the Permian, life struggled and ecosystems were re-established during the Triassic Period. Then, it all came crashing down again in the End Triassic Mass Extinction. Among terrestrial plants, about [60% of plant genera went extinct](#). Among terrestrial vertebrates, the Triassic-Jurassic boundary is marked by a [bone-bed](#) and about 42% of all [terrestrial tetrapods went extinct](#). Among marine vertebrates, [conodonts went completely extinct](#) at the end of the Triassic and many other marine vertebrates were severely reduced. Among marine invertebrates, ammonites, brachiopods and many others also suffered severe extinctions.

So what caused it?

The best candidate for the cause of the End Triassic Mass Extinction is massive volcanic eruptions, in this case from the flood basalts of the [Central Atlantic Magmatic Province](#) (CAMP). As with the End Permian Mass Extinction, the deposition of the CAMP increased the carbon dioxide in the atmosphere, [possibly doubling the concentration](#). Greenhouse warming led to ocean acidification. The possible release of methane hydrates when the ocean temperatures increased added to the climate chaos. While not as bad as the end Permian, the End Triassic was a pretty bad time for life on the planet.

The deposition of the CAMP volcanic rock also marks the beginning of the process that led to the breakup of Pangaea and the opening of the Atlantic Ocean. Also, the life that did survive, eventually thrived and diversified as conditions improved.

Standard Caveat

The purpose of my weblog postings is to spark people's curiosity in geology. Don't entirely believe me until you've done your own research and checked the evidence. If I have sparked your curiosity in the subject of this posting, follow up with some of the links provided here. If

you want to, go out into the field and examine some rocks on your own with the help of a good field guide. Follow the evidence and make up your own mind.

In science, the only authority is the evidence.