# **IMPACTS 2**

**Mass Extinctions** 

Dr Mitch D'Arcy





Pangaea, about 250 million years ago – the crime scene for today's class

### **IMPACTS 2**

Mass Extinctions

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### IMPACTS MINI-MODULE

- 1. Biostratigraphy and Geological Time
- Mass Extinctions
- 3. Impacts and the Extinction of the Dinosaurs
- Impacts and Humans: Frequency and Mitigation



### **IMPACTS 2**

**Mass Extinctions** 

Dr Mitch D'Arcy

### LEARNING GOALS

- Define the characteristics of a mass extinction
- 2. List the 'Big 5' mass extinction events and their order through time
- 3. Distinguish between broad extinction-producing phenomena
- 4. Describe the significance and magnitude of the End-Permian (also known as Permo-Triassic, P/T) event
- List the causes and effects of the End-Permian mass extinction
- 6. Describe the significance and magnitude of the End-Triassic event
- 7. List the causes and effects of the End-Triassic event
- Appreciate that open questions remain about mass extinctions and Earth's geological history, and that we do not yet have all the answers

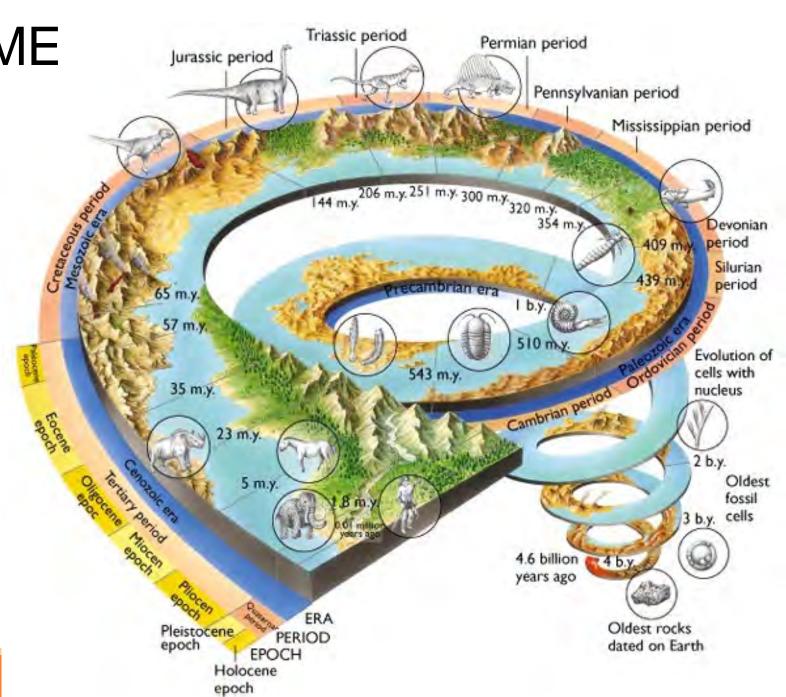


GEOLOGICAL TIME

How have we built our understanding of Earth's geological history?

- Understanding the Earth as a system
- Steno's laws of stratigraphy
- Biostratigraphy
- Correlation
- (and radiometric dating)

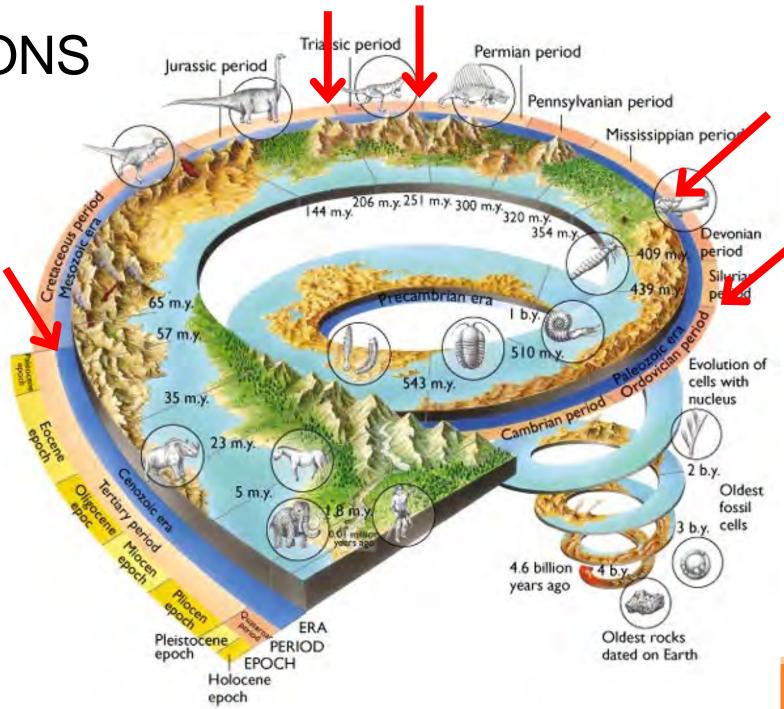
We learned that the Earth has experienced major changes through time.



MASS EXTINCTIONS

There have been five major extinction events:

- End Cretaceous (66 Ma)
- End Triassic (201 Ma)
- > End Permian (251 Ma)
- ➤ Late Devonian (360 Ma)
- Late Ordovician (450 Ma)



# There have been five major extinction events:

- End Cretaceous (66 Ma)
- End Triassic (200 Ma)
- End Permian (250 Ma)
- Late Devonian (360 Ma)
- Late Ordovician (450 Ma)

#### INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

www.stratigraphy.org

International Commission on Stratigraphy

2





	Erath F	System Era	Series / Epoch		
	yen	my the	Q"		
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			Miocene M	Messinian <	7.246
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				Barremian	~ 121.4
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				Valanginian	~ 132.6
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	'n			Aalenian	174.1 ±1.0
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D.		Na Na	Kasimovian	307.0 ±0.1	
		Isyl	Middle	Moscovian	315.2 ±0.2
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		an	Upper	Serpukhovian	323,2 ±0,4
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	nia	Middle	Givetian	382.7 ±1.
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			Emsian	
		Lower	Pragian	407.6 ±2. 410.8 ±2.
			Lochkovian	
		Pridoli		419.2 ±3.
		Ludlow	Ludfordian	423.0 ±2. 425.6 ±0.
	a		Gorstian	427.4 ±0.
	L.	Wenlock	Homerian Sheinwoodian	430.5 ±0. 433.4 ±0.
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100	M	Llandovery	Aeronian	438.5 ±1. 440.8 ±1.
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Phanerozoic Paleoz Nig	7	Upper	Katian	453.0 ±0.
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	믿		Dapingian 4	470.0 ±1.
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			Tremadocian <	485.4 ±1.
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			Jiangshanian 4	
			Paibian <	~ 494 ~ 497
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	C C		Drumian <	~ 504.5
	brian		Wuliuan	~ 509
	Cam		Stage 4	~ 514
	0		Stage 3	
			Stage 2	~ 521
		Terreneuvian	Fortunian	~ 529
			4	538 8 +0

	Eallen Es	Ediacaran
	Neo- proterozoic	Cryogenian
		Tonian
	Meso- proterozoic	Stenian
o		Ectasian
Proterozoic		Calymmian
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Pre	Paleo- proterozoic	Orosirian
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Pi		Siderian 2
	Neo- archean	
ean	Meso- archean	
Archean	Paleo- archean	
	Eo- archean	

Units of all ranks are in the process of being defined by Global Boundary Stratolype Section and Politis (GSSP) for their lower boundaries, including those of the Archean and Proterozoic, long defined by Global Standard Stratigraphic Ages (GSSA). Italic fonts indicate informal units and placeholders for unnamed units. Versioned charts and detailed information on ratfield GSSPs are available at the website http://www.stratigraphy.org. The URL to this chart is found below.

Numerical ages are subject to revision and do not define units in the Phanerozoic and the Ediacaran; only GSSPs do. For boundaries in the Phanerozoic without ratified GSSPs or without constrained numerical ages, an approximate numerical age (-) is provided.

Ratified Subseries/Subepochs are abbreviated as U/L (Upper/Late), M (Middle) and U/E (Lower/Early). Numerical ages for all systems except Quatemary, upper Paleogene, Cretaceous, Triassic, Permian, Cambrian and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012), those for the Quatemary, upper Paleogene, Cretaceous, Triassic, Permian, Cambrian and Precambrian were provided by the relevant ICS subcommissions.

Colouring follows the Commission for the Geological Map of the World (www.ccgm.org)

or the orgm.org)

Chart drafted by K.M. Cohen, D.A.T. Harper, P.L. Gibbard, N. Car (c) International Commission on Stratigraphy, February 2022

To cite: Cohen, K.M., Finney, S.C., Gibbard, P.L. & Fan, J.-X. (2013; updated) The ICS International Chronostratigraphic Chart. Episodes 36: 199-204.

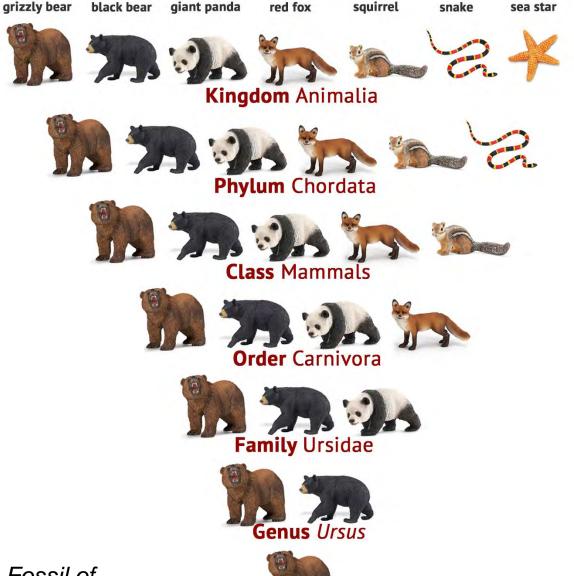


### **TAXONOMY**

A species is a group of living organisms that are capable of viable interbreeding.

For extinct organisms preserved as fossils, we use their physical characteristics to identify species.

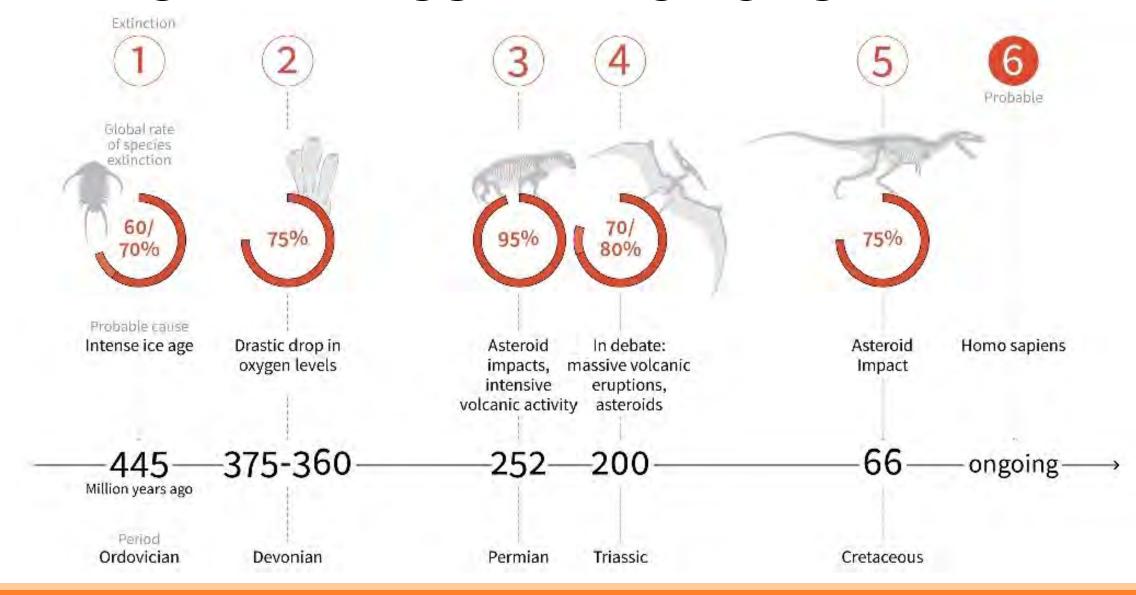




Fossil of Ursus spelaeus Species ursus arctos

Taxonomy of the grizzly bear

### THE BIG FIVE MASS EXTINCTIONS



#### 1. Biological Causes

- Competition
- Predation
- Pathogens
- Biological effects on the rest of the Earth system
  - ➤ E.g., mosses might have caused the Late Ordovician glaciation: Weathering the continents caused atmospheric CO₂ to drop by 22x, and the first soils washed into the oceans caused algal blooms and anoxia.



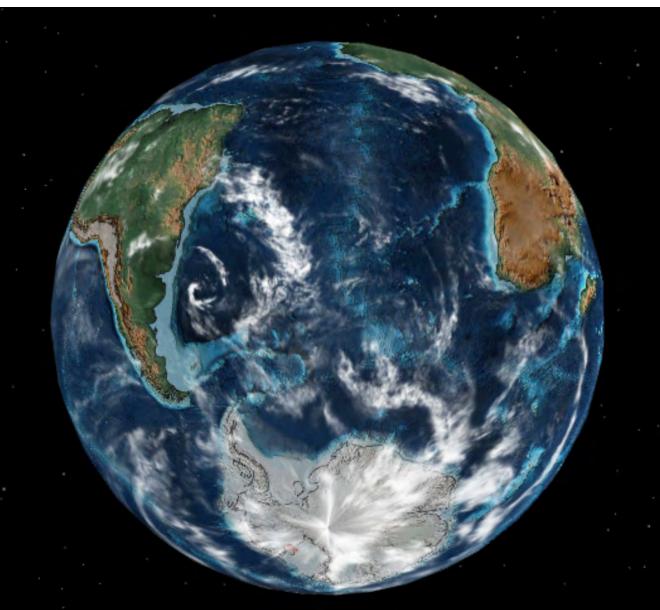
Generally, biological causes lead to extinctions, but not MASS extinctions

#### 2. Plate Tectonics

Plate tectonics can cause changes in climate and sea level.

Example: The Late Ordovician glaciation was probably promoted by Gondwana moving to the South Pole.

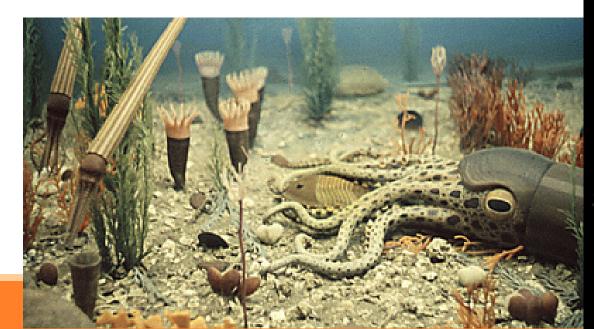


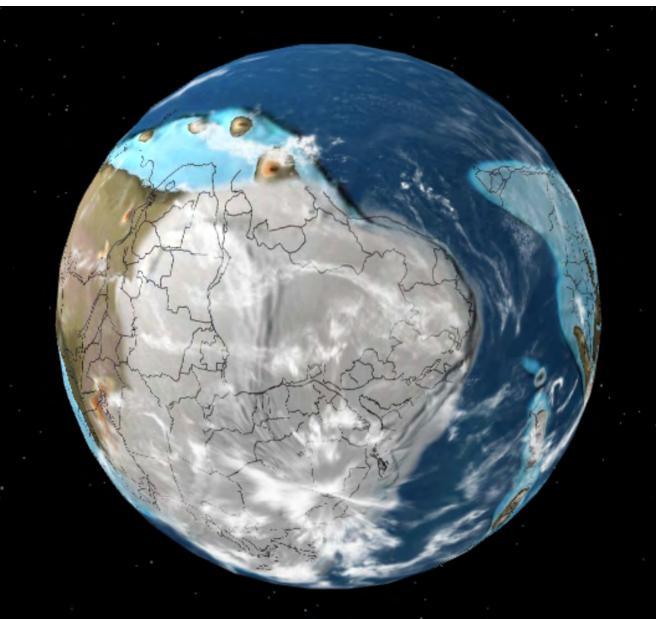


#### 2. Plate Tectonics

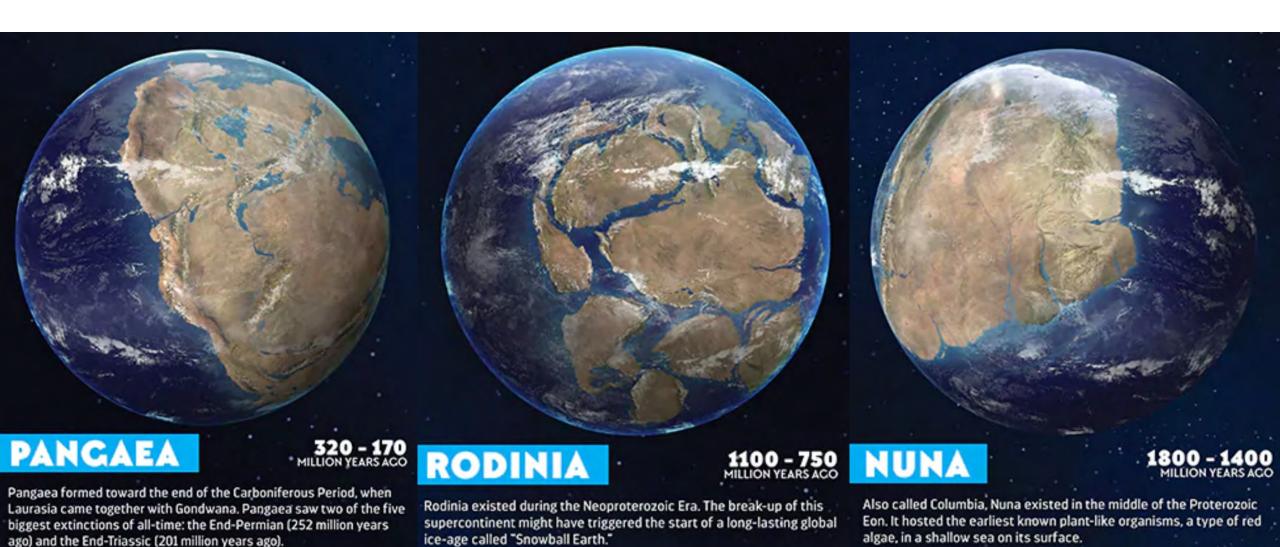
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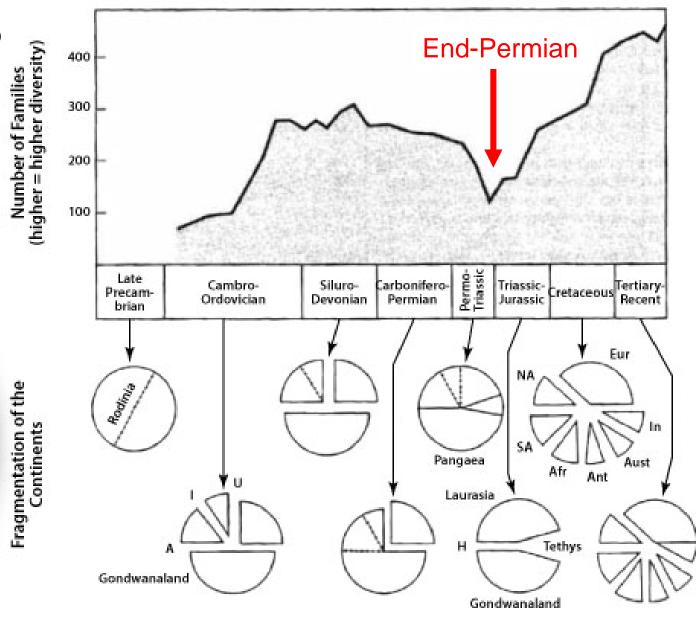
### SUPERCONTINENTS



# SUPERCONTINENTS

Biodiversity decreases when supercontinents form – on land and in the oceans.





The eruption of Hunga Tonga— Hunga Ha'apai in January 2022

#### 3. Climate Change

In the geological past, sudden climate changes were typically caused by volcanism, especially flood basalts.

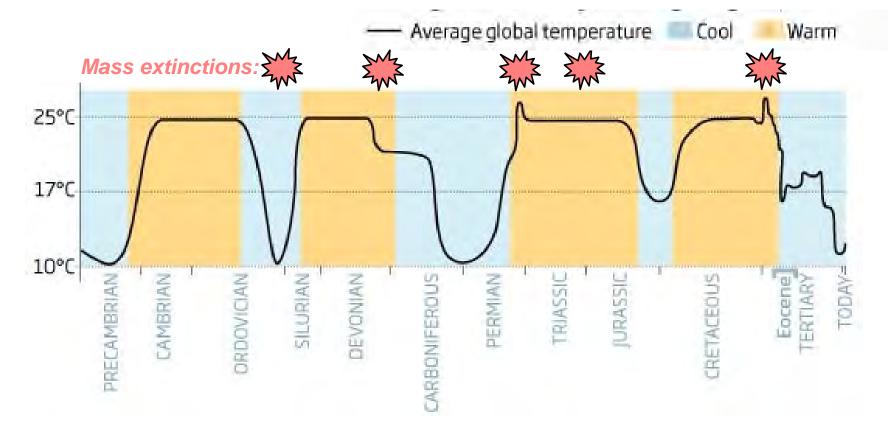
Long-term shifts between icehousegreenhouse climate states have also been influenced by volcanism and tectonics.



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Long-term shifts between icehousegreenhouse climate states have also been influenced by volcanism and tectonics.



Icehouse climate = Ice present at the poles Greenhouse climate = No ice present at the poles

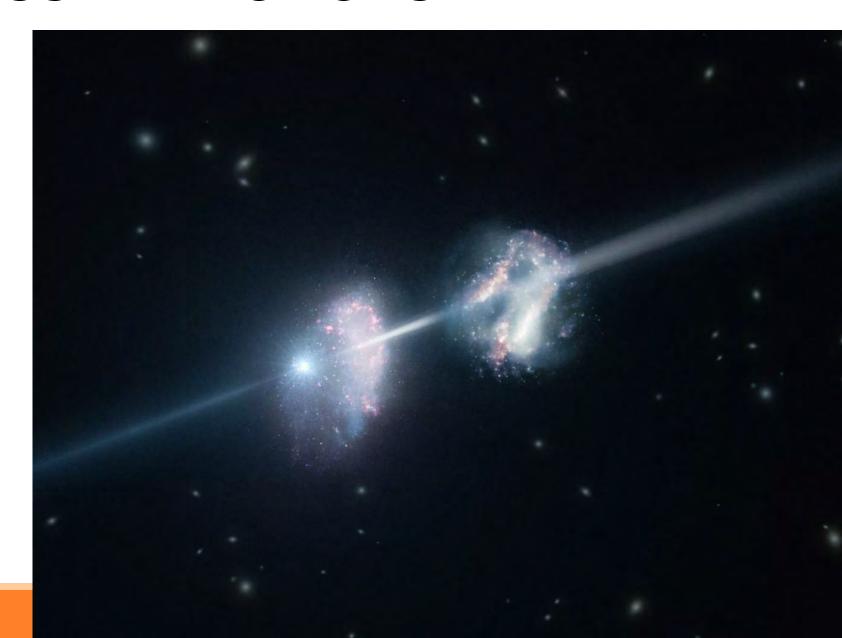
#### 4. Extraterrestrial Events

- Asteroid impacts
  - E.g., end-Cretaceous mass extinction
- Gamma radiation bursts
  - E.g., perhaps the end-Ordovician mass extinction?



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- Asteroid impacts
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- Gamma radiation bursts
  - E.g., perhaps the end-Ordovician mass extinction?



Mass extinctions are probably caused by a combination of factors.

Late Ordovician (450 Ma)	Late Devonian (360 Ma)	End Permian (251 Ma)	End Triassic (201 Ma)	End Cretaceous (66 Ma)
Glaciation of Gondwana	Rapid climate and sea level changes	Volcanism	Volcanism	Impact(s)
Configuration of tectonic plates	Impact?	Massive climate change	Climate change	Volcanism
Evolution of moss	Volcanic eruptions?	Pangea supercontinent	Impact?	Sea level fall
Gamma radiation burst?	Nearby supernova?	Impact?		

All of these causes disrupt the Earth system, and therefore the biosphere.

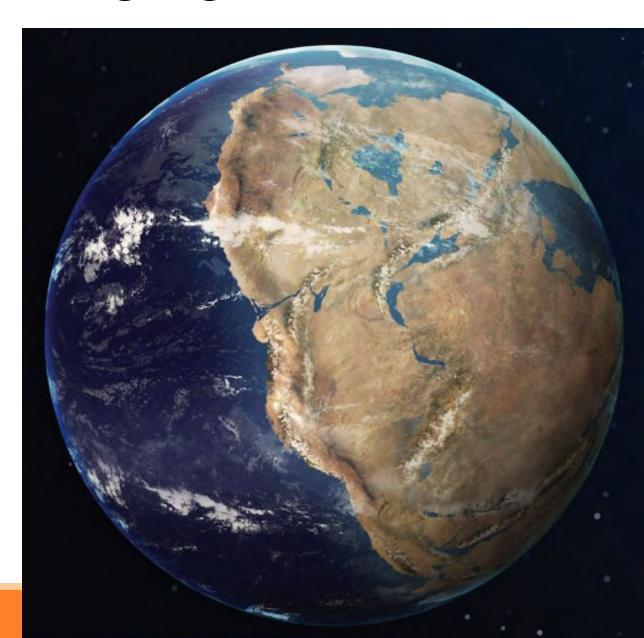


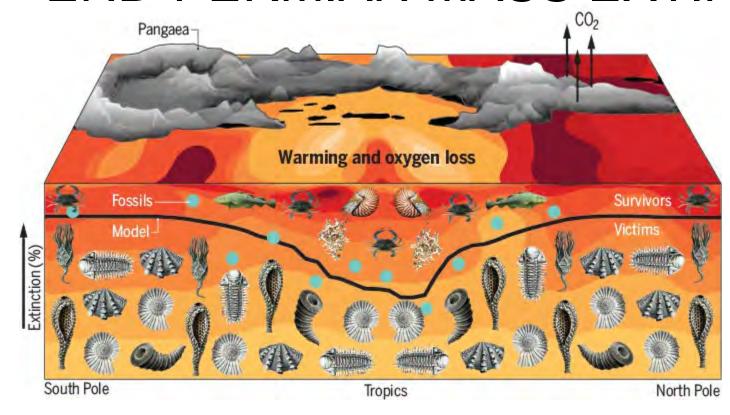
The Permian world had a massive supercontinent called **Pangaea**.

Pangea was huge and dry, causing the Carboniferous Rainforest Collapse ~300 Myr ago.

By 290 Ma, most forests were replaced by vast deserts and an ice cap in the southern hemisphere – **arid wastelands.** 

There were **fewer ecological niches** on land, and **fewer continental shelves** in the oceans.



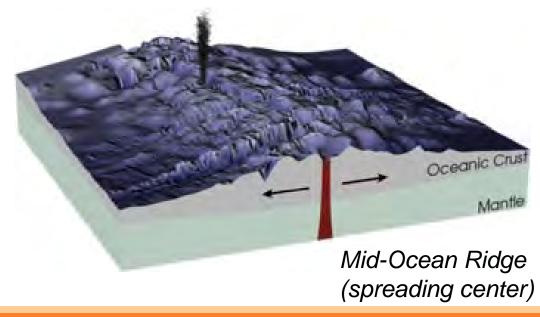


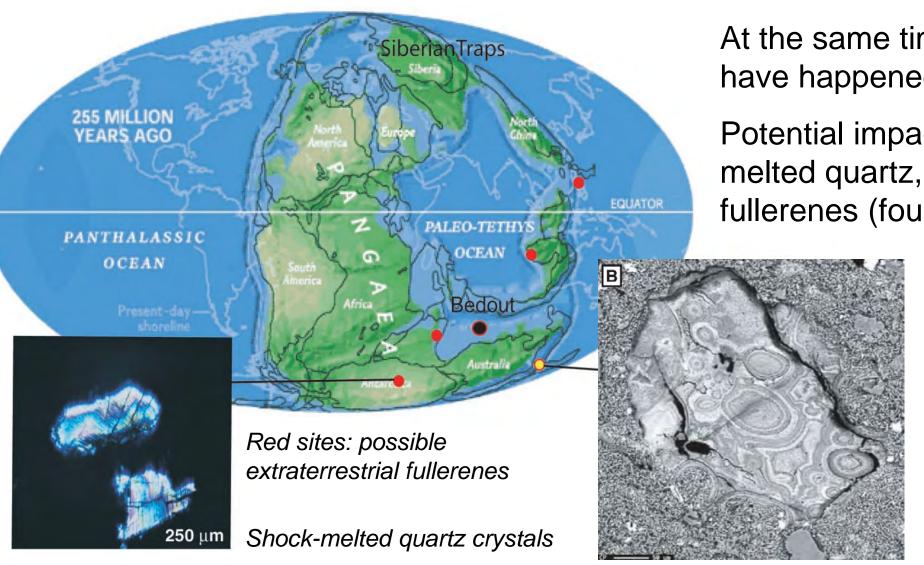
#### Sea level fall

Due to plate tectonics (mid-ocean ridge activity) slowing in the Permian.

#### Ocean stagnation

Polar waters were unable to sink, and ocean circulation was weakened – resulting in **anoxia** (a lack of oxygen).





At the same time, an **impact** *might* have happened at the Bedout site.

Potential impact breccia, shockmelted quartz, and extraterrestrial fullerenes (found in asteroids).

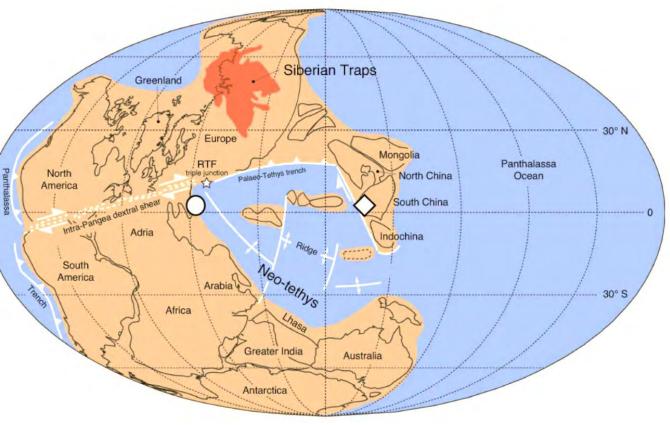
Only a single plagioclase crystal could be dated, but it gave an age of 250.1 ± 4.5 Ma.

An impact is not yet confirmed.

The **Siberian Traps** erupted at ~250 Ma. This was a 'Large Igneous Province' in Siberia.

2-3 million km<sup>3</sup> of basalt lava erupted, releasing huge amounts of carbon dioxide and methane.





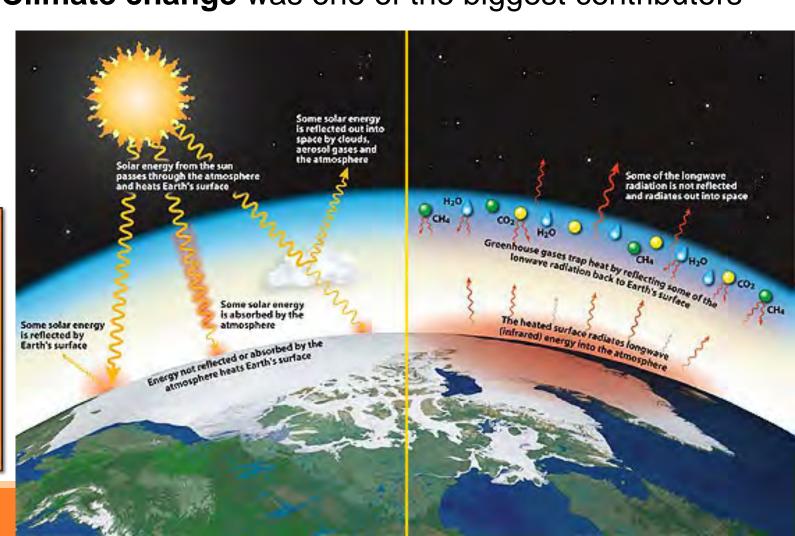
The eruption set fire to the largest coal, oil, and gas deposits on Earth at the time.

Massive amounts of **greenhouse gases** were released into the atmosphere and **global temperatures soared**. **Climate change** was one of the biggest contributors

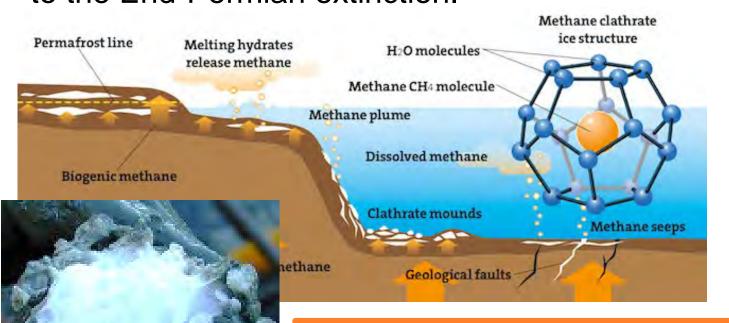
to the End-Permian extinction.

Greenhouse gases act like a warming blanket in the Earth's atmosphere.

They absorb radiation and emit some of it back down to the Earth's surface.



Massive amounts of **greenhouse gases** were released into the atmosphere and **global temperatures soared**. **Climate change** was one of the biggest contributors to the End-Permian extinction.



Then, methane clathrates melted.

Clathrate: Solid crystal structure containing methane (CH<sub>4</sub>) from the decay of organic material, common in deep-ocean sediments.

Ocean warms → melts clathrates → releases CH<sub>4</sub>

Methane is an even stronger greenhouse gas than CO<sub>2</sub>

Massive amounts of **greenhouse gases** were released into the atmosphere and **global temperatures soared**. **Climate change** was one of the biggest contributors to the End-Permian extinction.

If you existed at the end of the Permian, would you rather live...

#### In the ocean



#### On the land



Massive amounts of **greenhouse gases** were released into the atmosphere and **global temperatures soared**. **Climate change** was one of the biggest contributors to the End-Permian extinction.

If you existed at the end of the Permian, would you rather live...



### THE AFTERMATH: TRIASSIC

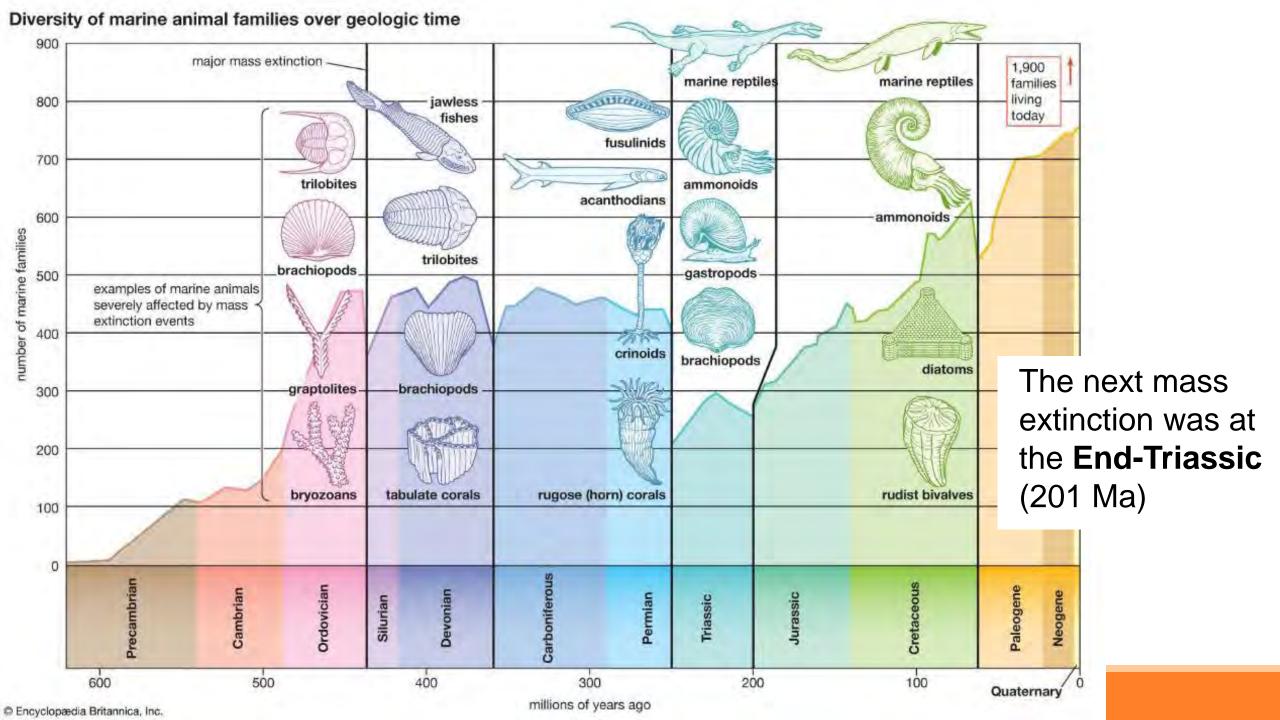
No coal is known anywhere on Earth until 243 Ma (the <u>Triassic</u> <u>Coal Gap</u>). It took until 230 Ma for plant diversity to recover to preextinction levels.

With 90-96% of all species extinct, there was a lot of **ecological space** (opportunities for the survivors to evolve and dominate available ecological niches).

Life evolved, and a new type of reptile appeared... the **dinosaurs**.



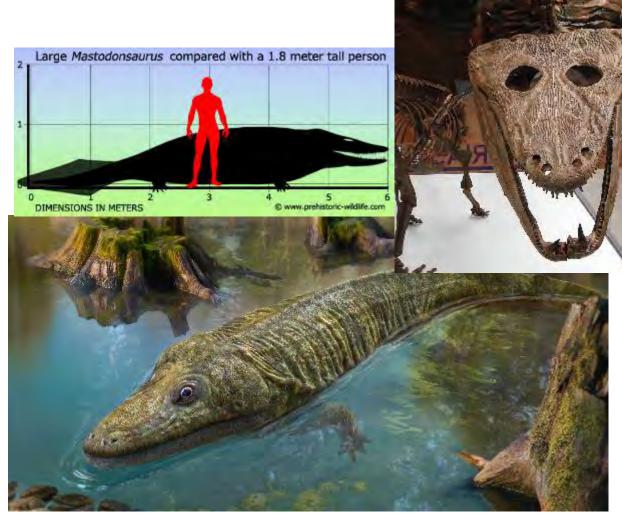
Nyasasaurus Perhaps the earliest 'dinosaur' (debated) from ~240 Ma.



Occurred at 201 Ma. 70-80% of species extinct.

- More than half of animals: many large amphibians, reptiles, and synapsids (early mammals)
- Major extinction of plants (perhaps as high as 60%)
- Large decline in ammonites
- Conodonts extinct Index Fossils from Cambrian to Triassic





Mastodonsaurus A (large!) Triassic amphibian that went extinct

# END-TRIASSIC MASS EXTINCTION (201 Ma)

What caused the End-Triassic mass extinction?

It's still unclear...

# **END-TRIASSIC MASS EXTINCTION (201 Ma)**

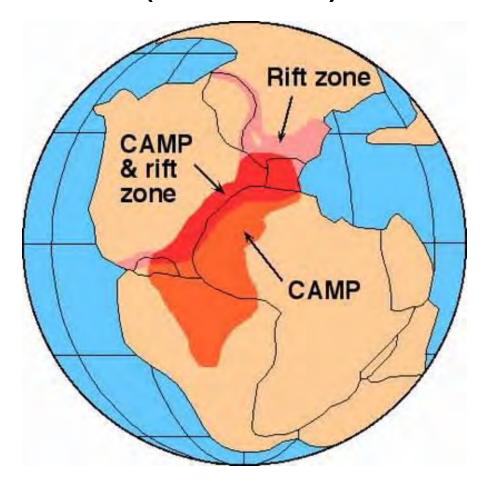
Attributed to the emplacement of the **Central Atlantic Magmatic Province (CAMP).** 

3 million km<sup>3</sup> basalt erupted at 201.5 Ma, releasing large amounts of carbon dioxide ( $CO_2$ ), but eruptions were also rich in sulphur dioxide ( $SO_2$ ).

The oceans acidified, and carbonate deposition stopped globally at the Triassic-Jurassic boundary.

Atmospheric CO<sub>2</sub> approximately doubled, but SO<sub>2</sub> would have had a short-lived cooling effect.

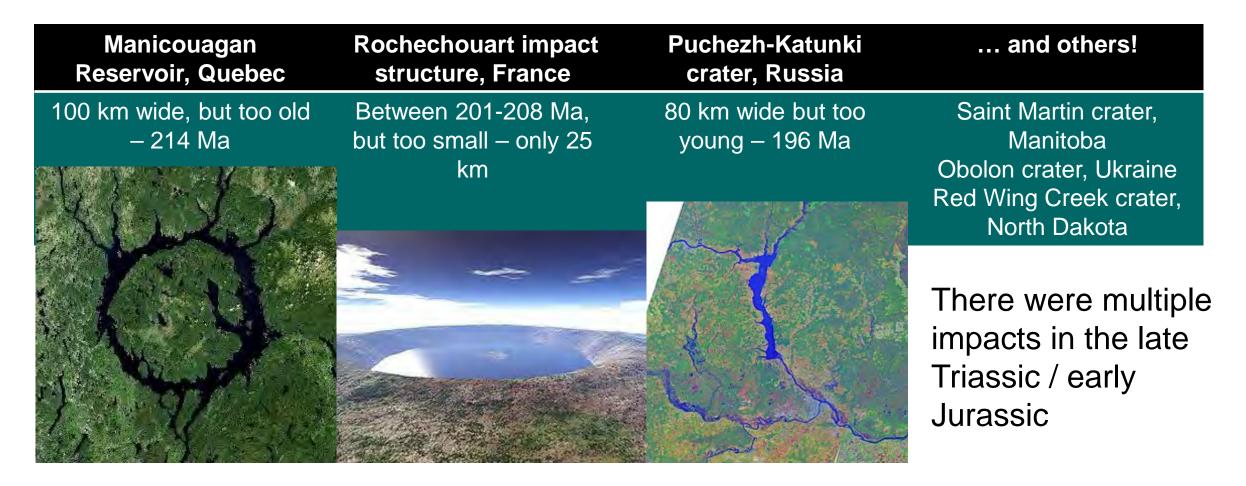
So **volcanism** and **climate change** definitely played a role, but the details are not certain.



Central Atlantic Magmatic Province

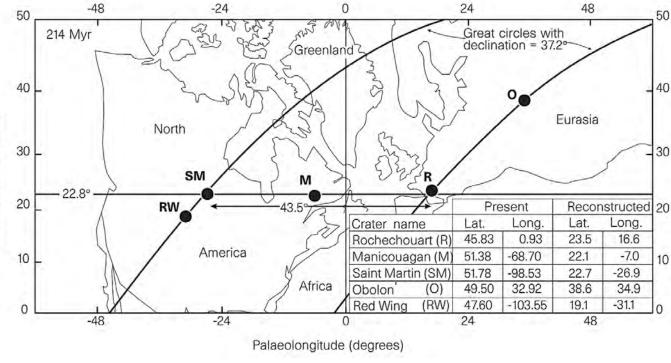
# END-TRIASSIC MASS EXTINCTION (201 Ma)

What about impacts?

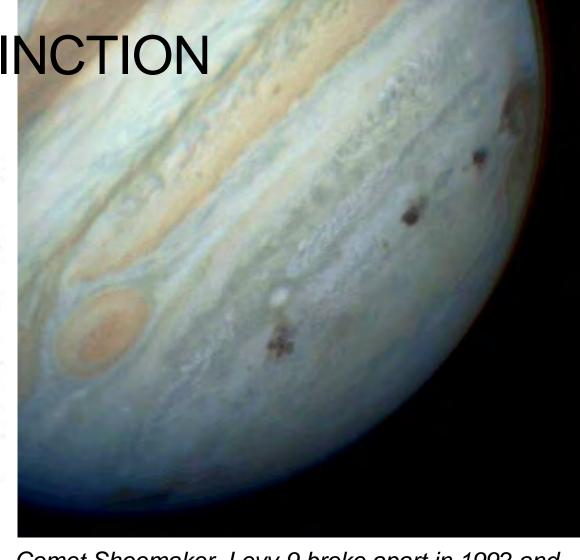


#### What about impacts?

Palaeolatitude (degrees)



In 1998, John Spray at the University of New Brunswick noticed a pattern...

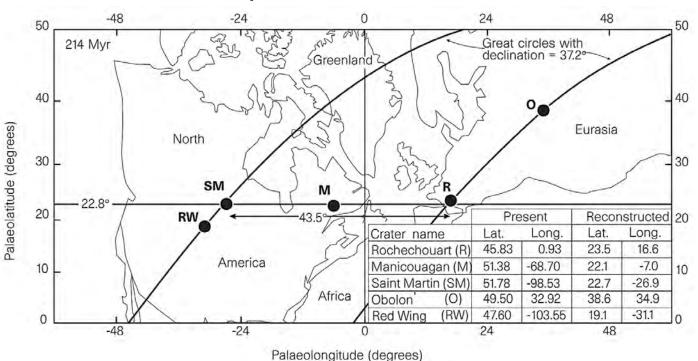


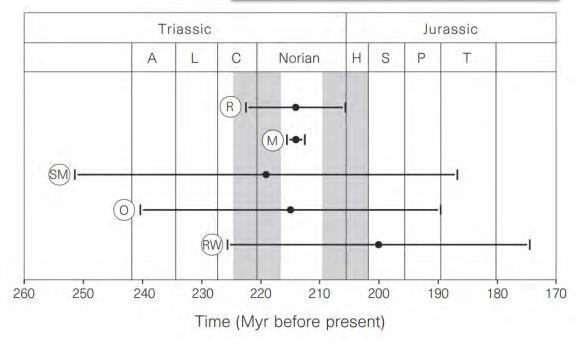
Comet Shoemaker–Levy 9 broke apart in 1992 and collided with Jupiter in 1994.

Image from Hubble space telescope.

The Geological Timescale has changed since 1998!

#### What about impacts?



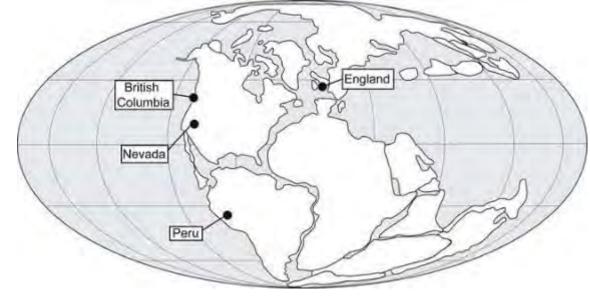


In 1998, John Spray at the University of New Brunswick noticed a pattern...

This remains an unsolved question.

British Columbia is one of the few places where the Triassic-Jurassic boundary is well preserved – you can touch it!

Geologists studying the Triassic-Jurassic contact on Haida Gwaii







These fossils are common in BC – what are they called?

The dinosaurs really took over after the End-Triassic mass extinction, as many competitor animals went extinct. The dinosaurs adapted to their **ecological niches** by **adaptive radiation**.



Aetosaurus A heavily-armoured Triassic herbivore reptile



Stegosaurus A heavily-armoured Jurassic herbivore dinosaur

### **IMPACTS 2**

**Mass Extinctions** 

Dr Mitch D'Arcy

### SUMMARY

- Mass extinctions wipe out at least 30% of species across multiple ecosystems, relatively quickly compared to geological timescales
- 2. Mass extinctions can be caused by biological factors, plate tectonics, volcanism, climate change, and extraterrestrial events (e.g., impacts)
- 3. Usually, mass extinctions involve multiple causes
- 4. The End-Permian mass extinction (251 Ma) was the worst of the big five, with 90-96% of species going extinct. Lots of things went wrong at the same time!
- 5. Shortly after, the End-Triassic mass extinction happened (201 Ma)
- 6. It's not all bad... Mass extinctions create ecological niches and lead to adaptive radiation, e.g., the End-Permian and End-Triassic mass extinctions led to the rise of the dinosaurs.



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### IMPACTS MINI-MODULE

Biostratigraphy and Geological Time



- Mass Extinctions V
- Impacts and the Extinction of the Dinosaurs
- Impacts and Humans: Frequency and Mitigation

