

# IMPACTS 3

## Impacts and the Extinction of the Dinosaurs

Dr Mitch D'Arcy



*Thescelosaurus leg*

*Recovered from the Tanis fossil site, North Dakota, US*

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# IMPACTS MINI-MODULE

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



# IMPACTS 3

## Impacts and the Extinction of the Dinosaurs

Dr Mitch D'Arcy

# LEARNING GOALS

1. Describe the character of the K/Pg (Cretaceous Palaeogene) extinction
2. Discuss the evidence used to support the impact theory for the K/Pg extinction
3. Describe the location and probable nature of the K/Pg impactor
4. Describe the initial and long-term effects of the impact and their environmental consequences
5. Consider other potential causes of the K/Pg environmental collapse





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)

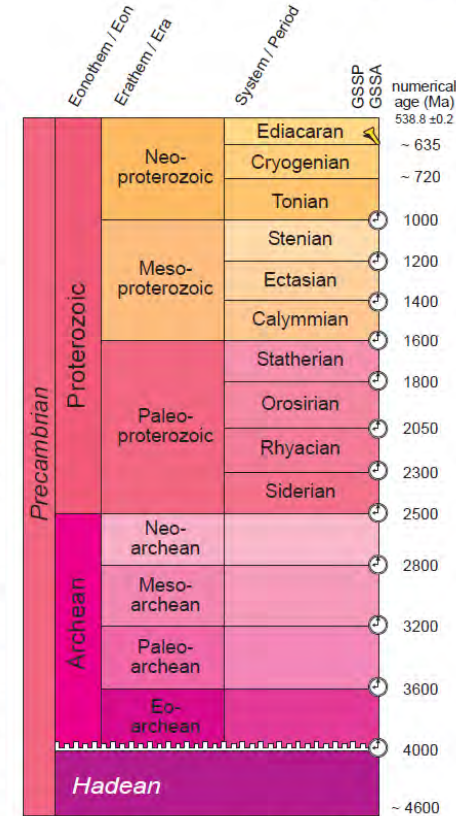
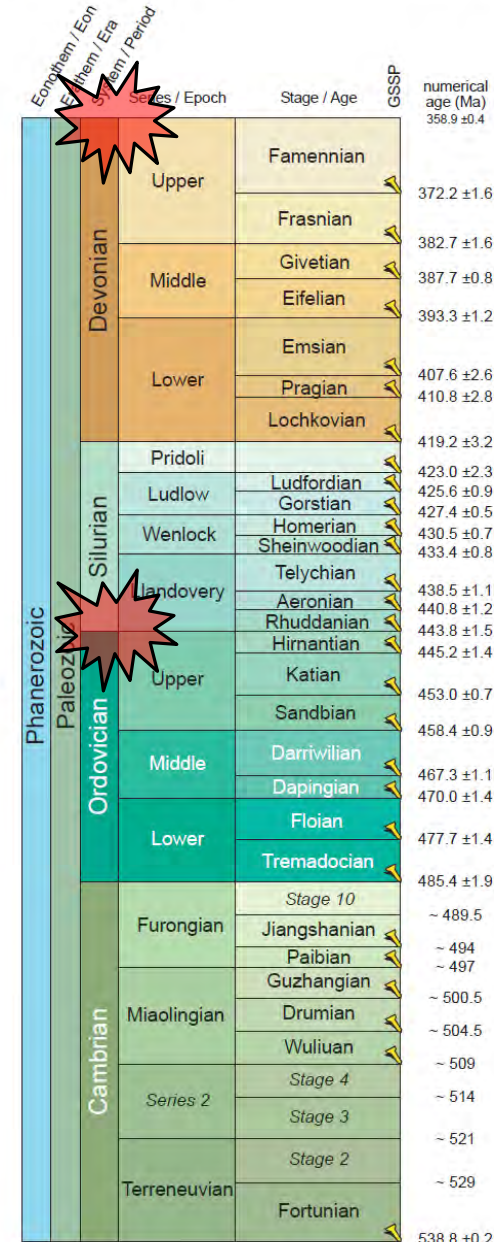
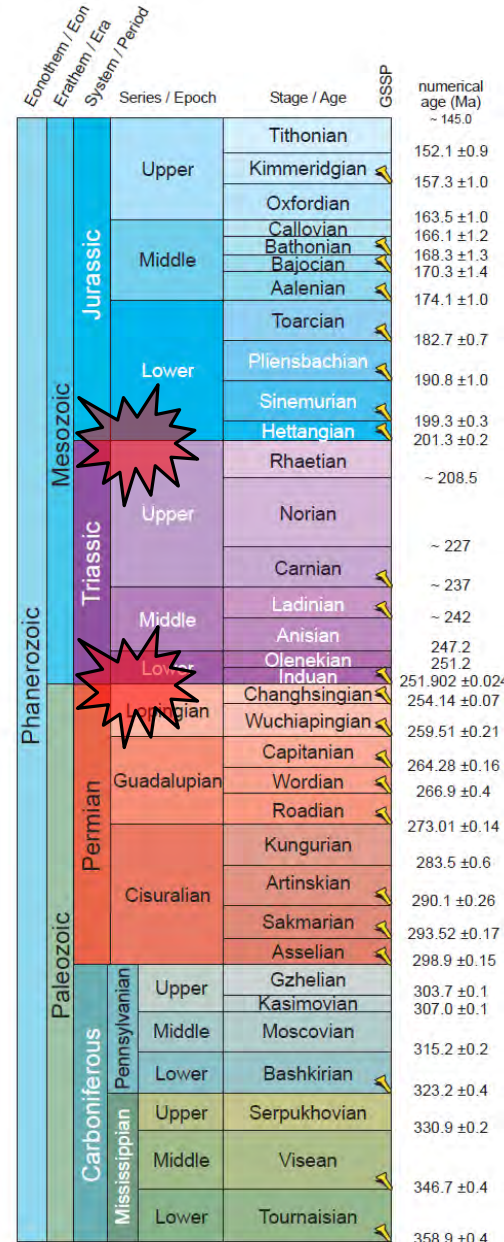
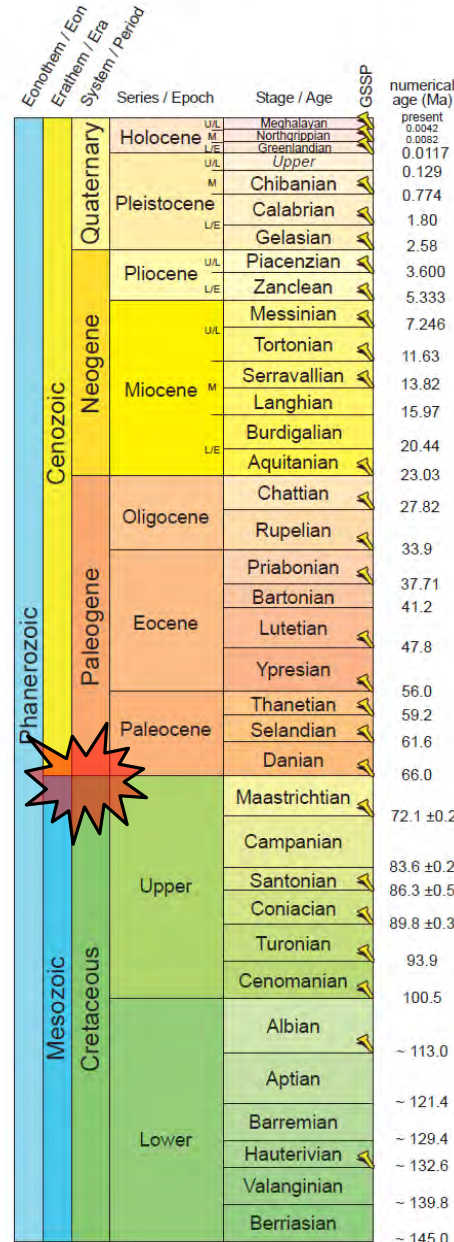


# INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

www.stratigraphy.org

International Commission on Stratigraphy

v 2022/02



Units of all ranks are in the process of being defined by Global Boundary Stratotype Section and Points (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 ratified 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 L/E (Lower/Early). Numerical ages for all systems except Quaternary, upper Paleogene, Cretaceous, Triassic, Permian, Cambrian and Precambrian are taken from 'A Geologic Time Scale 2012' by Gradstein et al. (2012), those for the Quaternary, 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.cgmw.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.



# CRETACEOUS-PALAEOGENE EXTINCTION

Also known as  
the K/Pg  
extinction event

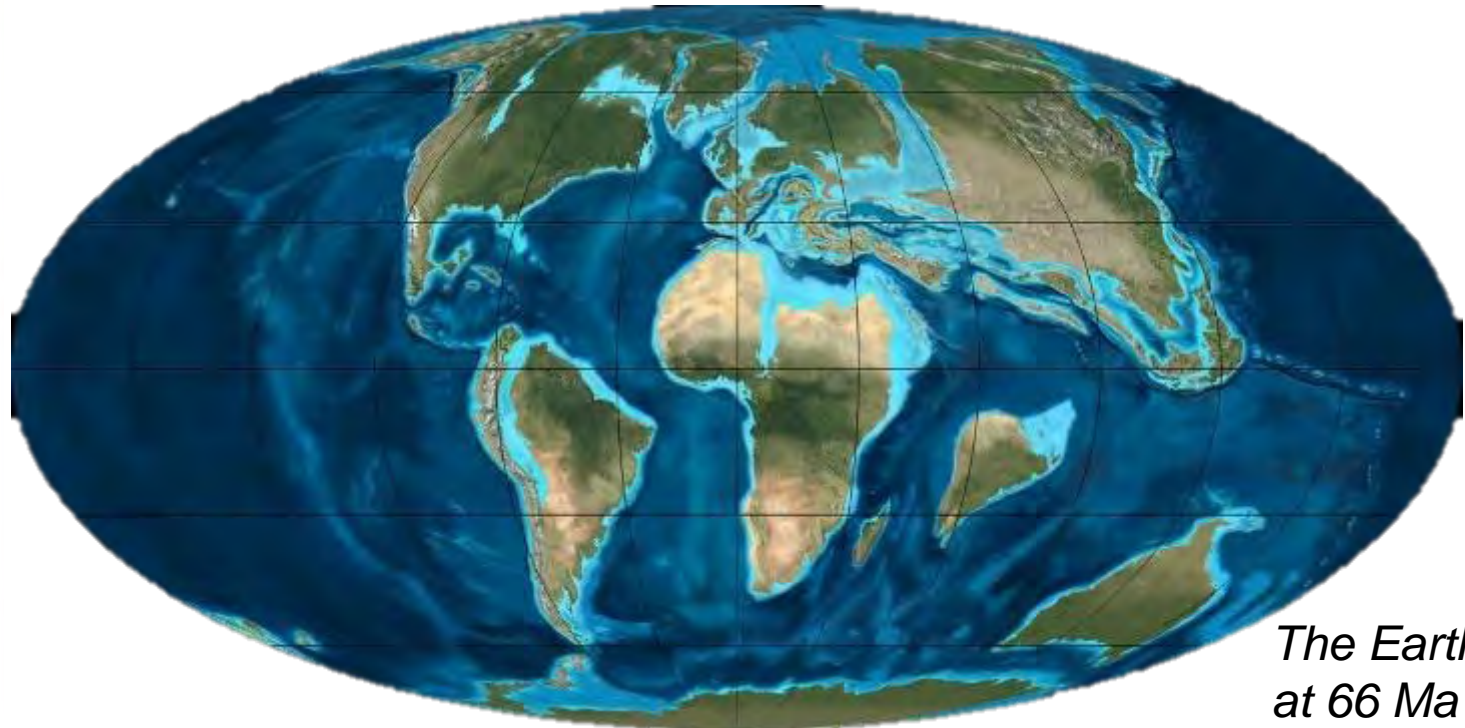
K = Cretaceous  
Pg = Palaeocene

Old terminology  
was  
Cretaceous-  
Tertiary (K/T),  
but we don't  
use this  
anymore

Eonothem / Eon		Eratheon / Era		System / Period		Series / Epoch	Stage / Age	GSSP	numerical age (Ma)
Phanerozoic	Cenozoic	Quaternary	Holocene	U/L	Meghalayan				present
				M	Northgalian				0.0042
				L/E	Greenlandian				0.0082
		Pleistocene	Upper	U/L					0.0117
				M	Chibanian				0.129
			Lower	L/E	Calabrian				0.774
					Gelasian				1.80
		Pliocene	Upper	U/L	Piacenzian				2.58
				L/E	Zanclean				3.600
					Messinian				5.333
	Neogene	Miocene	Upper	U/L	Tortonian				7.246
					Serravalian				11.63
				M	Langhian				13.82
					Burdigalian				15.97
				L/E	Aquitania				20.44
		Oligocene	Upper		Chattian				23.03
					Rupelian				27.82
		Eocene	Upper		Priabonian				33.9
					Bartonian				37.71
					Lutetian				41.2
	Mesozoic	Paleogene	Upper		Ypresian				47.8
					Thanetian				56.0
					Selandian				59.2
					Danian				61.6
		Cretaceous	Upper		Maastrichtian				66.0
					Campanian				72.1 ± 0.2
					Santonian				83.6 ± 0.2
					Coniacian				86.3 ± 0.5
					Turonian				89.8 ± 0.3
					Cenomanian				93.9
					Albian				100.5
					Aptian				~ 113.0
					Barremian				~ 121.4
		Lower	Lower		Hauterivian				~ 129.4
					Valanginian				~ 132.6
					Berriasian				~ 139.8
									~ 145.0

The dinosaurs first appeared ~240 Ma on Pangaea.

After more than 170 Myr, they went extinct at the end of the Cretaceous period, at **66 Ma**.



*The Earth  
at 66 Ma*



# CRETACEOUS-PALAEOGENE EXTINCTION

At least 50% of all species went extinct, including the dinosaurs\*.

On land, no animals larger than a dog survived, except for crocodiles and alligators.

80-90% of marine species extinct.

Half of plants extinct.

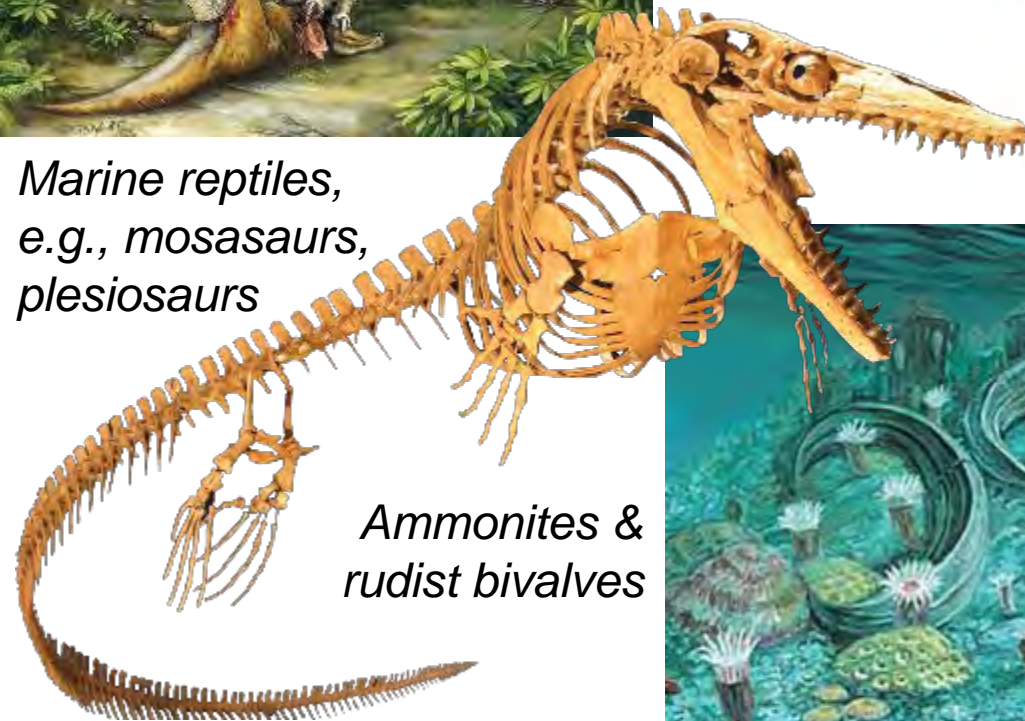
\*Technical note: all of the non-avian dinosaurs went extinct. Birds survived, and are now considered part of the Dinosauria clade of animal life.



*Variety of plants,  
all on-avian  
dinosaurs,  
pterosaurs*



*Marine reptiles,  
e.g., mosasaurs,  
plesiosaurs*



*Ammonites &  
rudist bivalves*



# CRETACEOUS-PALAEOGENE EXTINCTION

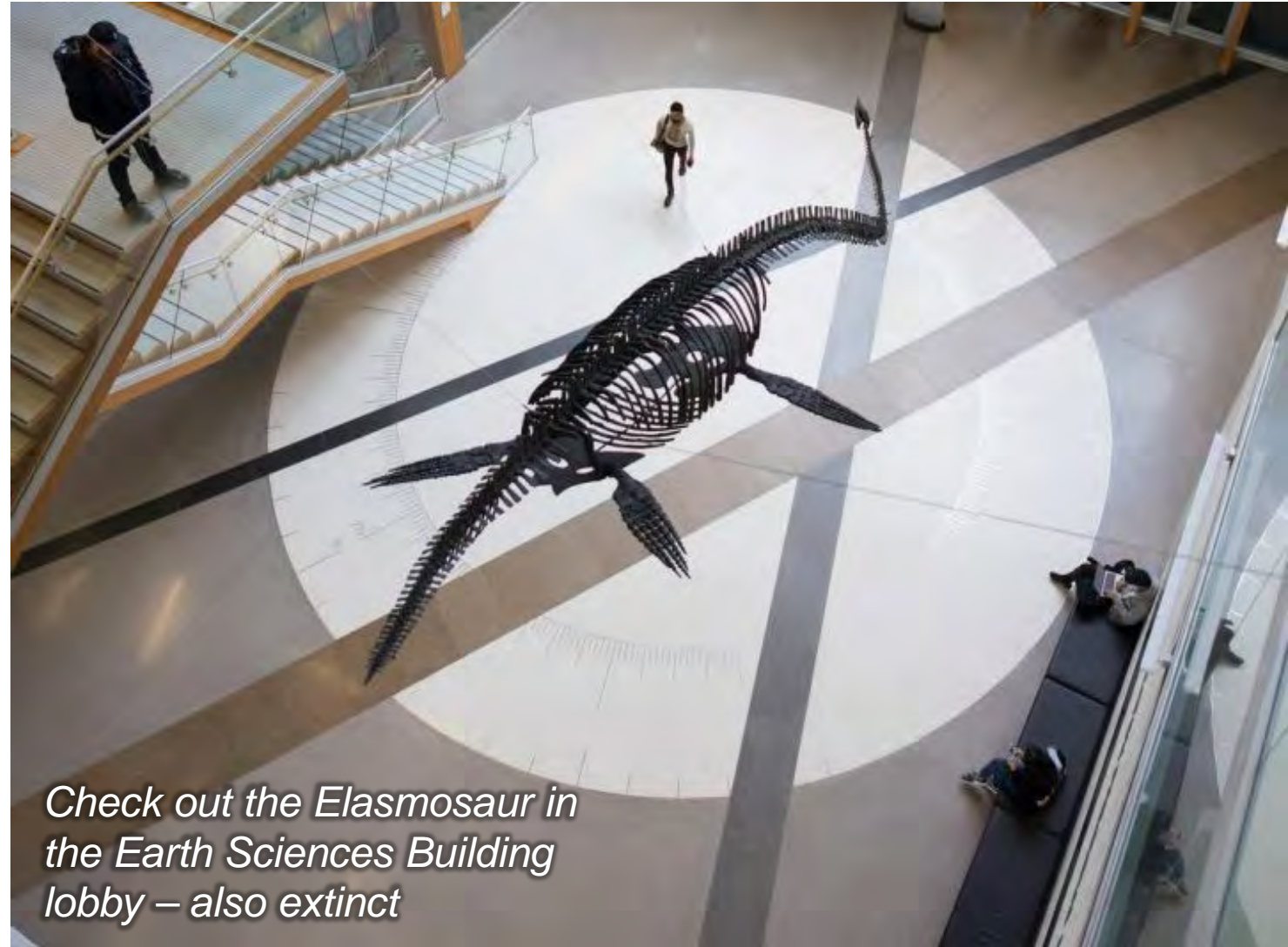
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Half of plants extinct.

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*Check out the Elasmosaurus in the Earth Sciences Building lobby – also extinct*



# CRETACEOUS-PALAEOGENE EXTINCTION

Explained with the **impact of a large asteroid** by father and son duo Walter and Luis Alvarez in 1980. This is called the **Alvarez Hypothesis**.

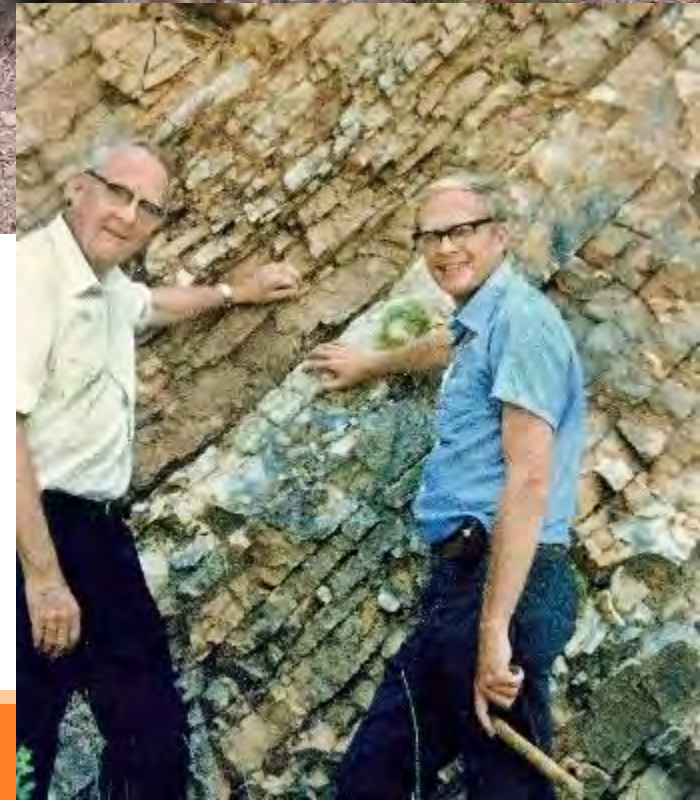
They discovered the **Iridium Anomaly**:

- There is a 1cm clay layer at the top of the Cretaceous, rich in iridium
- Iridium is very rare on Earth's surface, and this layer is enriched over 300x background levels
- Extraterrestrial objects like asteroids contain higher levels of iridium
- Suggested impact of a 10 km+ asteroid



*White layer marking the K-Pg boundary in Gubbio, Italy*

*Walter and Luis Alvarez discovered the iridium anomaly here in 1980*



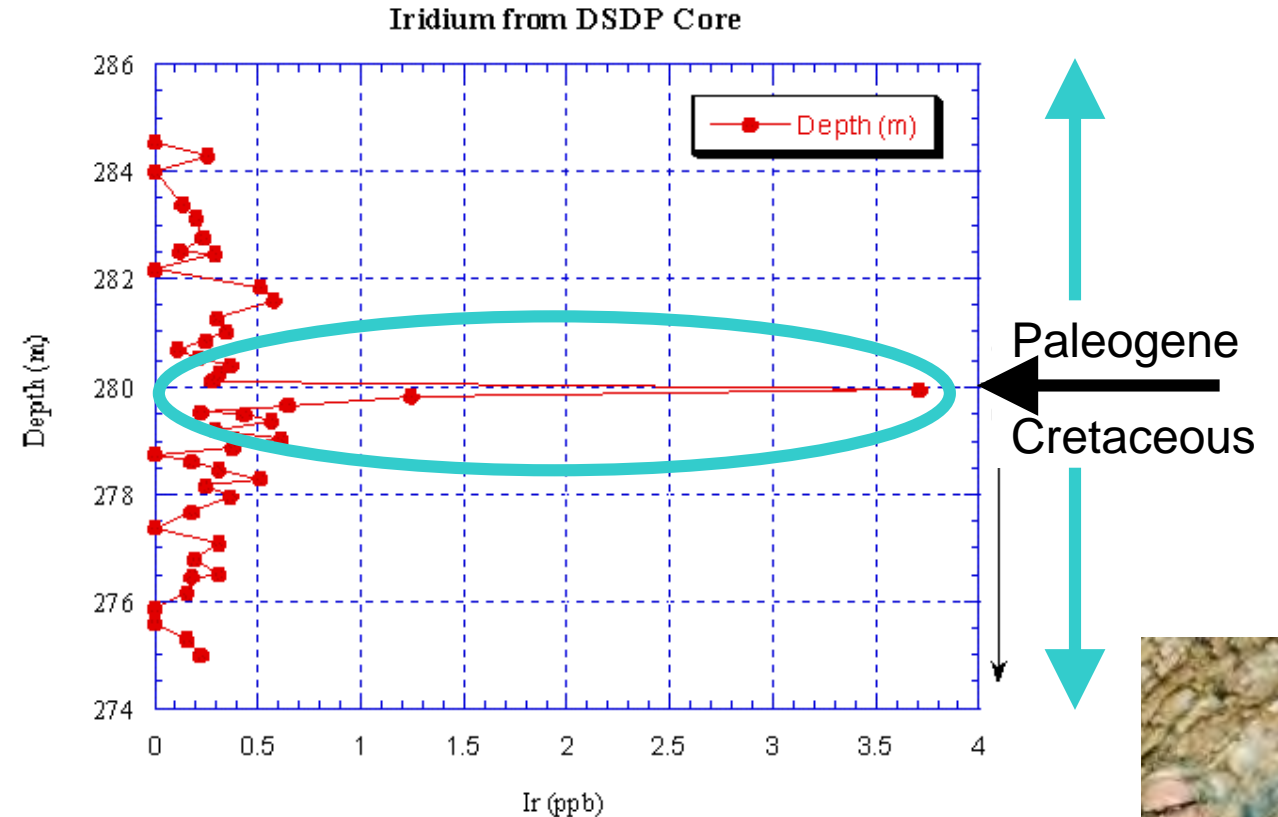


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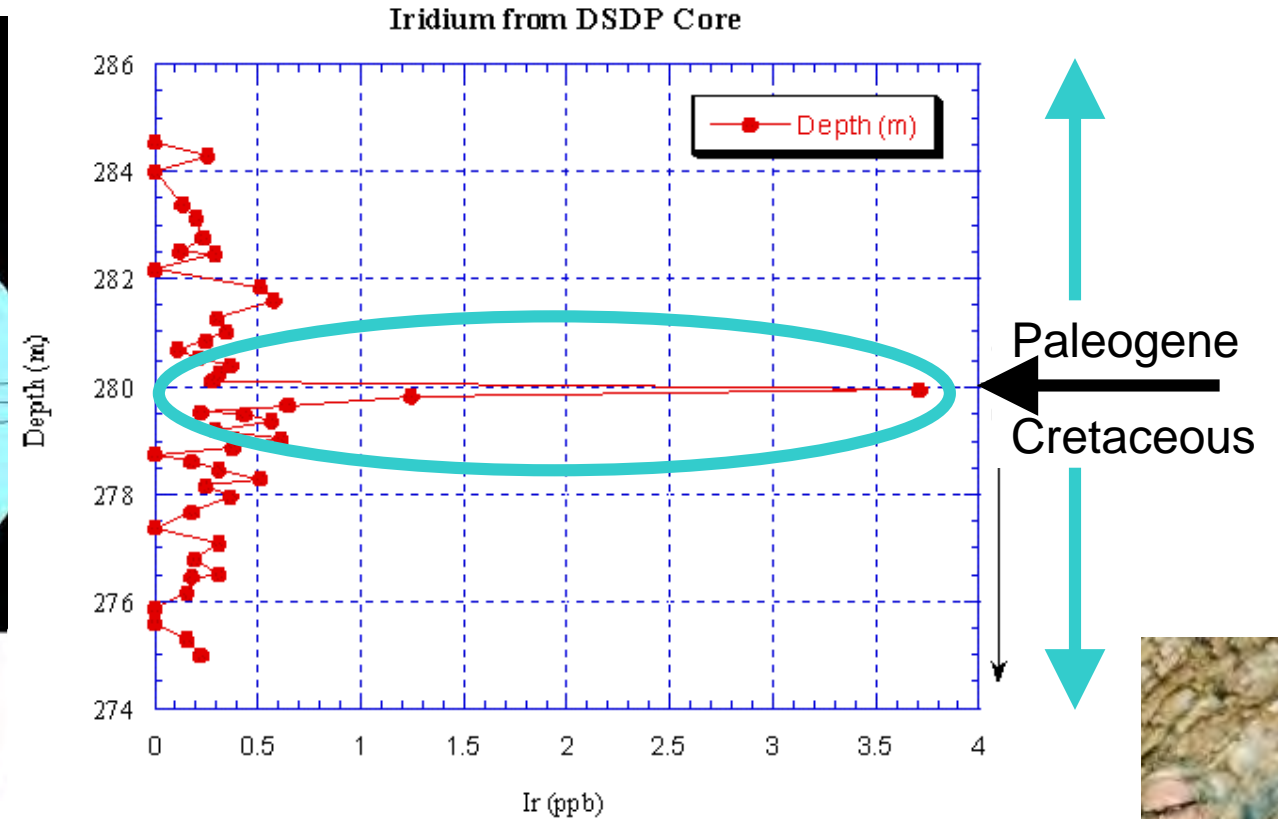
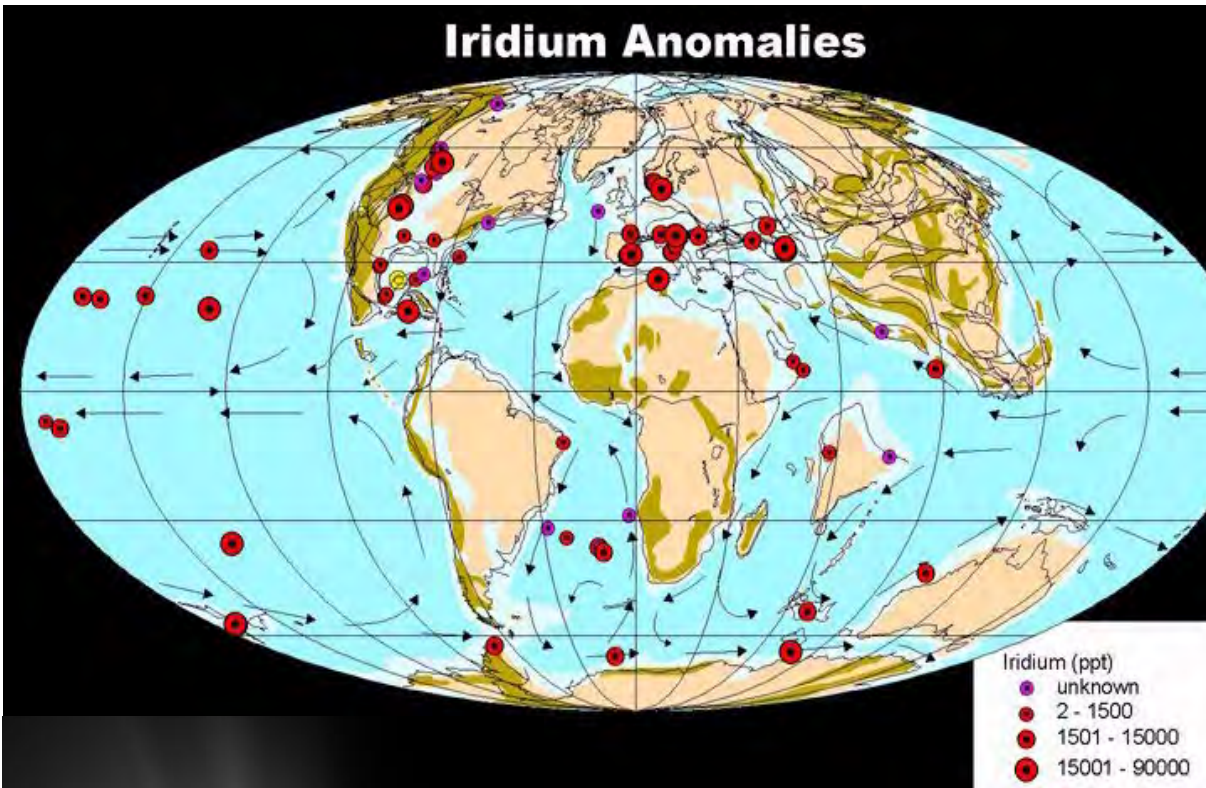
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*The Iridium Anomaly has now been found all over the world*



# CRETACEOUS-PALAEOGENE EXTINCTION



The Iridium Anomaly has been found across the world.

Missions like NASA Deep Impact (2005) confirmed that comets and asteroids contain suitable amounts of iridium





# CRETACEOUS-PALAEOGENE EXTINCTION

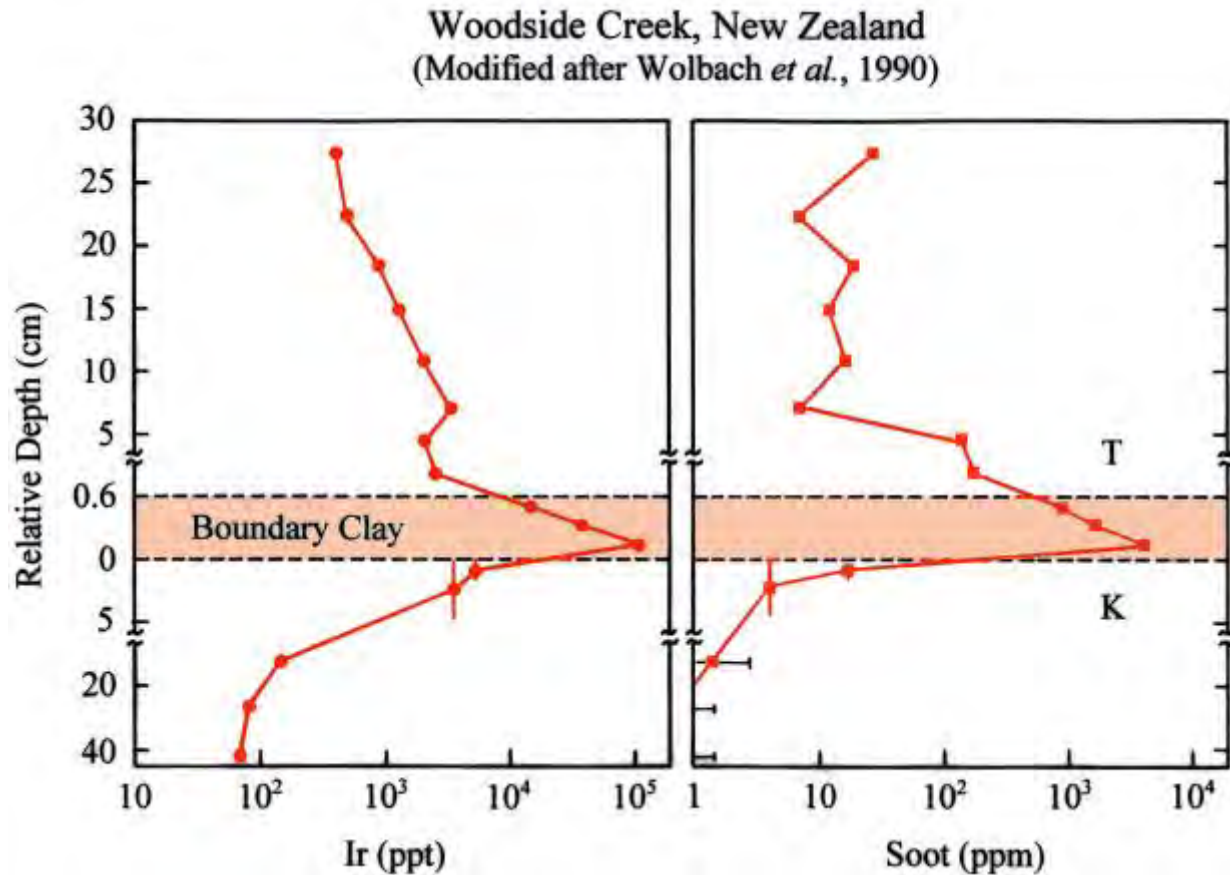
[www.youtube.com/watch?v=kpLY0YwMACE](https://www.youtube.com/watch?v=kpLY0YwMACE)

How Asteroids Really Killed The Dinosaurs - Part 2 | Last Day  
Of The Dinosaurs



# FURTHER EVIDENCE FOR A K-Pg IMPACT

**Soot** is also concentrated in the clay layer containing the iridium anomaly.



Soot is a form of black carbon produced by burning of organic matter.

This suggests there were massive forest fires on a global scale.

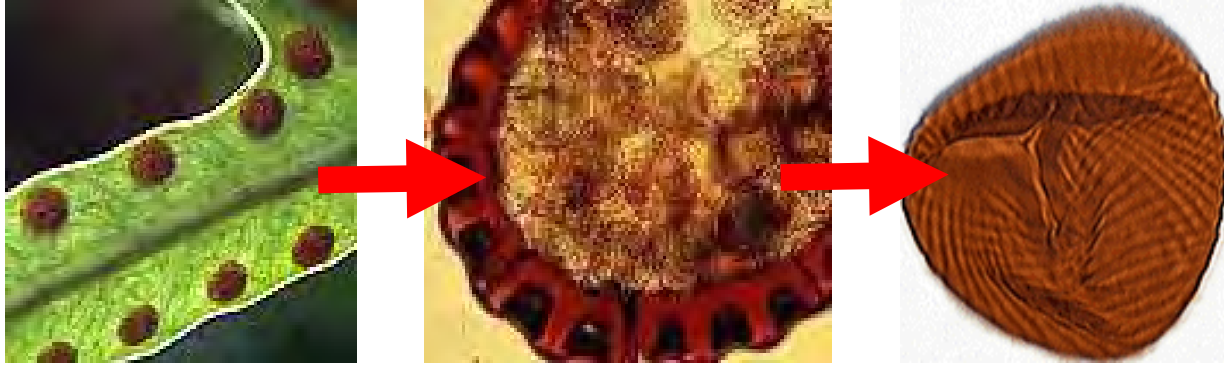




# FURTHER EVIDENCE FOR A K-Pg IMPACT

**Fern spores** dominate the sediment samples at the K-Pg boundary.

Ferns are the first plants to colonise burned landscapes, so they are good proxies for forest fires.



A fern spore



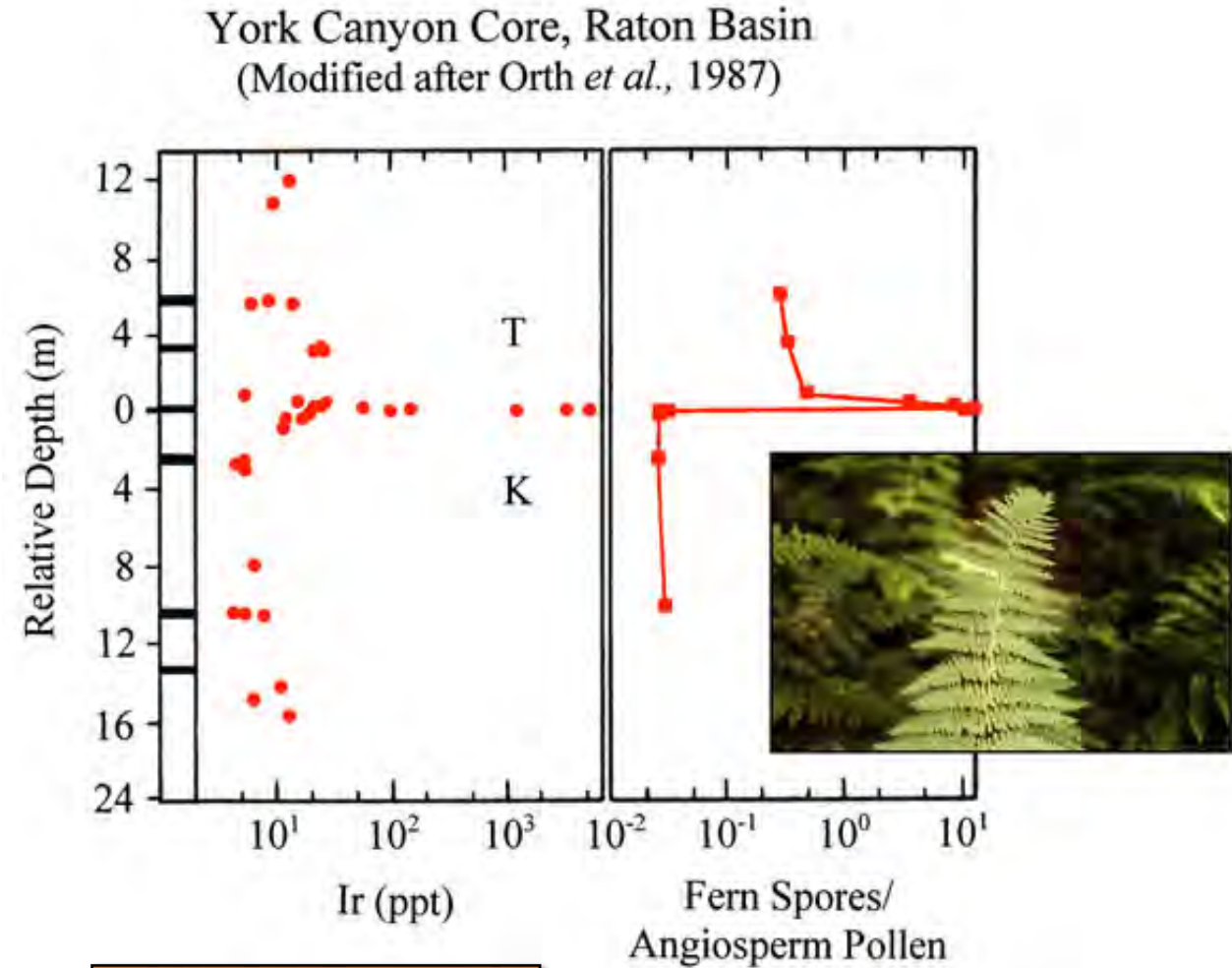
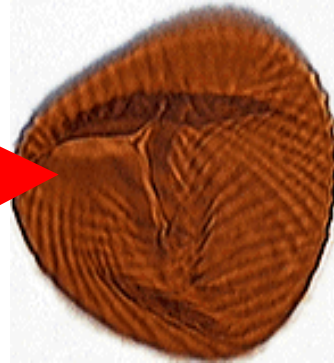
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This is called  
the **Fern Spike**

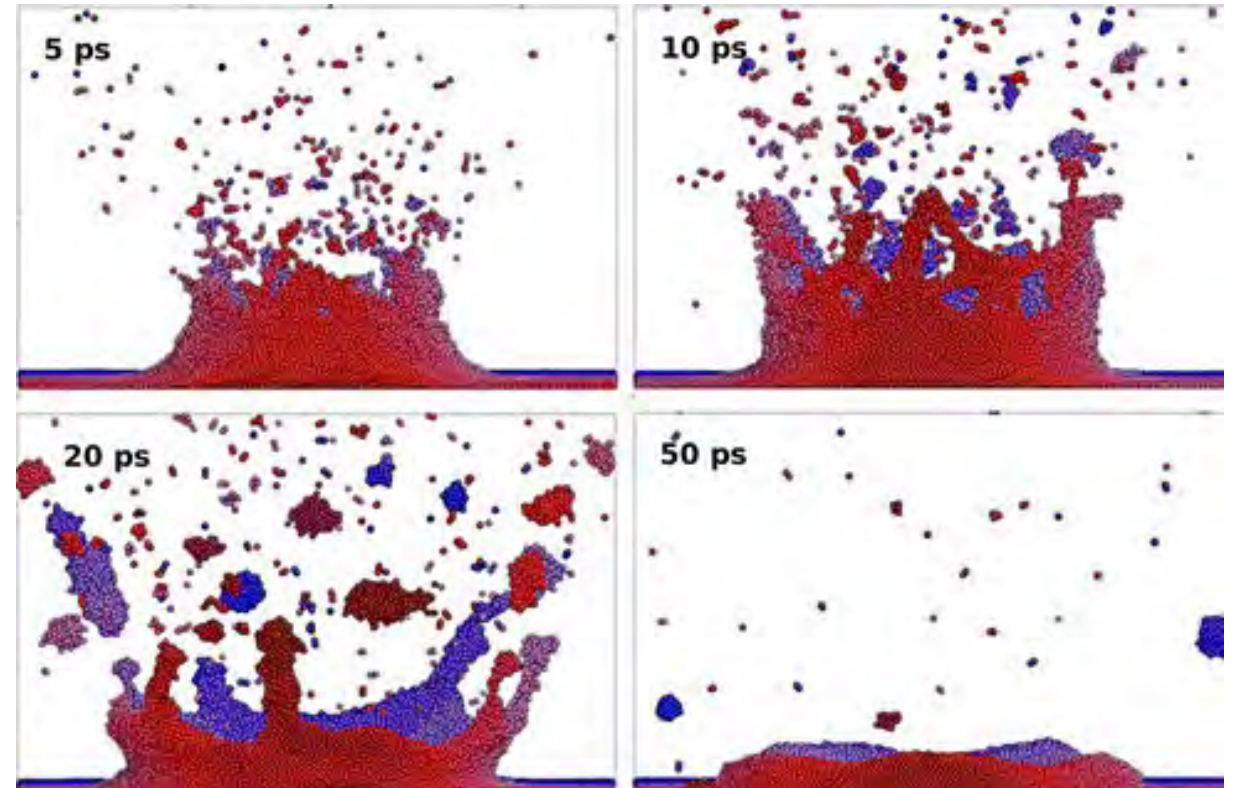


# FURTHER EVIDENCE FOR A K-Pg IMPACT

We also find **tektites** at the K-Pg boundary, in many different locations.

**Tektites** are natural glass particles produced by melting rocks during an impact.

They have aerodynamic shapes as they travel through the air and cool.

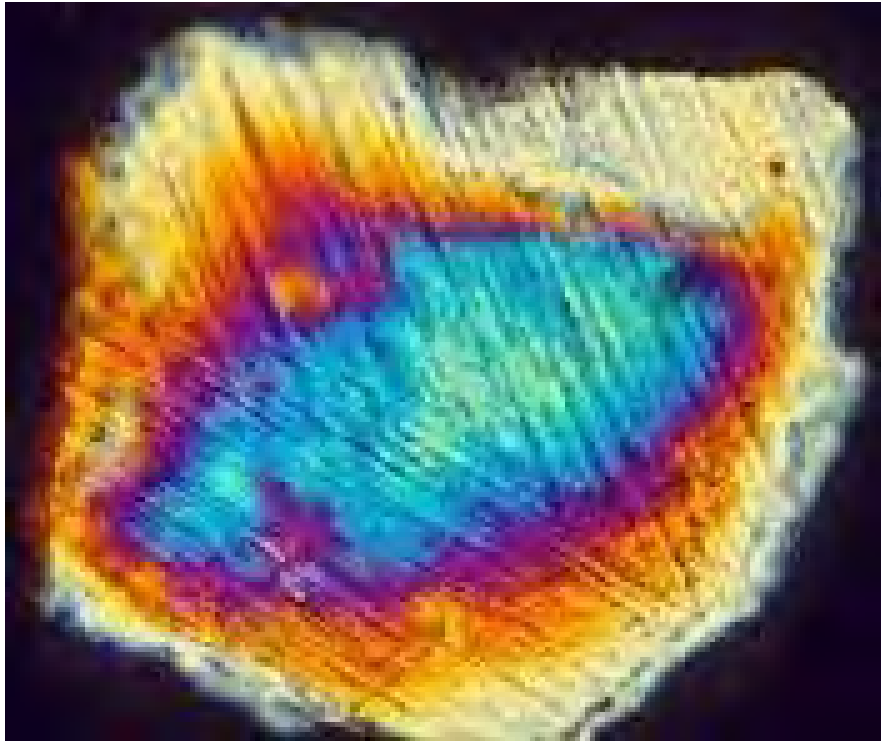


Tektites suggest the impact was large

# FURTHER EVIDENCE FOR A K-Pg IMPACT

Many K-Pg sections contain **Shocked Quartz**, with lots of internal fractures.

These fractures are thought to form when extraterrestrial impacts produce intense seismic waves that shatter rock (equivalent to a M ~16 earthquake).



*The cross-hatched lines in this grain of quartz are called **shock lamellae**.*

*Shock lamellae are visible under polarized light.*

*The lamellae are produced by enormously high pressures, where the crystal structure turns to glass.*

*Shocked quartz is only produced during impacts.*

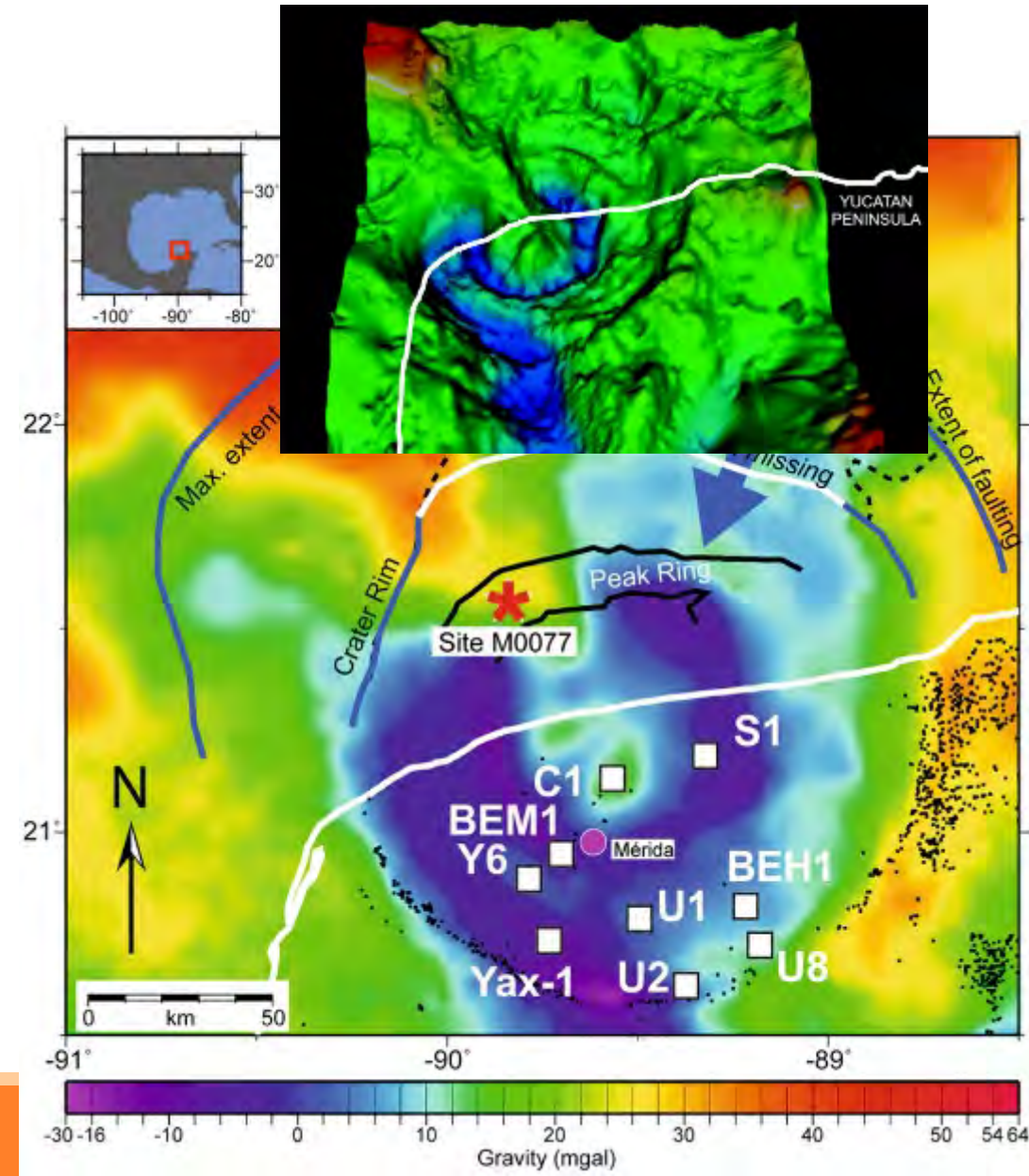


# FURTHER EVIDENCE FOR A K-Pg IMPACT

Geophysics has revealed a large crater at the Yucatan Peninsula, Mexico. This is the **Chicxulub Impact Crater**.

- 200 km diameter
- Thick layers of shocked quartz and tektites
- Tsunami deposits

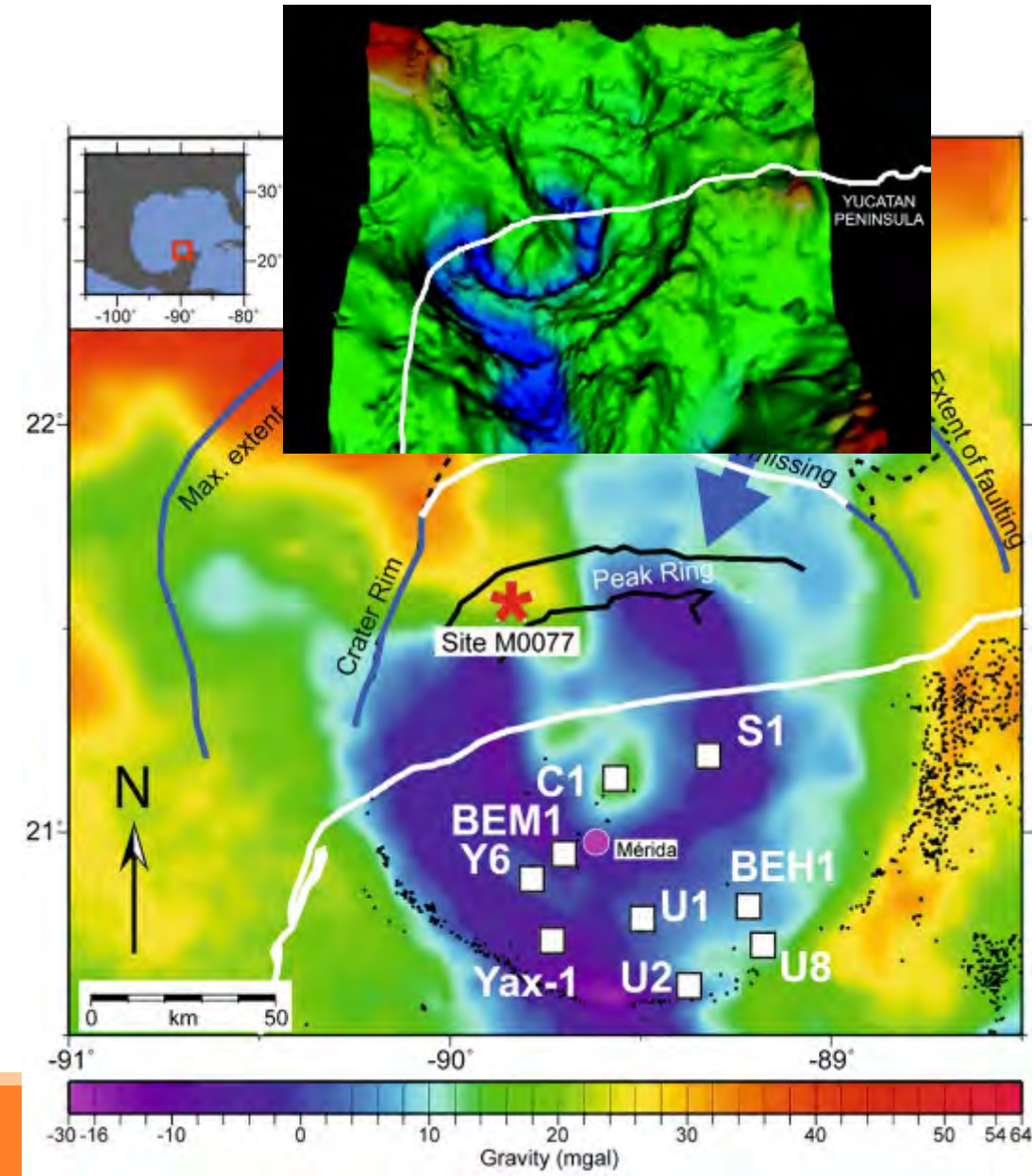
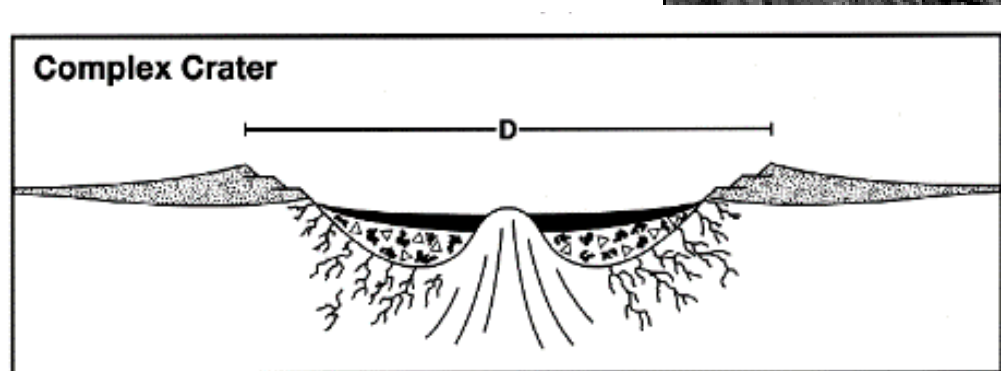
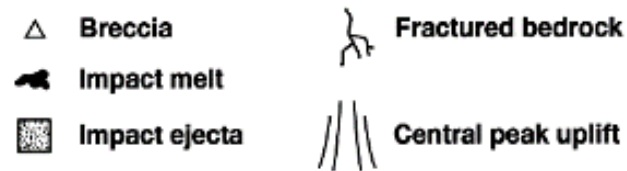
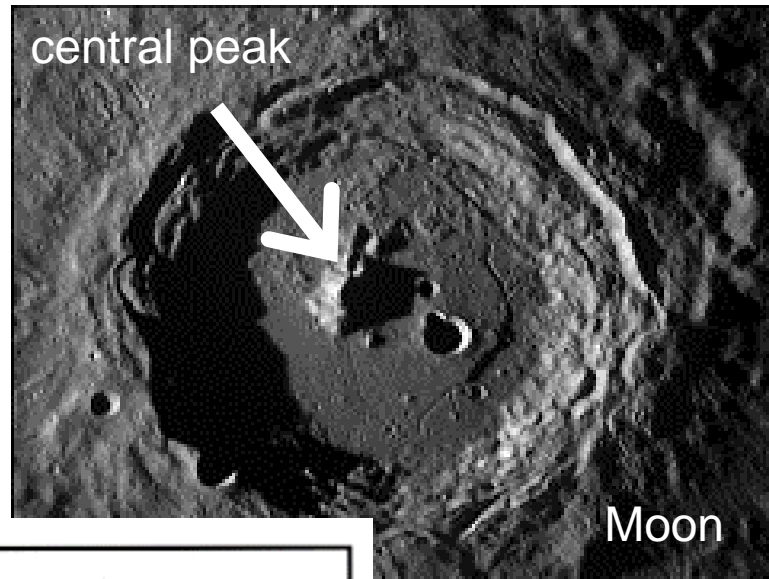
The crater was formed 66 Myr ago by a ~10 km wide asteroid (about the size of Mount Everest!) that probably originated in the outer asteroid belt.



# FURTHER EVIDENCE FOR A K-Pg IMPACT

The Chicxulub Crater structure is very typical of **large complex craters**.

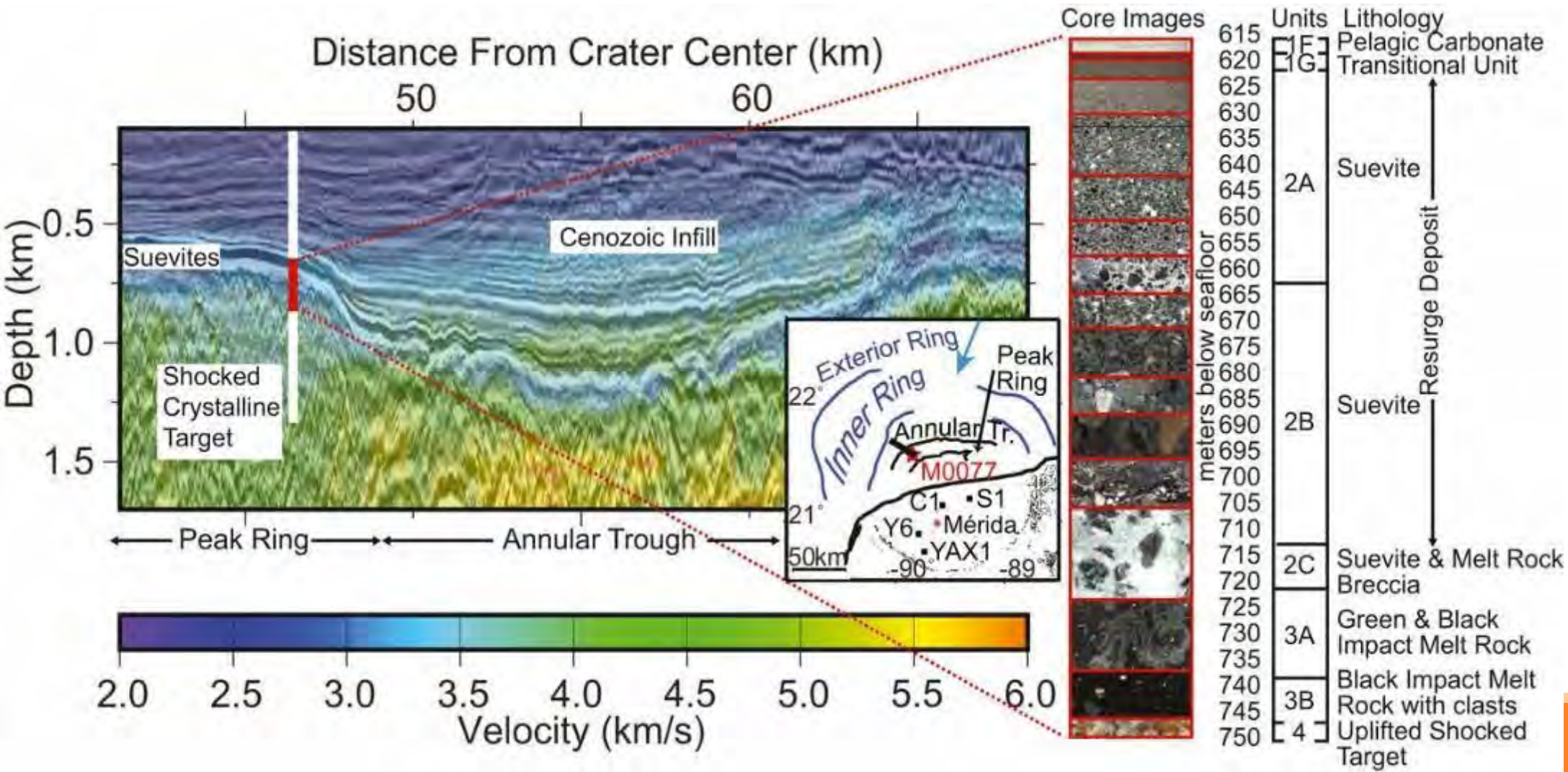
- Concentric ringed structure
- Central peak





# FURTHER EVIDENCE FOR A K-Pg IMPACT

The Chicxulub Crater has been drilled, and geologists found a rock called **suevite**.



*Suevite is a breccia (fractured rock) formed during impacts.*

*Chunks of rock are thrown up into the air but do not melt, so land back down in sediments.*



# FURTHER EVIDENCE FOR A K-Pg IMPACT

In April 2022, incredible fossil discoveries were reported from the **Tanis Fossil Site** in North Dakota.



What did geologists find?

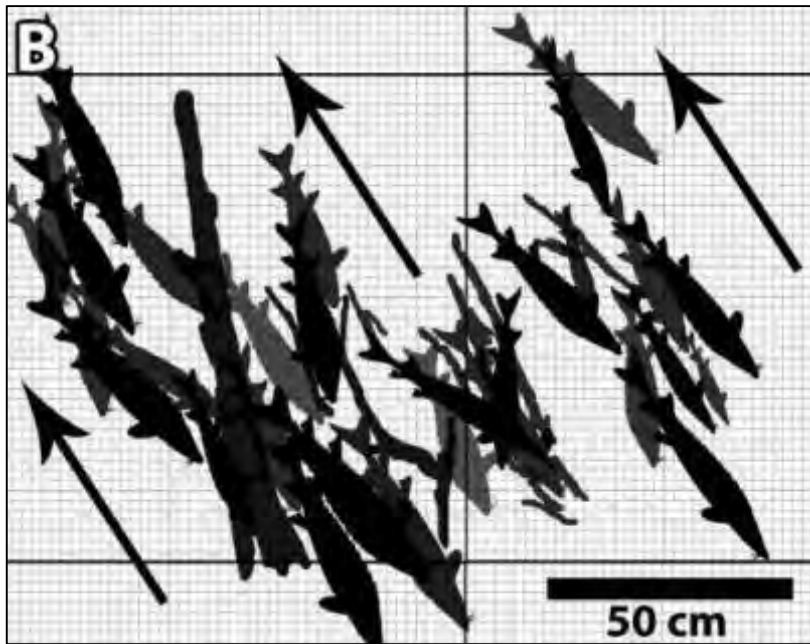
- Broken remains of dinosaurs
- Broken fish fossils with tektites in their gills
- ‘Log-jam’ of marine reptiles many km inland from the sea





# FURTHER EVIDENCE FOR A K-Pg IMPACT

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*Log-jam of marine reptiles far inland –  
“like a car-crash frozen in time”*





# FURTHER EVIDENCE FOR A K-Pg IMPACT

In April 2022, incredible fossil discoveries were reported from the Tanis Fossil Site in North Dakota.



*Fossil fish have been found that were ripped apart.*

*The fish also contain tektites in their gills, which would have rained down across North America as they tried to breathe.*



# FURTHER EVIDENCE FOR A K-Pg IMPACT

In April 2022, incredible fossil discoveries were reported from the Tanis Fossil Site in North Dakota.



*Thescelosaurus leg ripped from the body of the dinosaur.*

*The skin is preserved on the fossil because nothing was alive to scavenge the body.*



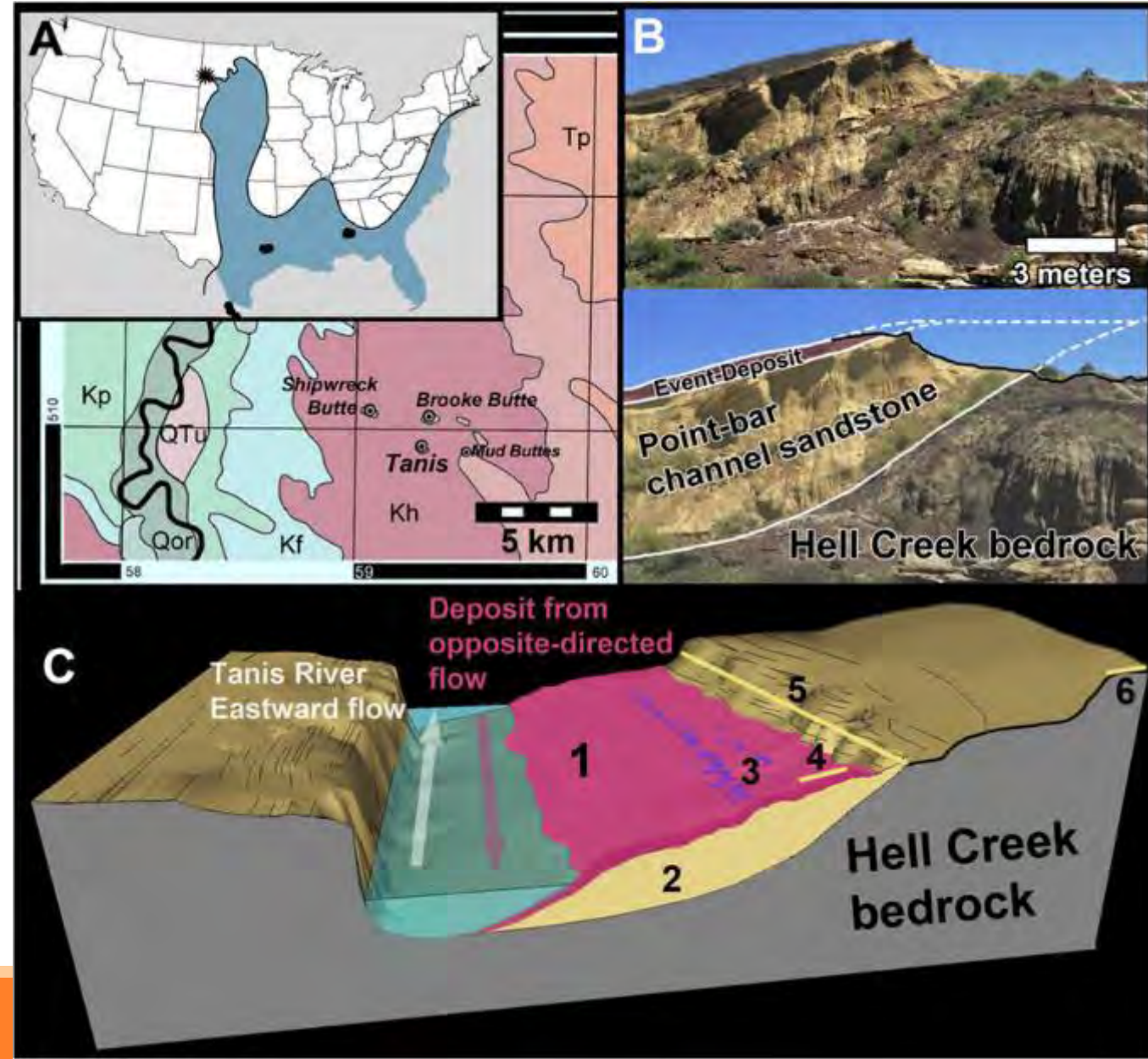


# FURTHER EVIDENCE FOR A K-Pg IMPACT

In April 2022, incredible fossil discoveries were reported from the **Tanis Fossil Site** in North Dakota.

This fossil site was only discovered in the US in 2022!

There are still lots of incredible geological discoveries waiting to be found.





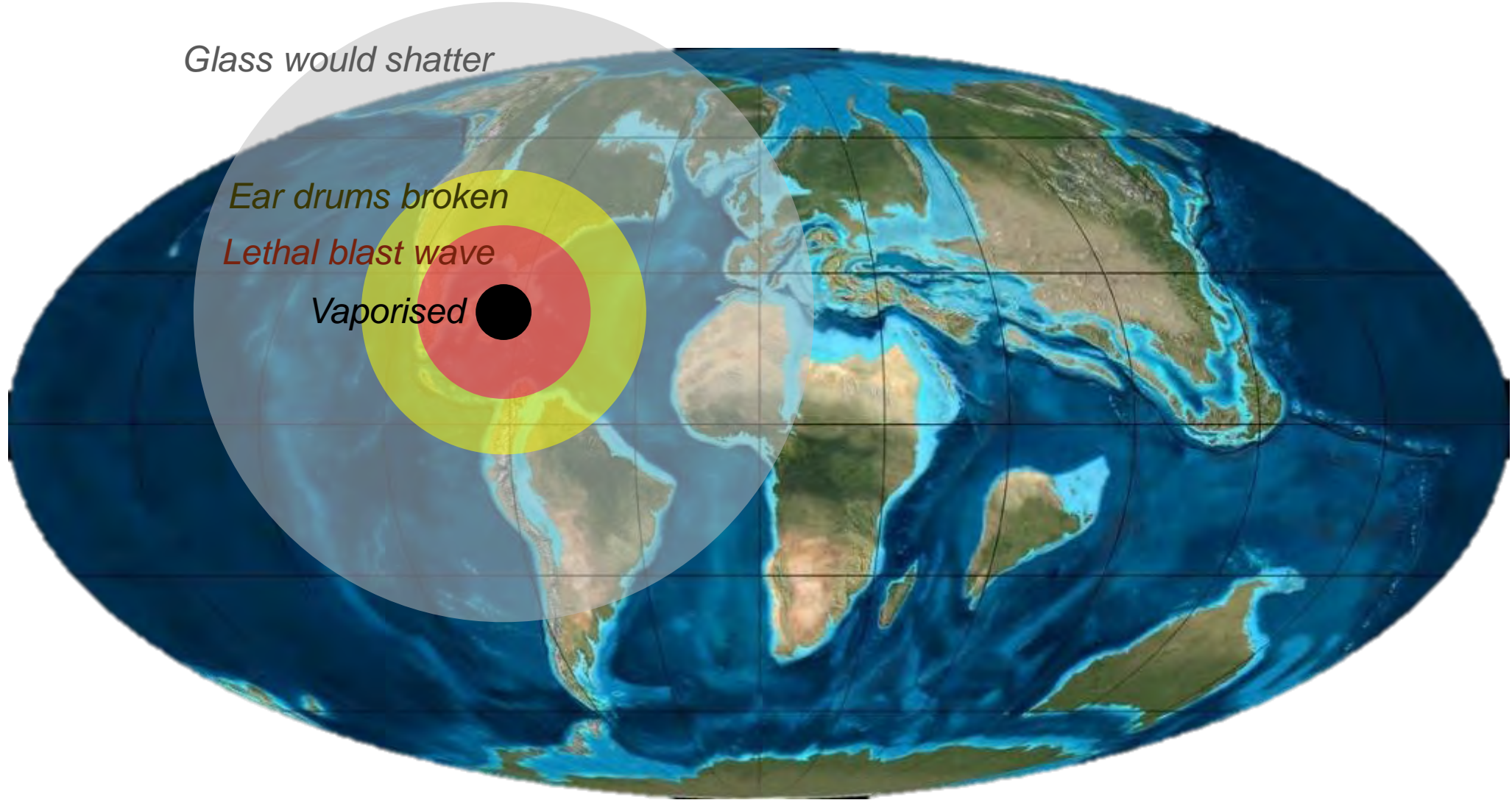
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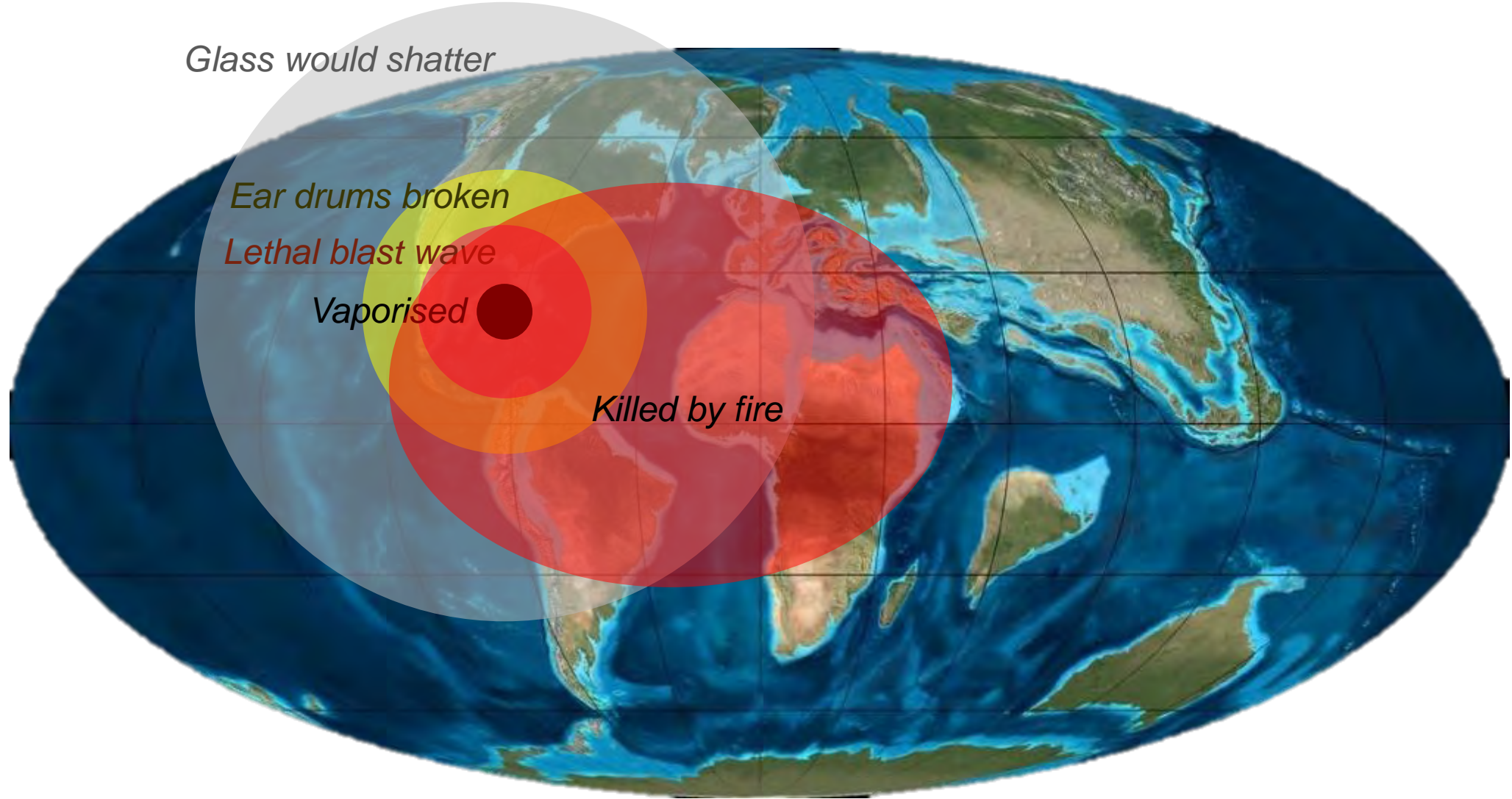


# CRETACEOUS-PALAEOGENE EXTINCTION

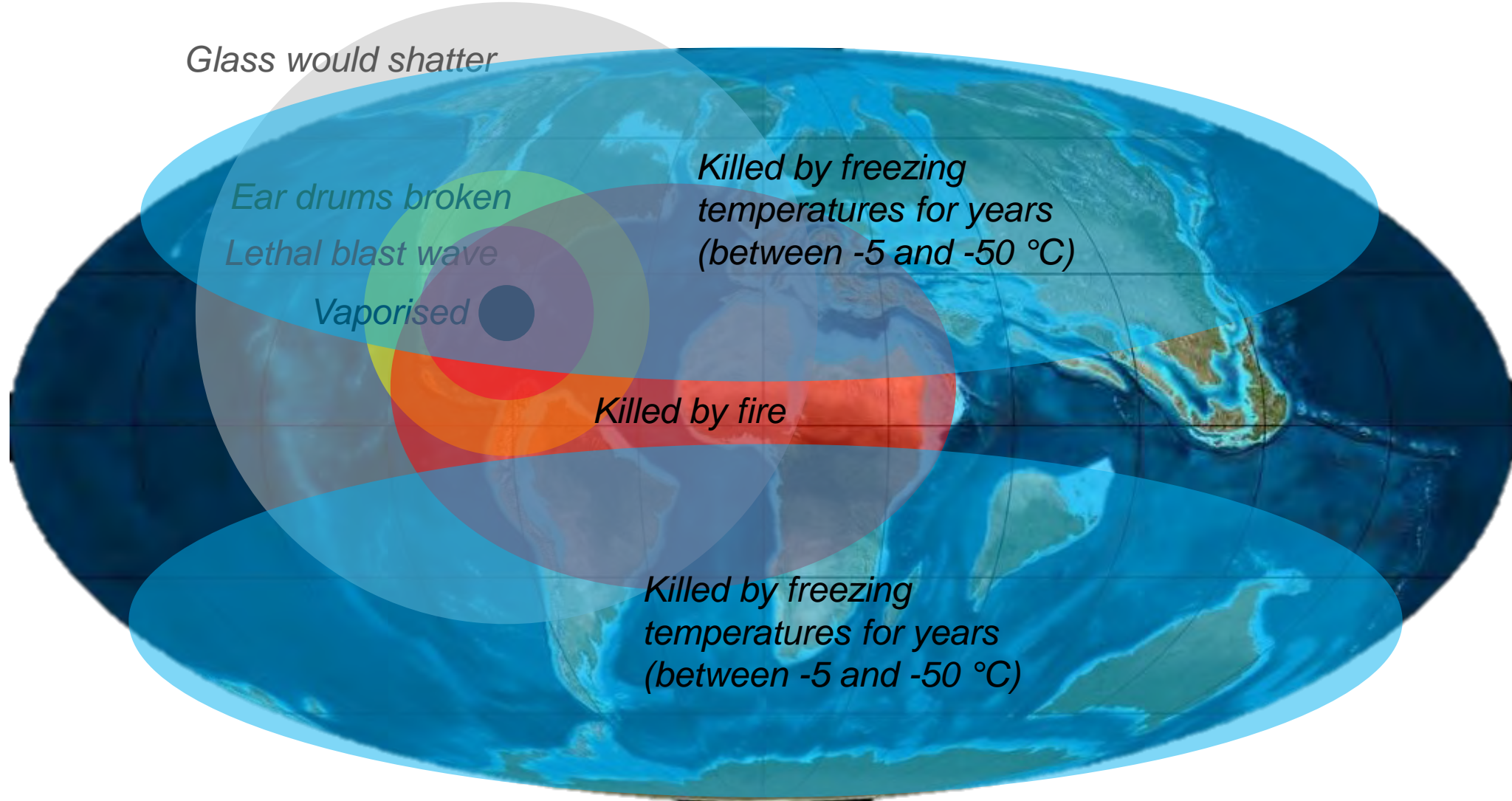




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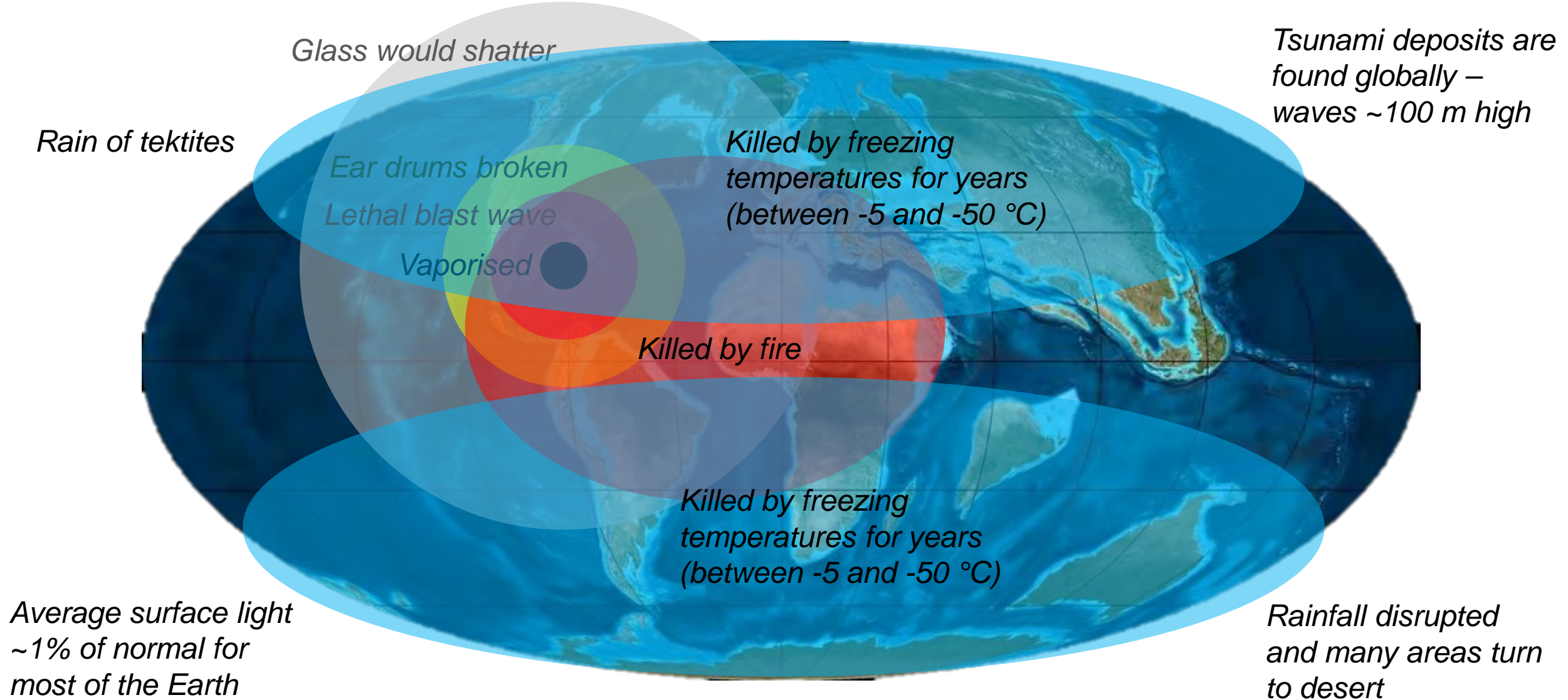


# CRETACEOUS-PALAEOGENE EXTINCTION





# CRETACEOUS-PALAEOGENE EXTINCTION



# AFTER THE IMPACT

Millions of tonnes of dust in the atmosphere would have **cooled the planet** and caused an 'impact winter' for years.

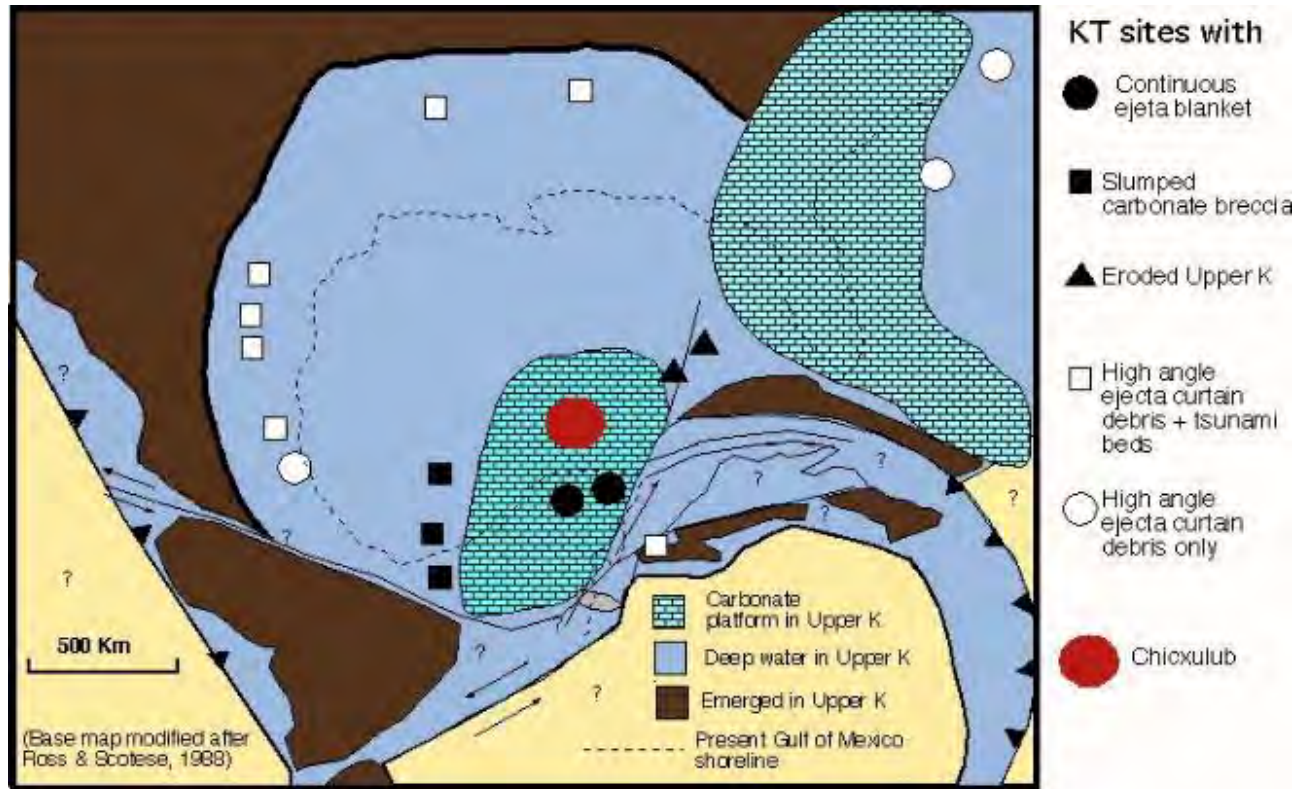
Dust would have blocked sunlight and **photosynthesis stopped**.

The fossil record indicates that biological production stopped and **food chains collapsed** on land and in the oceans.





# AFTER THE IMPACT

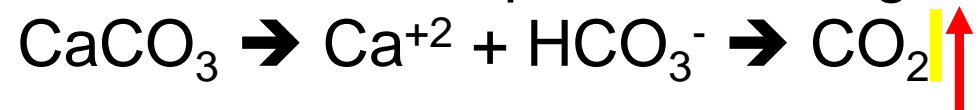


The asteroid hit a carbonate platform full of limestones.

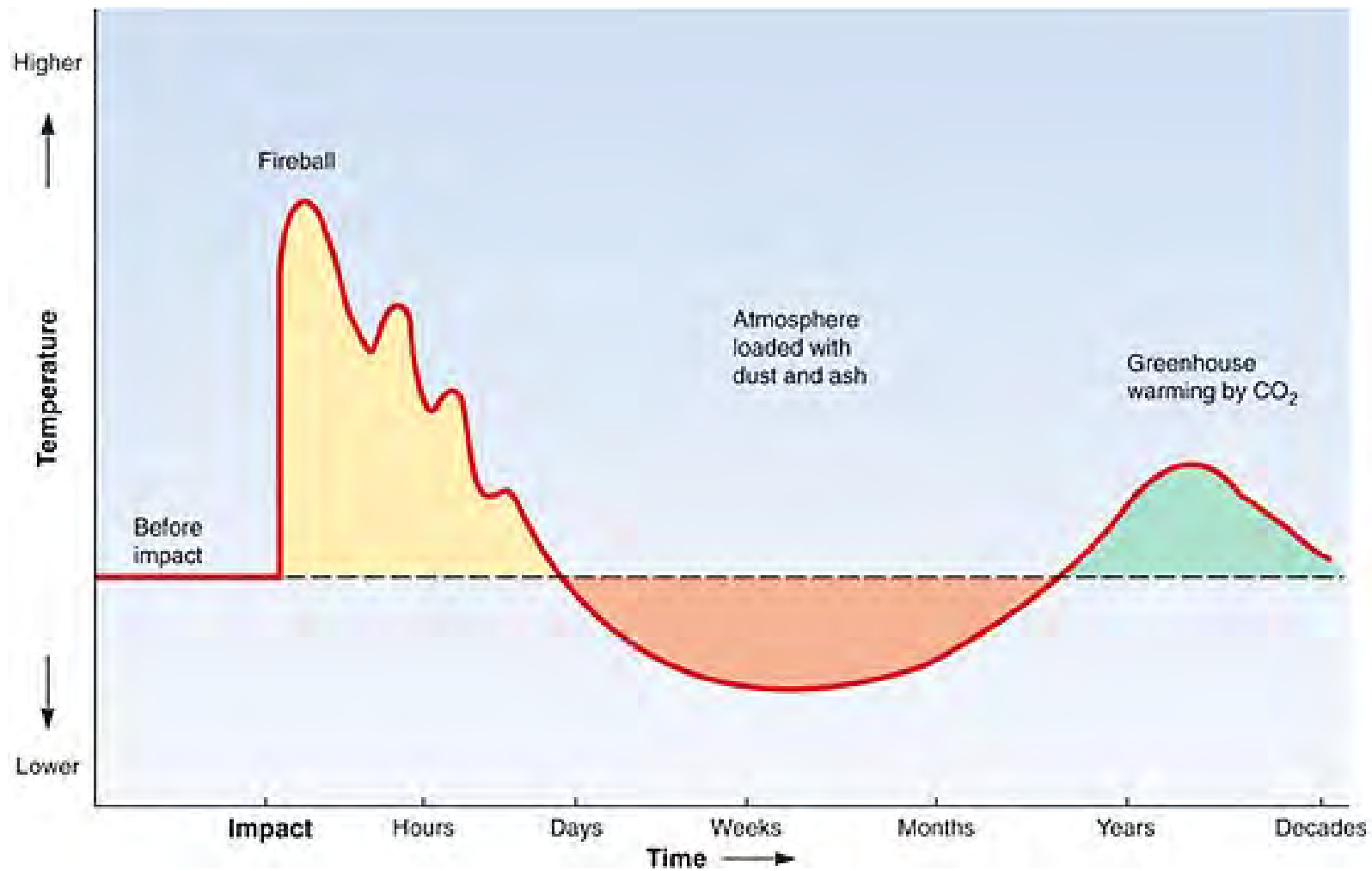
This increased atmospheric CO<sub>2</sub> and the greenhouse effect.

After the 'impact winter', average global temperatures rose 2-8 °C compared to before the impact, and this lasted for decades.

Yucatan limestones were vaporized during the impact:



# AFTER THE IMPACT





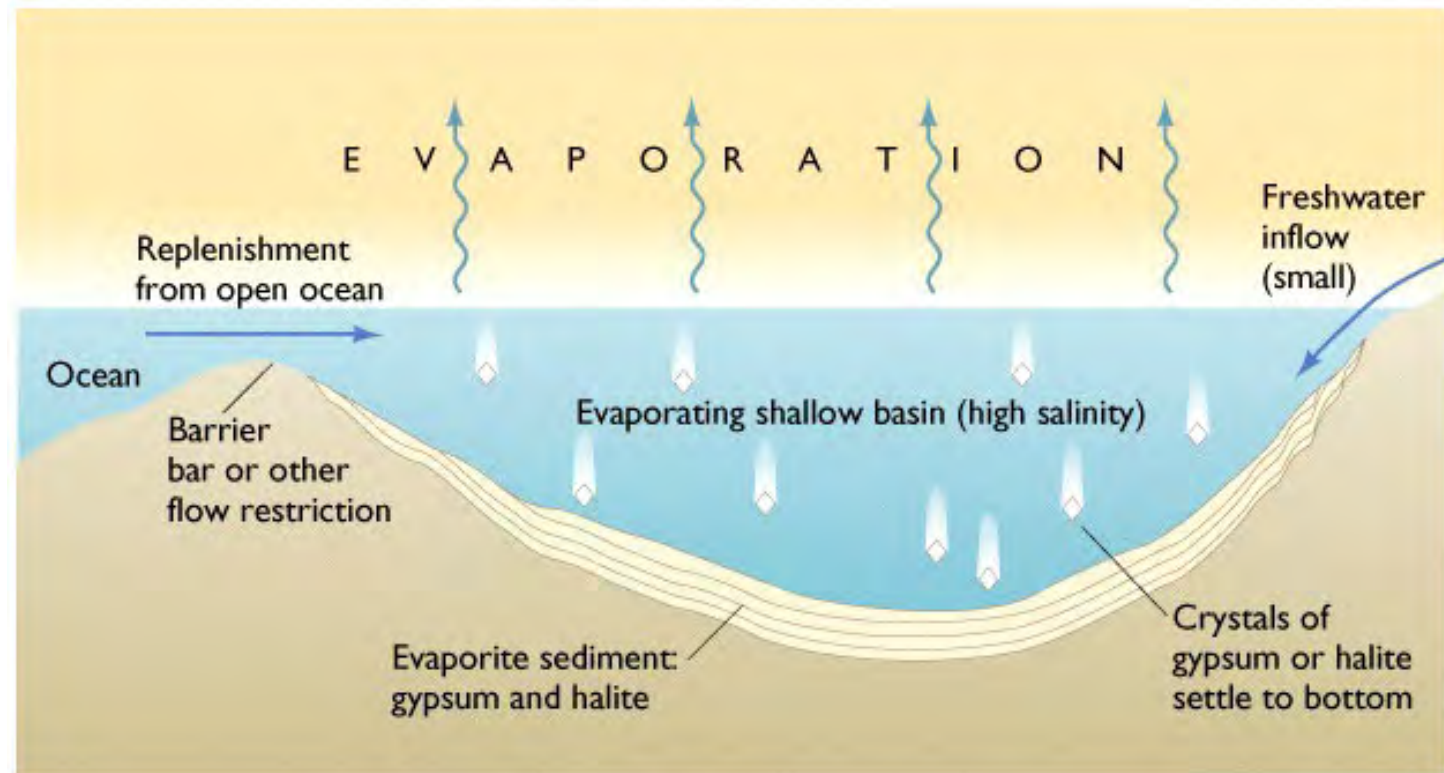
# AFTER THE IMPACT

The Yucatan Peninsula also contained **evaporites** as high rates of evaporation in the tropical seas led to precipitation of salts.

Evaporite minerals like **gypsum** are rich in sulphates.

When these sulphates were vaporized, they added  $\text{SO}_2$  to the atmosphere, which combines with water to form **sulphuric acid rain**.

Acid rain devastated primary producers (e.g., phytoplankton).



Salt Flats, Death Valley



# THE DECCAN TRAPS

The **Deccan Traps** erupted in India at 66.3 Ma – another **large igneous province** with huge amounts of flood basalt lava (~1 million km<sup>3</sup>).

This eruption may also have contributed to the Cretaceous-Palaeogene mass extinction by releasing CO<sub>2</sub> and SO<sub>2</sub>.

We know the Deccan Traps and the impact coincided because we find the iridium clay layer in the basalts.

After the impact, **global volcanic activity may have doubled**, adding to climate disruption and stress on the biosphere.



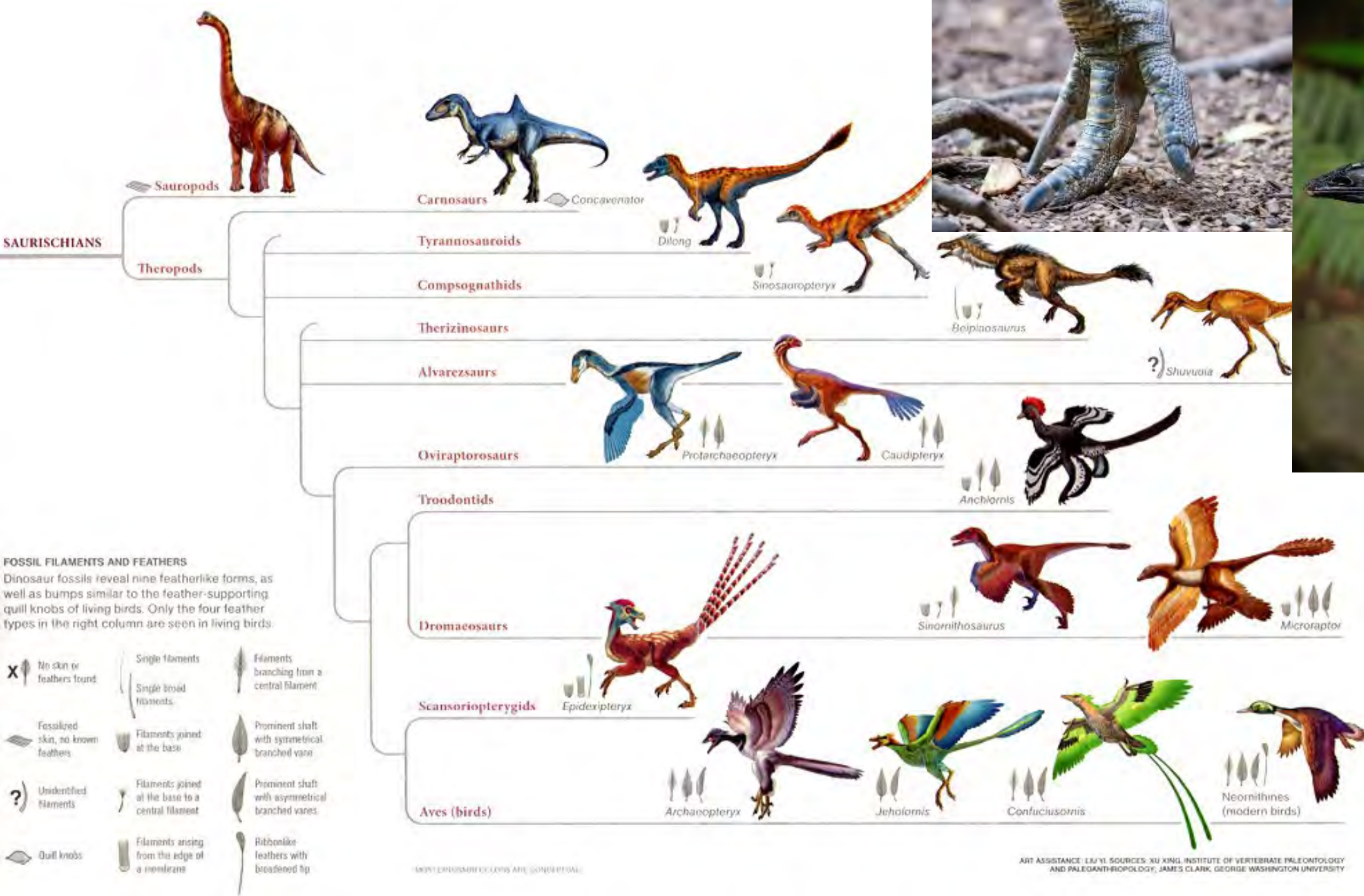


# CRETACEOUS-PALAEOGENE EXTINCTION

- The Cretaceous biosphere was already stressed – flood basalts had started erupting at the Deccan Traps, and the breakup of Pangaea meant that environments were changing.
- The **asteroid impact** was the main cause of the mass extinction, especially for the dinosaurs.
- The creatures best able to hide, burrow, hibernate and survive the conditions after the impact were **mammals**.
- Technically: only the **non-avian dinosaurs** went extinct...



*K/Pg sediments, Horseshoe Canyon, AB*



Cassowary

Modern birds are the only surviving group of dinosaurs.



# IMPACTS 3

## Impacts and the Extinction of the Dinosaurs

Dr Mitch D'Arcy

# SUMMARY

1. The Cretaceous-Palaeogene (K/Pg) mass extinction happened at 66 Ma, and involved the extinction of 50%+ of all species, including the non-avian dinosaurs, pterosaurs, many marine reptiles, ammonites, rudist reefs, half of plants, and much more.
2. The biosphere was stressed at the end of the Cretaceous, but the main cause of the K-Pg extinction was an asteroid impact, known as the Alvarez Hypothesis.
3. There is a growing body of evidence to support the Alvarez/impact hypothesis.
4. The impact would have caused a cascade of environmental and ecological collapses. Nonetheless, life persisted and the K-Pg mass extinction paved the way for the rise of the survivors: the mammals.

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