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# THE END-PERMIAN MASS EXTINCTION

CHAPTER 4 IN *THE ENDS OF THE WORLD: VOLCANIC APOCALYPSES,  
LETHAL OCEANS, AND OUR QUEST TO UNDERSTAND EARTH'S MOST  
MASS EXTINCTIONS*, BY PETER BRANNEN

**CLASSIFIED**

Presented by Samantha & instead Santez

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# CASE FILE CONTENTS

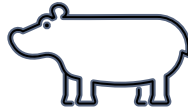
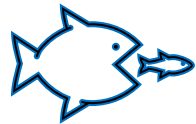
☐ Set the Scene: what did the Earth system look like during the Permian Period?

☐ Pangaea / Continental Drift

☐ Global Climate

☐ Life on Land

☐ Life in the Oceans



☐ Context: Mass Extinctions in Earth History

☐ What does this look like in the scientific record?

☐ How do we study it?



☐ Suspects:

☐ Asteroid?

☐ Carbon Dioxide?

☐ Volcanism?

☐ Ocean Acidification?

☐ Green Slime?



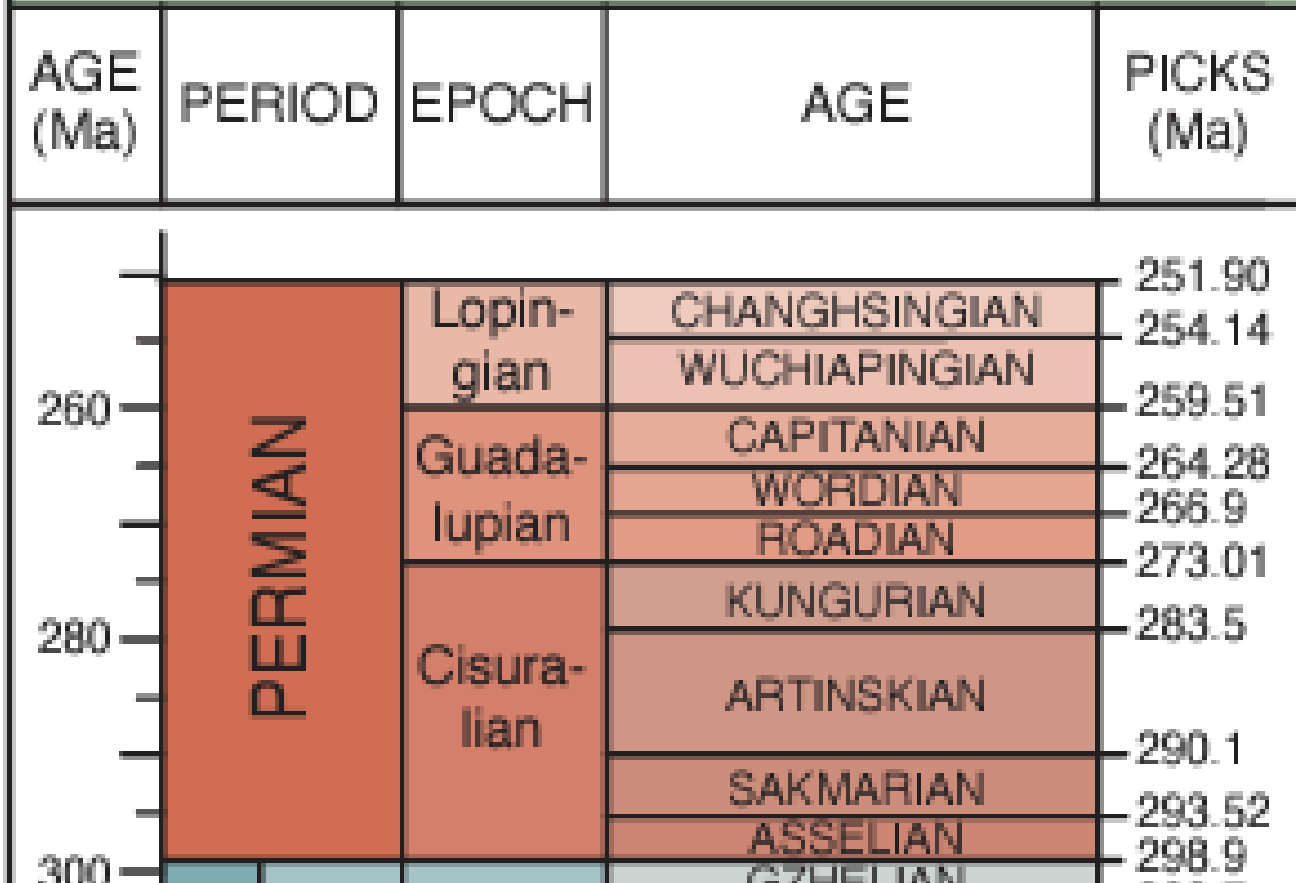
☐ Aftermath: How does life emerge from a global catastrophe?

☐ Surviving species

☐ What can we learn from events like the End-Permian mass extinction?

# PALEOZOIC

How long did the Permian Period last and how long ago did it end?



## Forms of life!

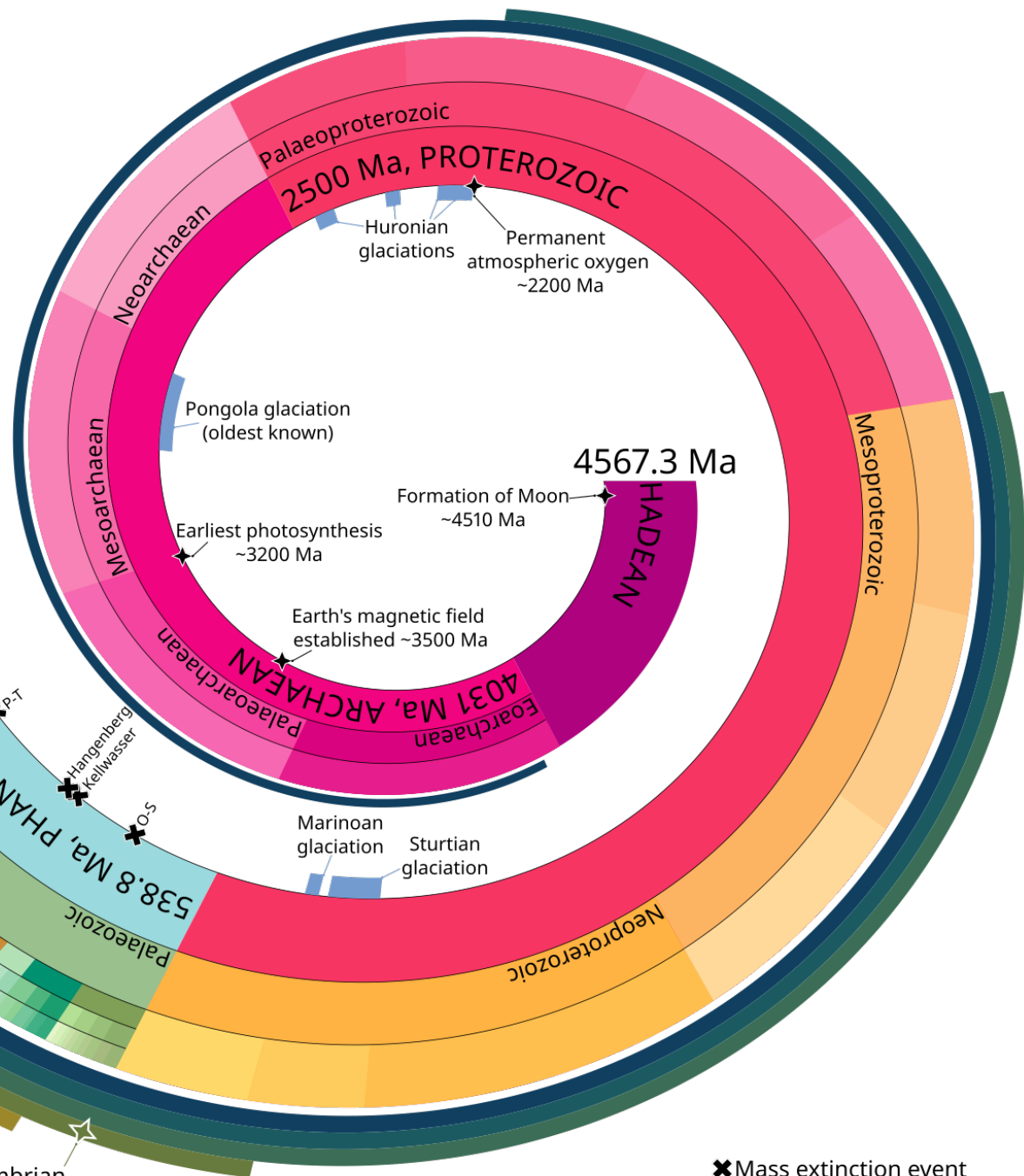
Hominins, 2 Ma  
 Mammalia, ~225 Ma  
 Non-avian dinosaurs, ~243-66 Ma  
 Land plants, ~500 Ma  
 Animalia, ~650 Ma  
 Multicellular life, ~1600 Ma  
 Eukaryotes, ~2200 Ma  
 Prokaryotes, ~4000 Ma

STAGE / AGE  
 SERIES / EPOCH  
 SYSTEM / PERIOD  
 ERATHEM / ERA  
 EONOTHEM / EON  
 0 Ma

Late Permian  
Period

First vertebrate land  
animals ~395 Ma

Cambrian  
explosion



✖ Mass extinction event



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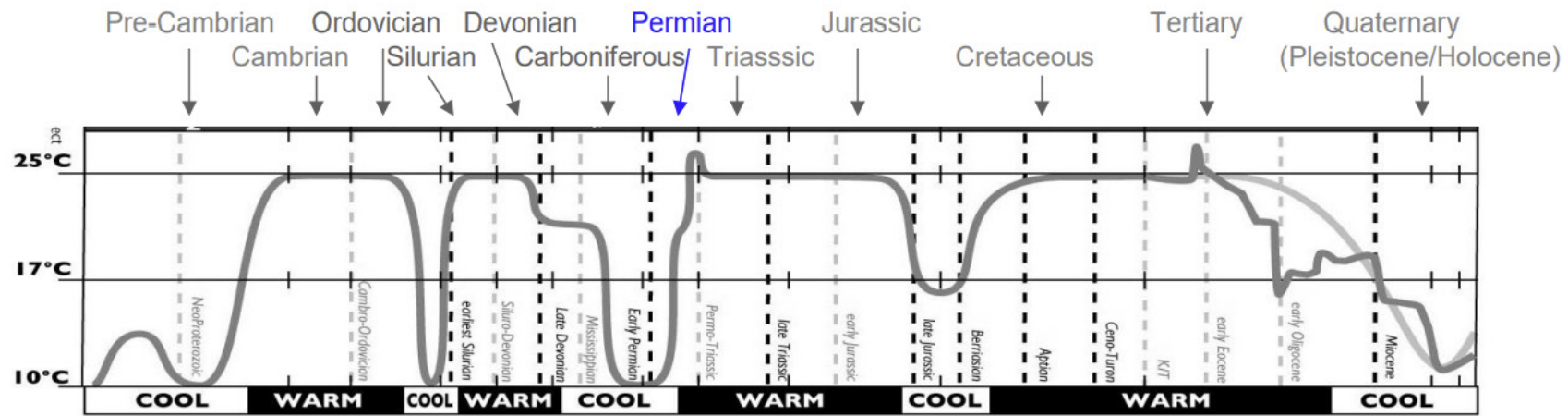
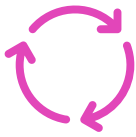
## ALFRED WEGENER AND 'CONTINENTAL DRIFT THEORY'

- Born in Berlin, Germany
- Meteorologist, geologist, and Arctic explorer

**What sparked Wegener's theory of continental drift?**

**How was his theory received by his peers?**





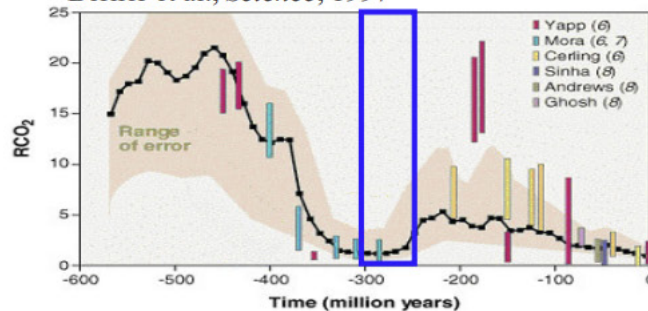
<https://www.ucl.ac.uk/GeolSci/micropal/foram.html>

<http://www.scotese.com>

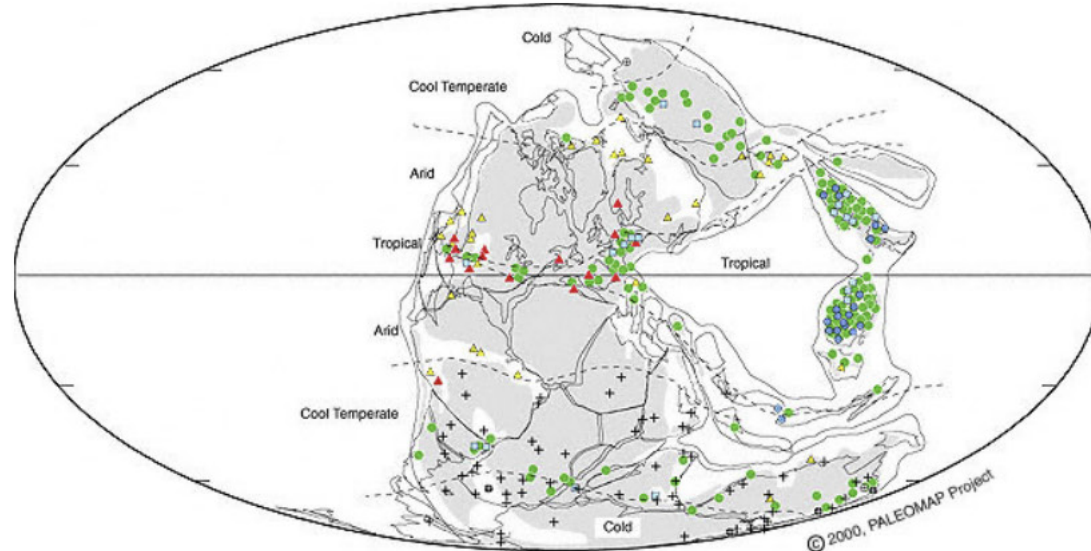
Eon	Era	Period	Epoch	Age Ma
Phanerozoic	Cenozoic	Quaternary	Holocene	0.01
			Pleistocene	1.64
		Neogene	Pliocene	5.2
			Miocene	23.3
		Palaeogene	Oligocene	35.4
			Eocene	56.5
			Palaeocene	65.0
		Mesozoic	Cretaceous	145.6
			Jurassic	208.0
			Triassic	245.0
	Palaeozoic	Permian	290.0	
		Carboniferous	362.5	
		Devonian	408.5	
		Silurian	439.0	
		Ordovician	510.0	
		Cambrian	570.0	
Proterozoic				2500
Archean				4000

Geologic Time Scale based on Harland et al 1989

Berner et al., *Science*, 1997



## Early Permian Climate (280 million years ago)



Much of the SH was covered by ice as glaciers pushed equator ward. Coal was produced in Equatorial & Temperate rainforests during warmer "Interglacial" periods.

Source: <http://www.scotese.com/epermcli.htm>


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# EARTH IN THE PERMIAN PERIOD

Pangaea means:

Panthalassa means:



 You are here.  
c. 255 mya



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# THE PERMIAN PERIOD: LIFE ON LAND

Synapsids

*Dimetrodon*



**What does Brannen refer to the hulking land beasts that dominated in the Permian Period as?**

*Cotylorhynchus*





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# THE PERMIAN PERIOD: LIFE ON LAND

Gorgonopsids



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# THE PERMIAN PERIOD: LIFE IN THE OCEANS



Permian Period Reef,  
Guadalupe Mountains  
National Park, Texas



Courtesy of the National Park Service

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# THE ULTIMATE MURDER MYSTERY

- Many theories for the End-Permian extinction
- (Varying) evidence for each of them

How do  
extinctions  
appear in the  
scientific record?

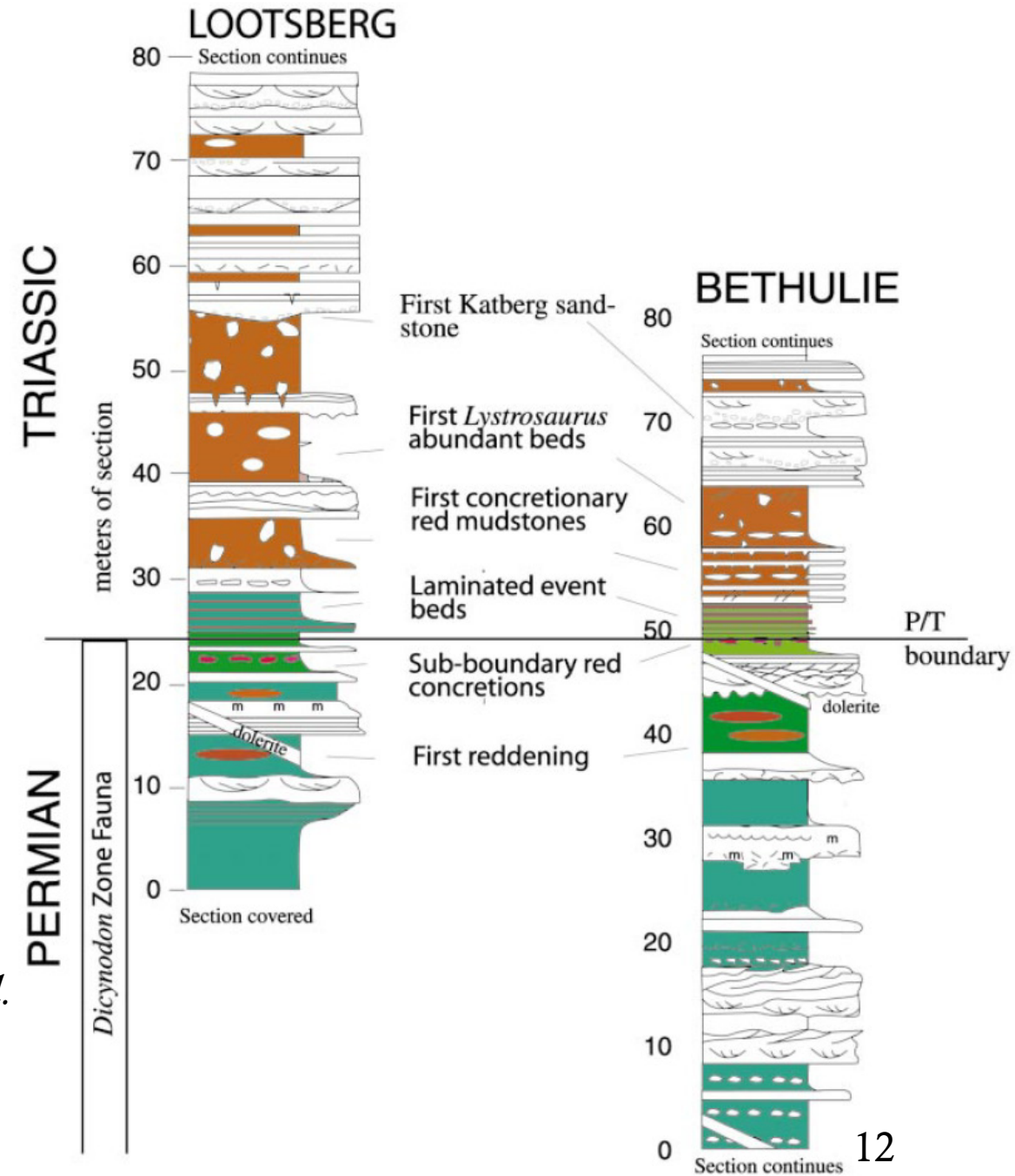
What methods  
do we use to  
study the past?

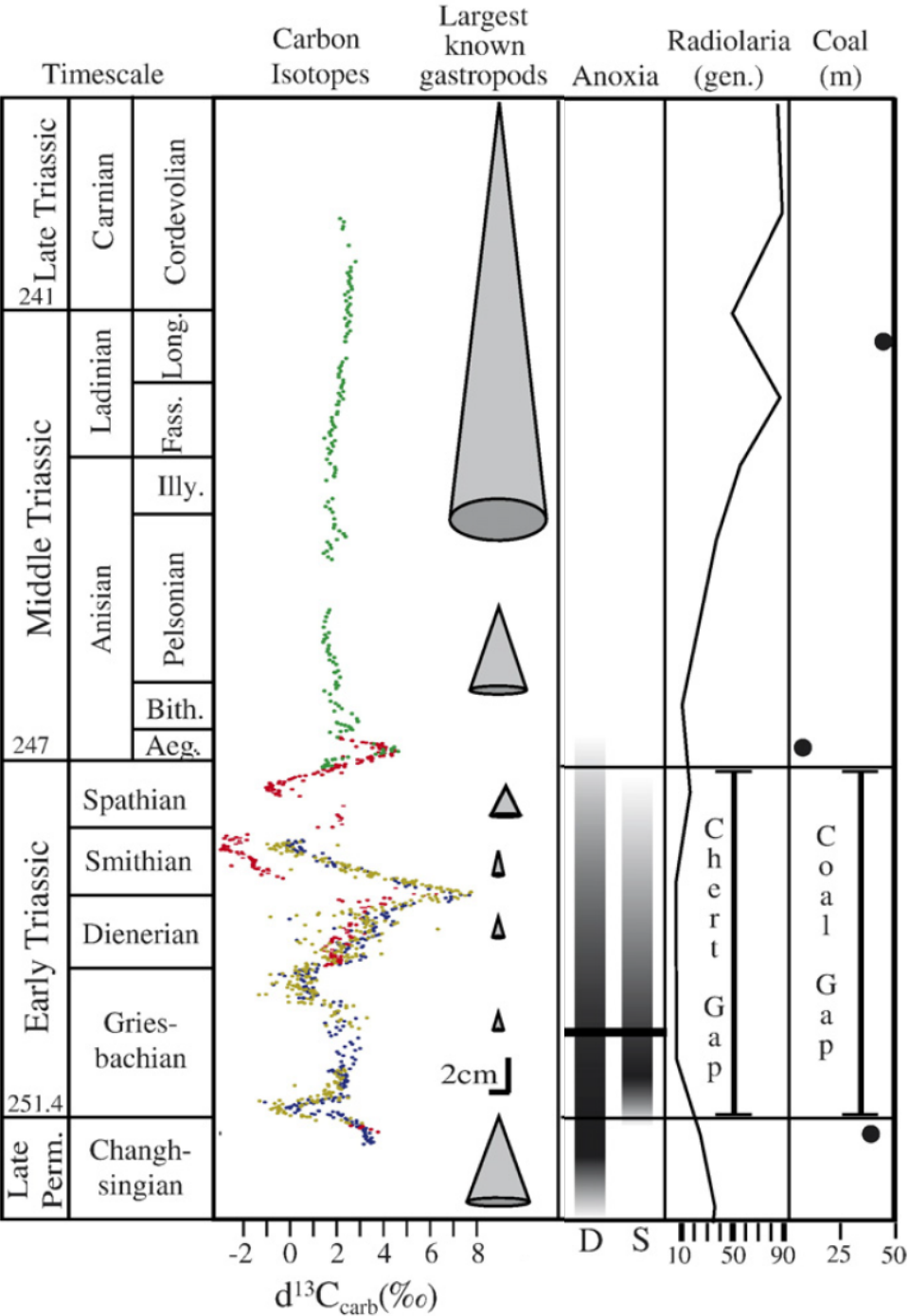


# THE SCIENTIFIC RECORD



*For most life on earth, a deathly silence passes over the fossil record.*  
Peter Brannen, page 110





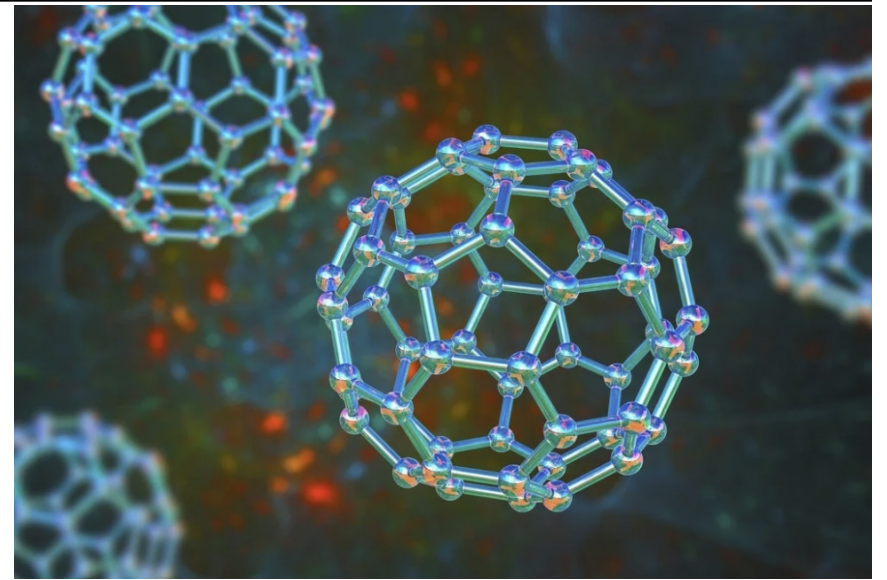
# THE SCIENTIFIC RECORD

What are the 'chert-gap' and the 'coal-gap'?

Courtesy of Knoll et al, 2007  
(doi:10.1016/j.epsl.2007.02.018)

# THEORY #1

- Primary Suspect: Extraterrestrial Body (e.g. asteroid)
  - Luann Becker, 2004: crater off the coast of Australia
  - Looking for a chemical signature
- Buckyballs
  - Buckminsterfullerenes
  - Claimed to be extraterrestrial in origin
    - Actually from Japan, Triassic Period
- Theory spread through popular media



Courtesy of Don Davis Via [NASA Image and Video Library](#)

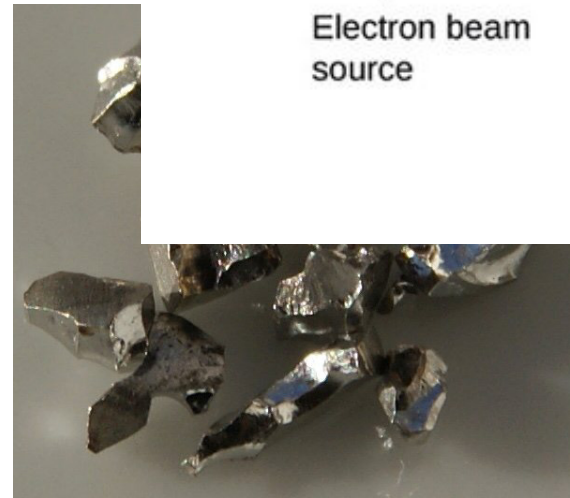


# THEORY #1

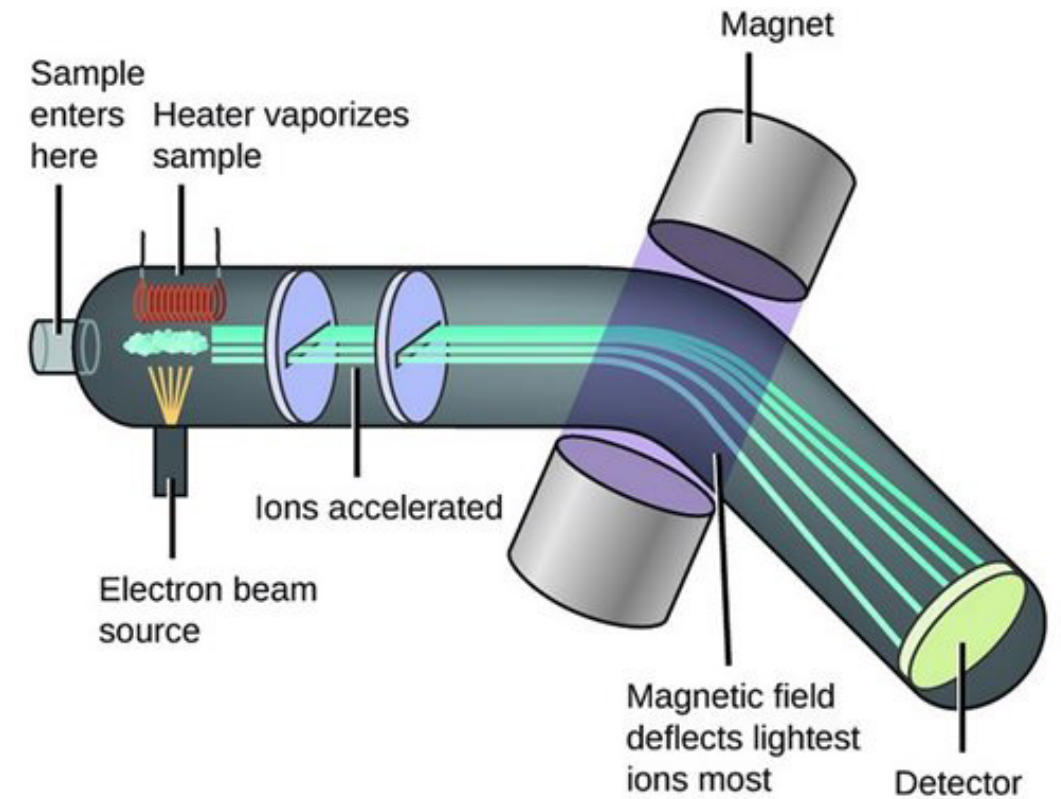
- Primary Suspect: Extraterrestrial Body (i.e. asteroid)
  - Peter Ward (UW Paleontologist) and Roger Smith (South African Museum)
  - Mid-1990s: Searching in the Karoo, South Africa
  - Alvarez Asteroid Impact Hypothesis (1980)



Courtesy of Don Davis Via [NASA Image and Video Library](#)



Courtesy of <http://images-of-elements.com/>, CC BY 3.0,  
<https://commons.wikimedia.org/w/index.php?curid=9140766>



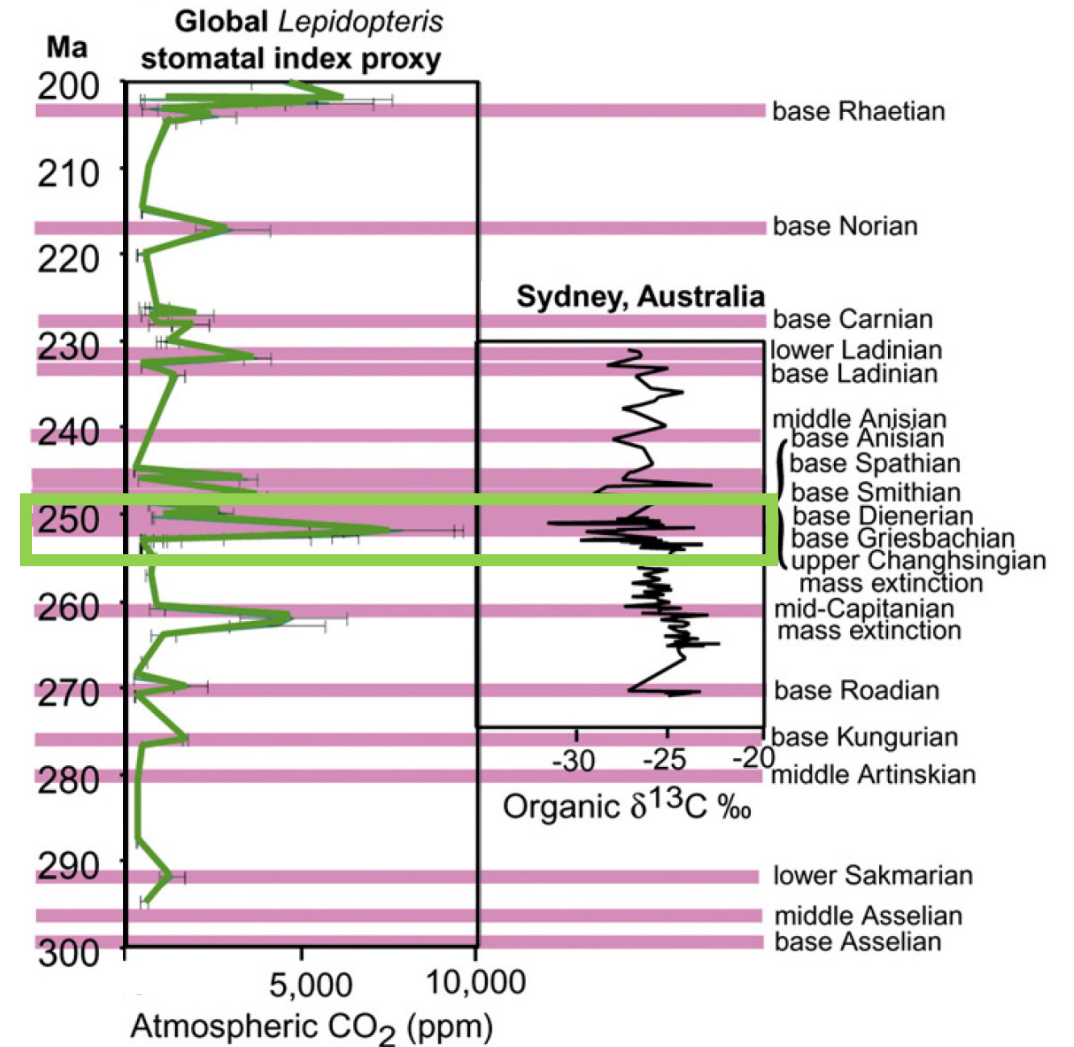
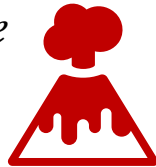
Schematic of a mass spectrometer

# THEORY #2

- Primary Suspect: “a wild swing in the carbon cycle”
- Mass spectroscopy
  - Global evidence for influx of isotopically light carbon
- Collapse of biosphere?
- Volcanism and the release of noxious fumes: halogenated butane, methyl bromide, and methyl chloride

*It doesn't matter whether carbon dioxide comes from “Volvos or volcanoes.”*

Peter Brannen, page 122-3



Courtesy of Retellack, 2013 (DOI: 10.1016/j.gr.2012.03.003)

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## THEORY #2: SIBERIAN TRAPS EXPLOSION



Courtesy of Paul Wignall

Let's talk numbers.

**How much carbon does Brannen say humans could release if we burned every drop of fossil fuels?**

**What is the estimated lower limit of carbon that was released at the End-Permian?**

**And the upper limit?**

Siberian flood-basalt flows in the Putorana Plateau, Taymyr Peninsula, Russia



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## THEORY #2: SIBERIAN TRAPS EXPLOSION



Courtesy of Paul Wignall

Let's talk numbers.

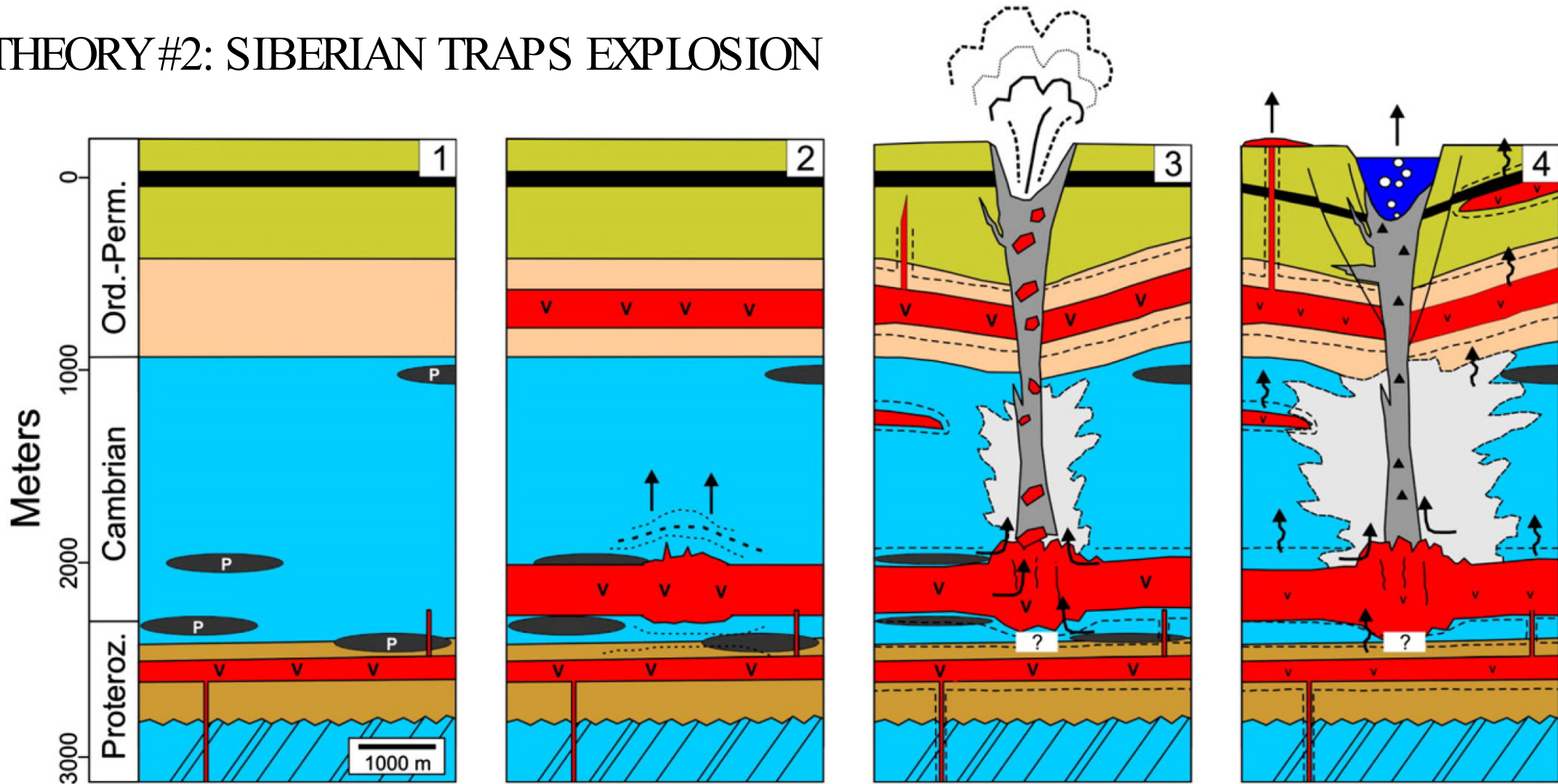
**What might the temperature have done due to a spike in carbon like this?**

**How much might have ocean temperatures risen?**

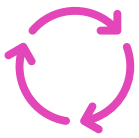
**What does 104 °F feel like?**

Siberian flood-basalt flows in the Putorana Plateau, Taymyr Peninsula, Russia

## THEORY #2: SIBERIAN TRAPS EXPLOSION



Courtesy of Svensen et al, 2009 (doi:10.1016/j.epsl.2008.11.015)



# THEORY #2+: OCEAN ACIDIFICATION

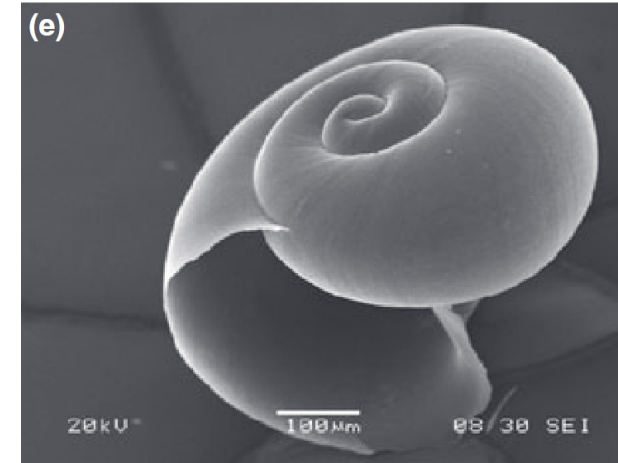
Primary Suspect: too much carbon dioxide

**The last time CO<sub>2</sub> was 400ppm, how much did sea level rise?**

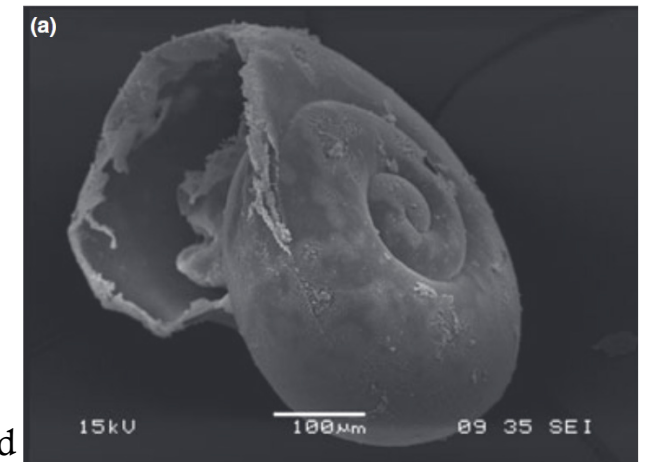
**Why does Brannen say that “timescale is everything”?**

*Paleontologists rarely get to see their hypotheses play out in real time, but the modern oceans of the Anthropocene offer something like an unwelcome proof-of-concept.*

Peter Brannen, page 133



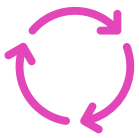
Healthy pteropod



Unhealthy pteropod

Courtesy of Bednarsak et al, 2012

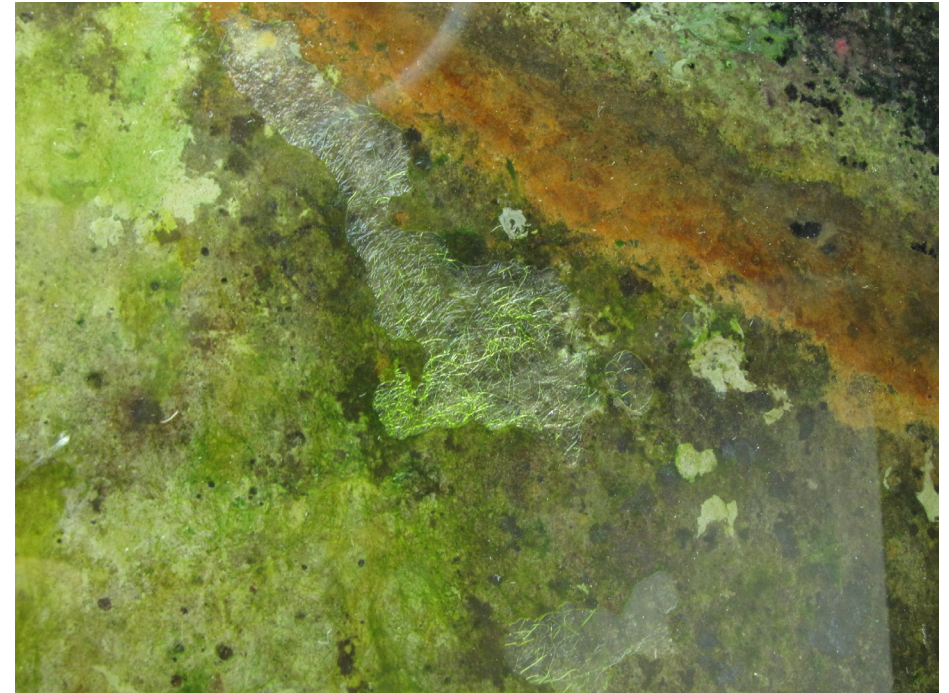




## THEORY #2++

- Primary Suspects: anoxia and hydrogen sulfide
  - What could happen to global circulation?

**What pigment has been found in the scientific record, and what does this pigment indicate?**

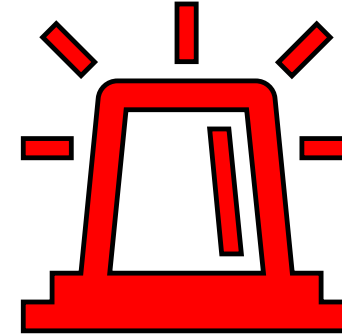


Courtesy of Winogradsky, Vassar

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# THE CULPRIT(S)

- Extremely high temperatures
- Intense ocean acidification, anoxia, and slime
- Volcanic sulfur dioxide and acid rain
- Noxious gases (not unlike weapons used in WWI)
- The destruction of the ozone layer due to immense releases of volcanic gases
- Poisoning from carbon dioxide
- Mercury toxicity



*Carbon dioxide-driven global warming is not just being simulated in climate models on government supercomputers, but is an experiment that the earth has already run many times in the deep past.*

Peter Brannen, page 111

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# LIFE AFTER CATASTROPHE



*Claraia*



*Lystrosaurus*



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# WHAT LESSONS CAN WE APPLY TO TODAY?

*Researchers don't study the worst catastrophe ever purely out of academic, or even morbid, curiosity. The End-Permian mass extinction is the absolute end-member—the worst-case scenario—for what happens when you jam too much carbon dioxide into the atmosphere.*

Peter Brannen, page 105

*Is it happening again? Most of us think so, but there are still so few of us who visit the deep past and compare it to the present and future.*

Peter Ward in *Under a Green Sky* (in Brannen, page 111)

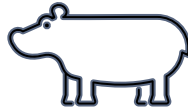
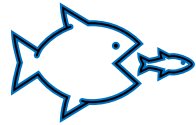
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# CASE SOLVED (?)

- ✓ Set the Scene: what did the Earth system look like during the Permian Period?



- ✓ Pangaea / Continental Drift
- ✓ Global Climate
- ✓ Life on Land
- ✓ Life in the Oceans



- ✓ Context: Mass Extinctions in Earth History
  - ✓ What does this look like in the scientific record?
  - ✓ How do we study it?



- ✓ Suspects:

- ✓ Asteroid?
- ✓ Vulcanism?
  - ✓ Noxious gases?
  - ✓ Lava?
- ✓ Ocean Acidification?



- ✓ Aftermath: How does life emerge from a global catastrophe?
  - ✓ Surviving species
  - ✓ What can we learn from events like the End-Permian mass extinction?