



**MASS EXTINCTIONS,  
THE EARTH SYSTEM  
&  
THE IMPORTANCE OF  
PRESERVING THE  
PLANET'S  
BIODIVERSITY.**

# Three questions:

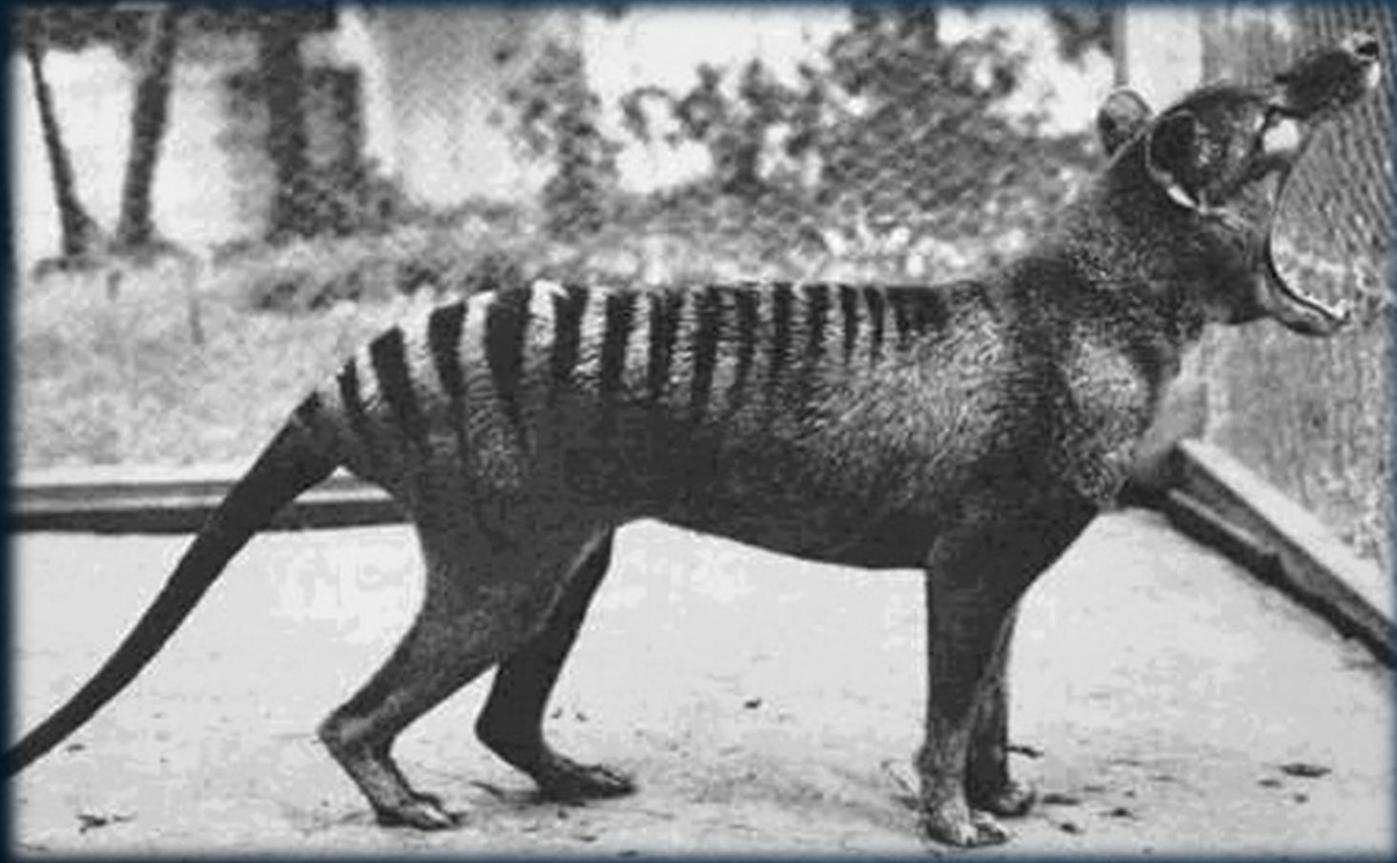
- 1: What the difference between an extinction and a mass extinction ?
- 2: What is the Earth System and what is its relationship with mass extinctions ?
- 3: Are we in the sixth extinction ?

## **Question 1**

What the difference between an extinction and a mass extinction ?

# EXTINCTION

A species is extinct when the last individual of that species dies.



Benjamin

Died in a Tasmanian zoo, on the 7<sup>th</sup> of September 1936.



1930 – Last Thylacine in the wild,  
Mawbanna, northwest Tasmania

Thylacines were *extinct in the wild*  
before Benjamin died – In other  
words they were *Functionally extinct*

# EXTINCTION

A species is extinct when the last individual of that species dies.

Extinction is the evil twin of origination (evolutionary appearance). Together, they control the level of diversity on the planet.

**Diversity = Origination – Extinction**

# PALAEONTOLOGY HAS A SLIGHTLY DIFFERENT VIEW OF CURRENT BIODIVERSITY

*To a first approximation, all life on Earth is extinct*

DAVID RAUP

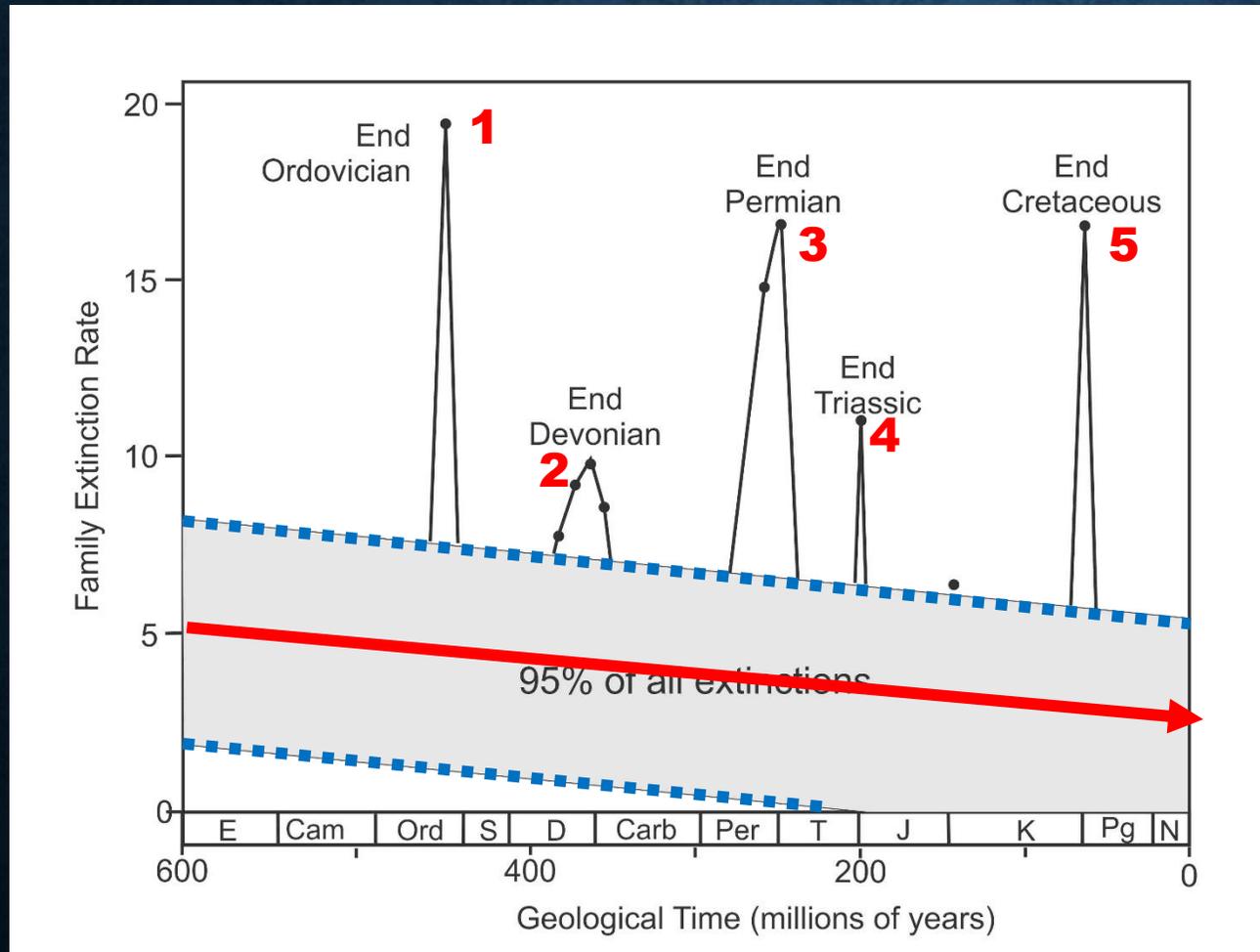
Of all the species that have ever existed over the 3.7 billion years of life's history, over 99% are extinct.

# A MASS EXTINCTION IS:

*The extinction, over a very short interval of geological time, of more than one geographically widespread higher taxon, resulting in a drop in overall diversity.*

From Sepkoski (1986)

# THERE HAVE BEEN SEVERAL MASS EXTINCTIONS RECORDED IN THE FOSSIL RECORD



The “Big Five”

But there are more –  
up to 19!

**NEVERTHELESS,  
THE BIG FIVE ARE  
VERY BIG INDEED**

## Marine species level extinction rates

	Families	Genera
End Ordovician	$84 \pm 7 \%$	$85 \pm 3 \%$
End Devonian	$79 \pm 9 \%$	$83 \pm 4 \%$
End Permian	$95 \pm 5 \%$	$95 \pm 2 \%$
End Triassic	$79 \pm 9 \%$	$80 \pm 4 \%$
End Cretaceous	$70 \pm 13 \%$	$76 \pm 5 \%$

Data from Jablonski, 1994

## **Question 2**

What is the Earth System and what is its relationship with mass extinctions ?

## PUTTING IT SIMPLY:

I think that *Most* mass extinctions appear to be associated with a major shift in the *Earth System*.

# THE EARTH SYSTEM

## *The planet's life support system*

It attempts to:

- Maintain the planet's climate in a more or less stable equilibrium.
- Ensure that the climate is suitable for the continuation of life on Earth.

In the process, it has increased the habitability of the planet.

The whole system is not perfect – it can (and has) allowed the climate to change, often significantly.

# THE EARTH SYSTEM

*It's a fully self-regulating machine using homeostatic like processes to maintain climatic equilibrium.*

# THE EARTH SYSTEM

*Some definitions (1)*

Homeostatic like processes

If you get too cold - Shiver



If you get too hot - Sweat



# THE EARTH SYSTEM

## *Some definitions (2)*

### **System:**

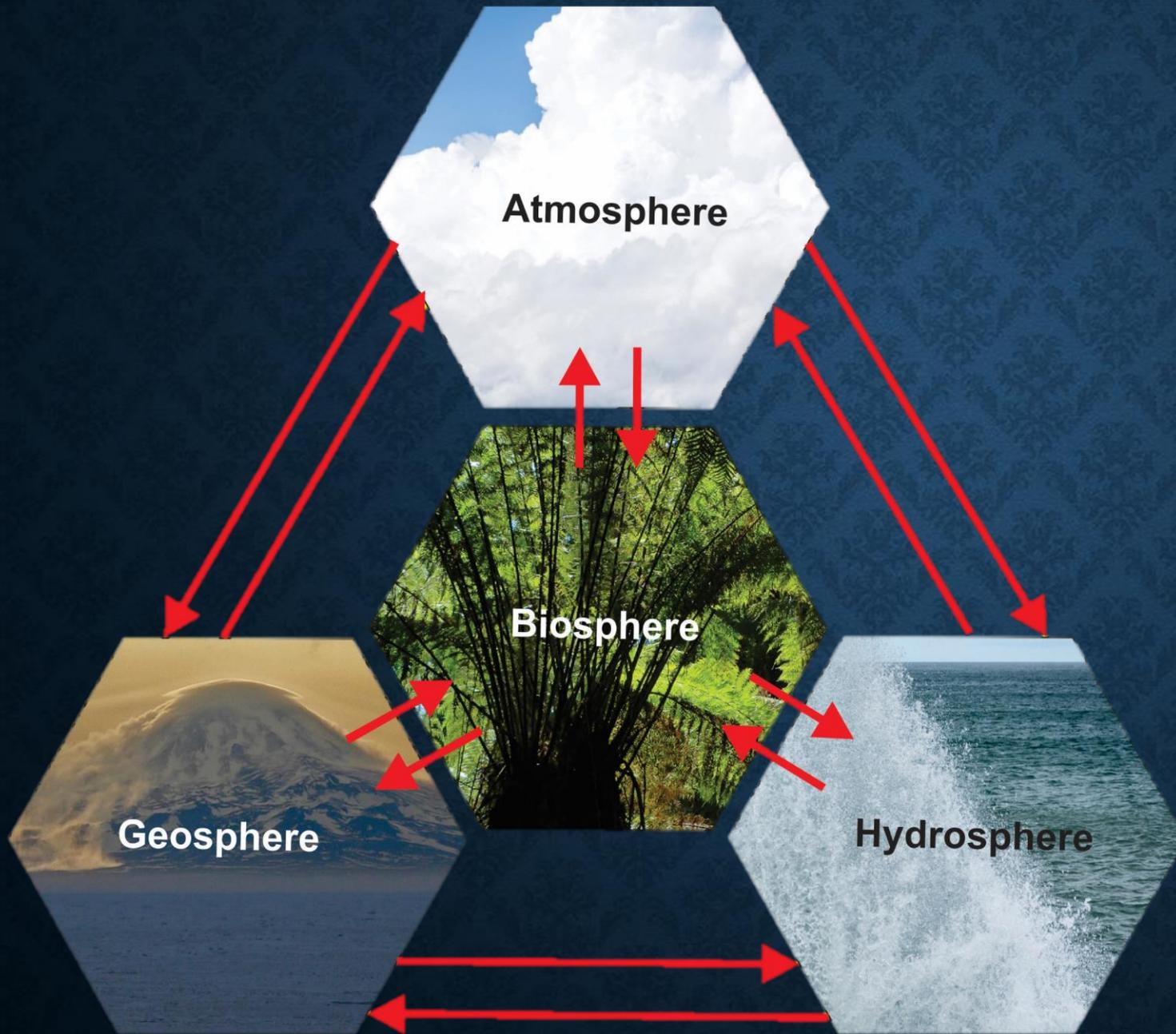
An machine, made up of different but related components that nevertheless function as a whole

### **Reservoir or sphere:**

Component of the system

### **Flux:**

The flow of energy or material between the reservoirs – also called mass transfer



A very simple  
Earth System model

Anthropogenic  
burning fossil fuel

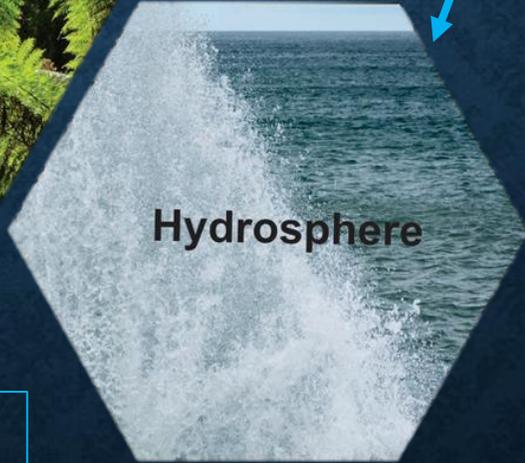
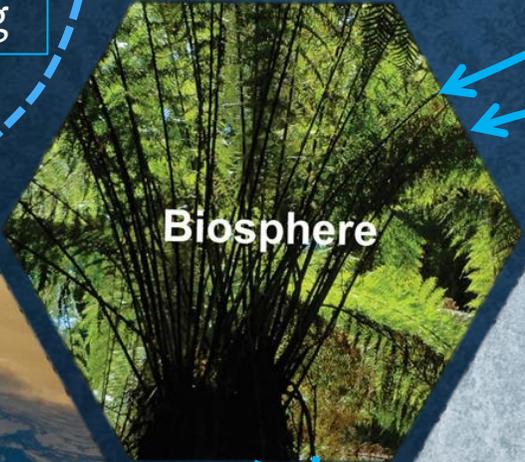
Volcanoes

Weathering

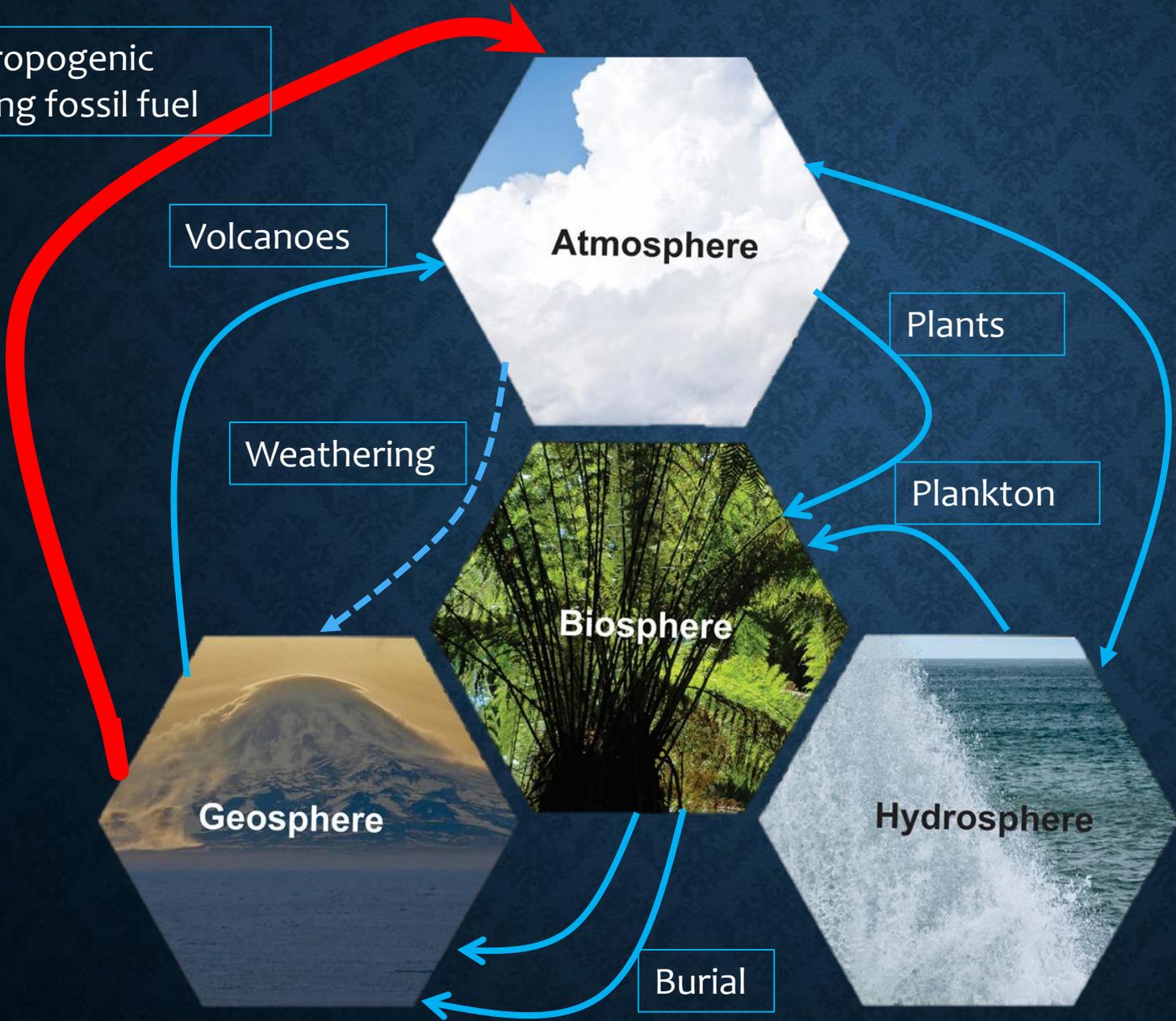
Plants

Plankton

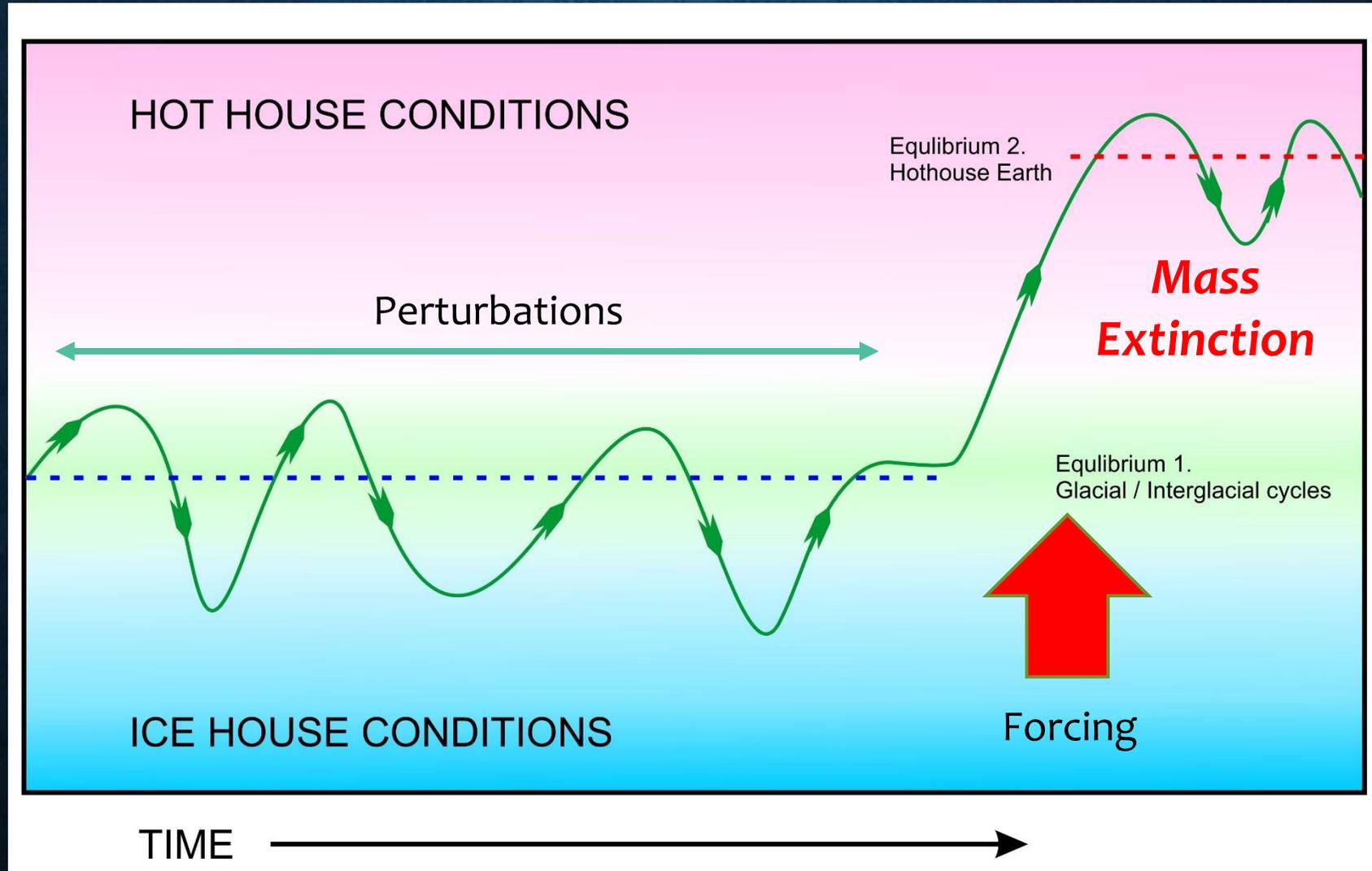
Burial



Carbon cycle  
(again simplified)



# DISTURBING THE SYSTEM: PERTURBATIONS AND FORCINGS



Anthropogenic  
burning fossil fuel

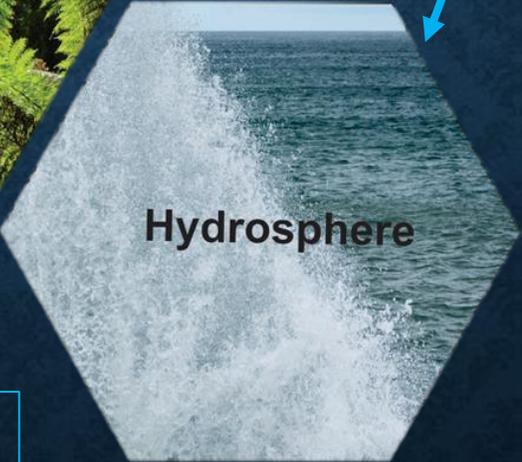
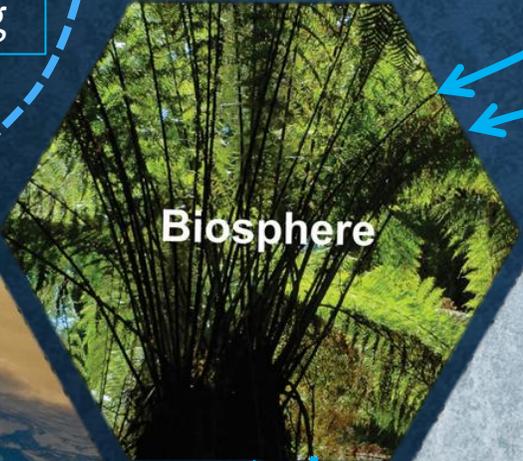
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Weathering



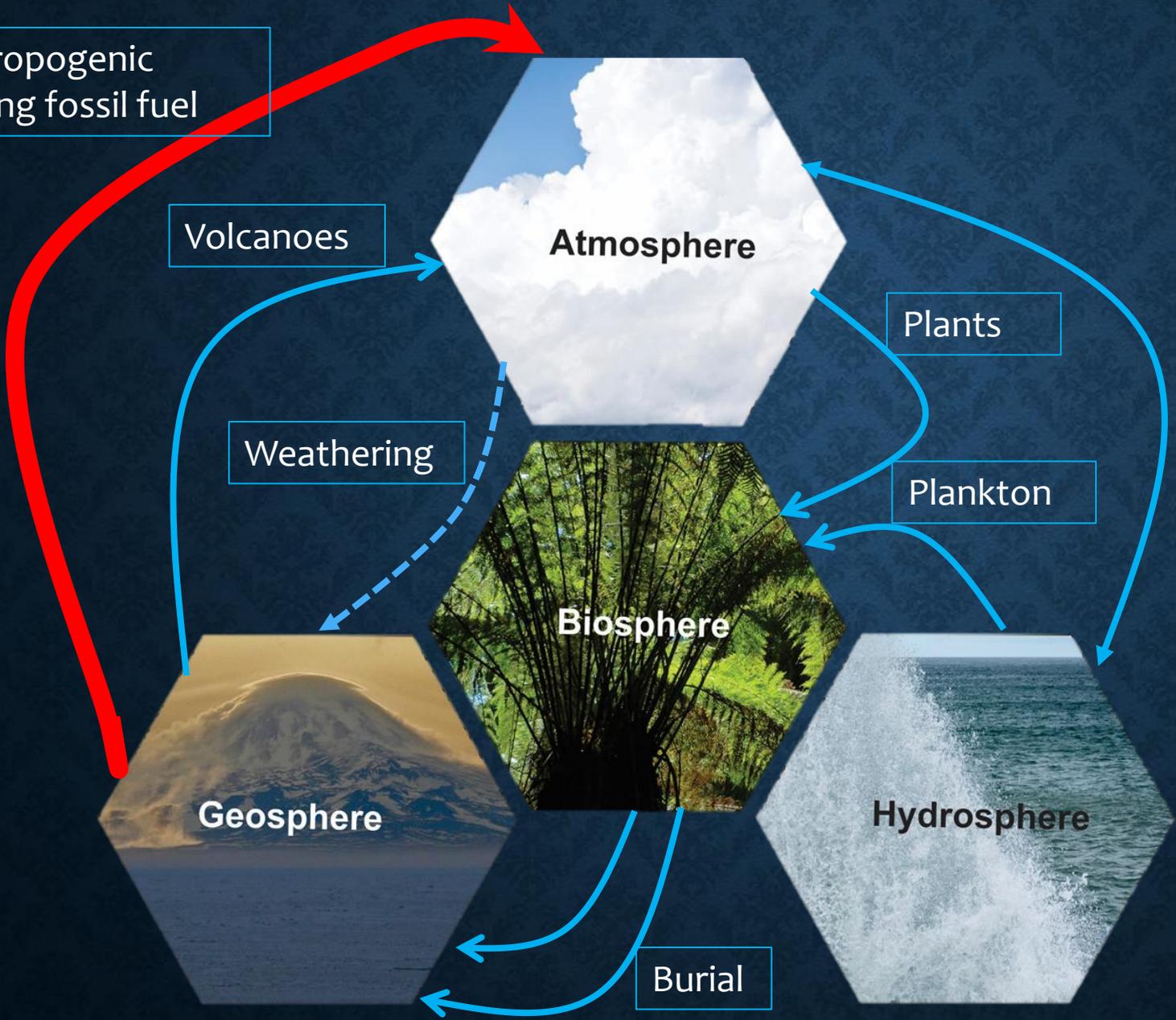
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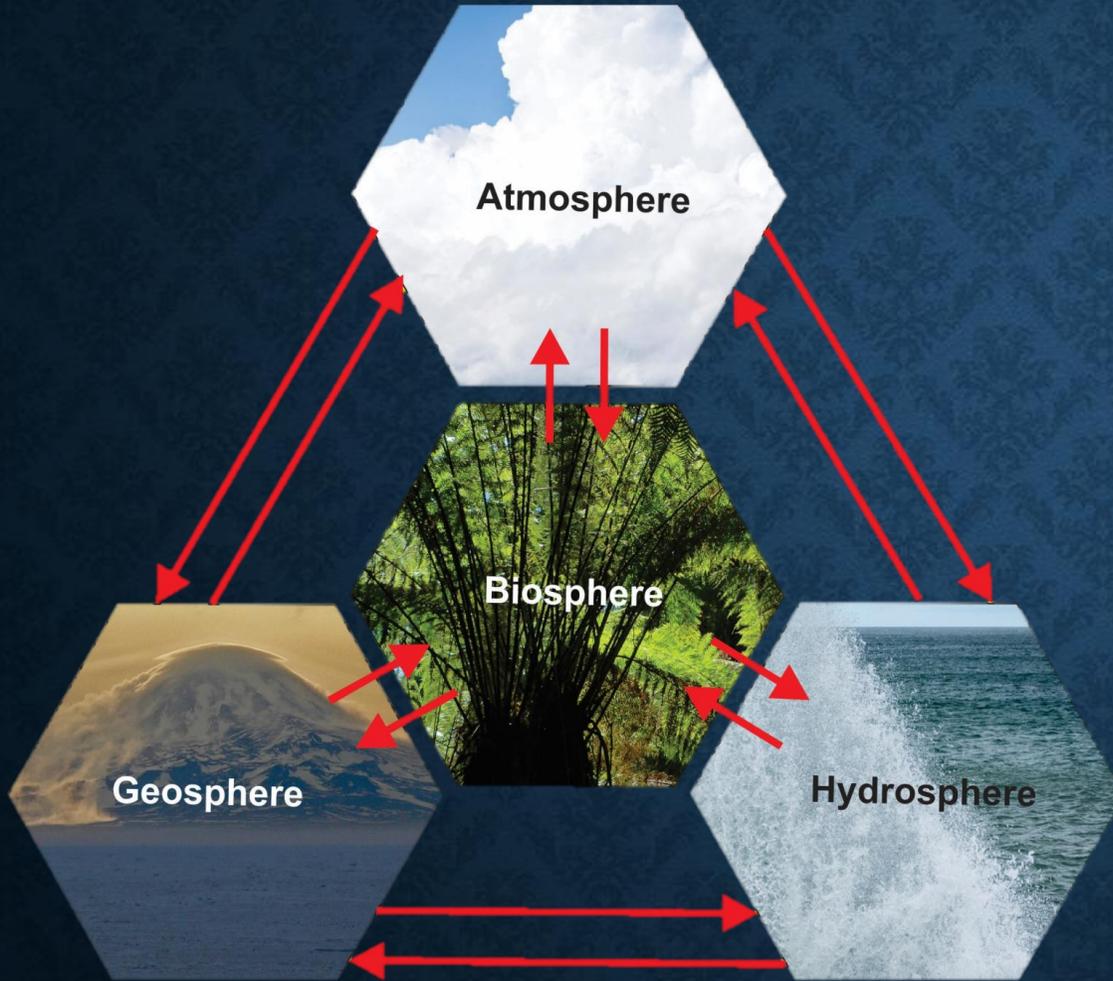


Burial

Carbon cycle  
(again simplified)



# Life – the biosphere – is at the heart of the Earth System



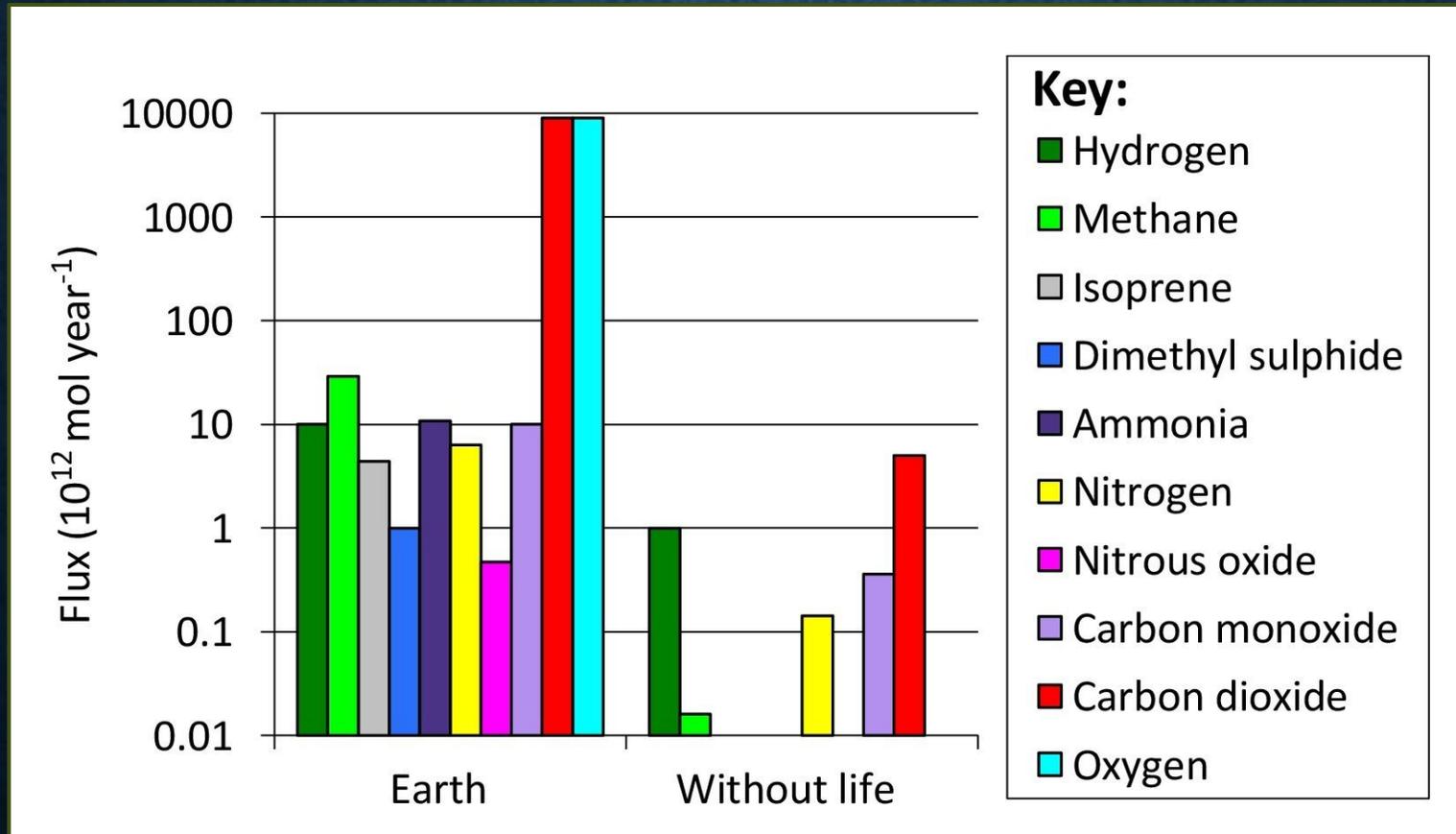
The Biosphere is NOT a passive player in the Earth System. It has, over time, actively changed the physical properties of the planet.

# THE EARTH SYSTEM AND THE COMPOSITION OF THE ATMOSPHERE

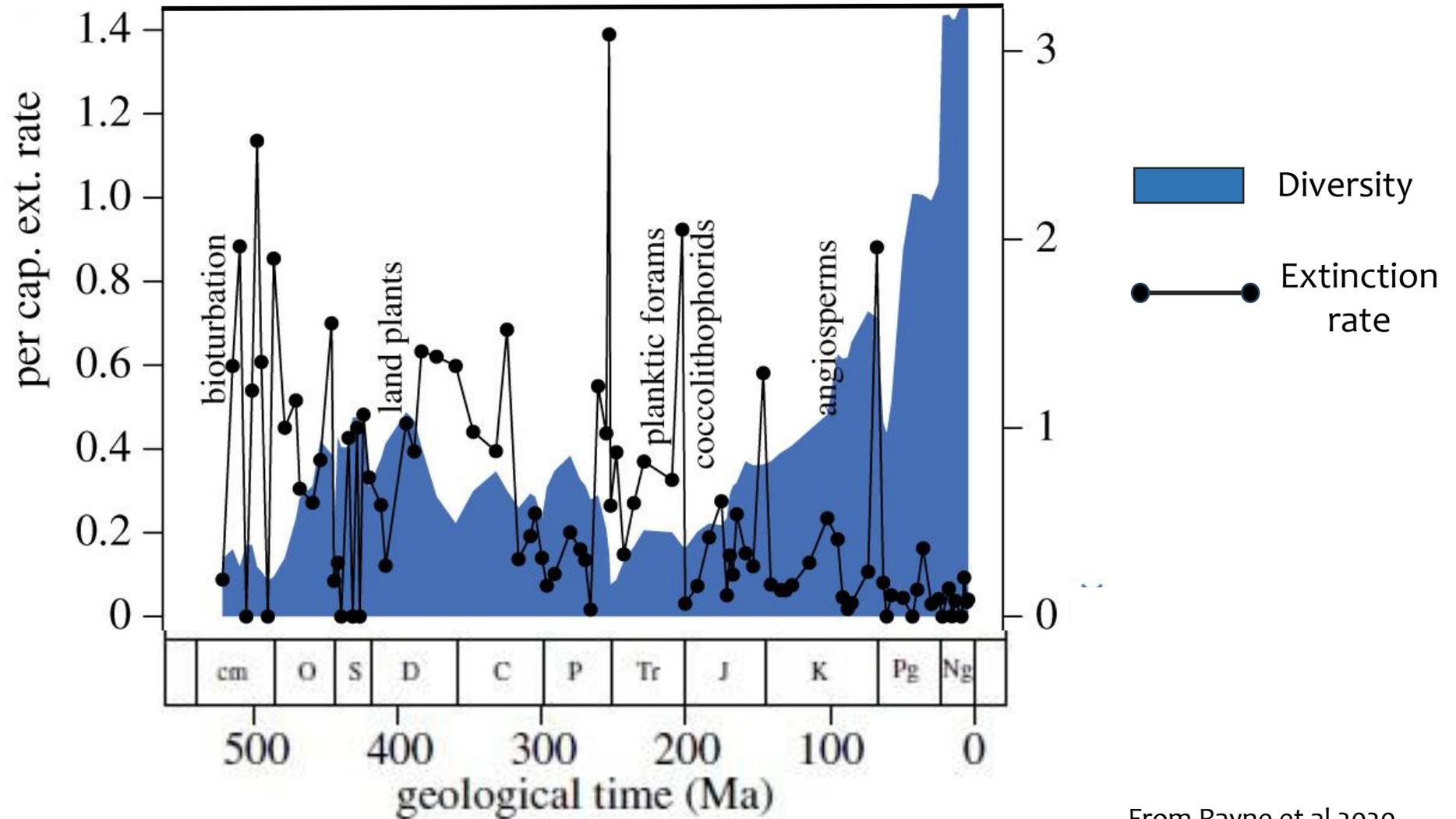
Gas	Earth (now)	Venus	Mars	Earth (no life)
CO <sub>2</sub>	0.03%	98%	95%	98%
N <sub>2</sub>	78%	1.8%	2.7%	1.9%
O <sub>2</sub>	21%	Tr	0.13%	Tr
T	15°C	464°C	-60°C	?

# THE EARTH SYSTEM AND THE ATMOSPHERE

## FLUXES OF GASES MOVED THROUGH THE BIOSPHERE

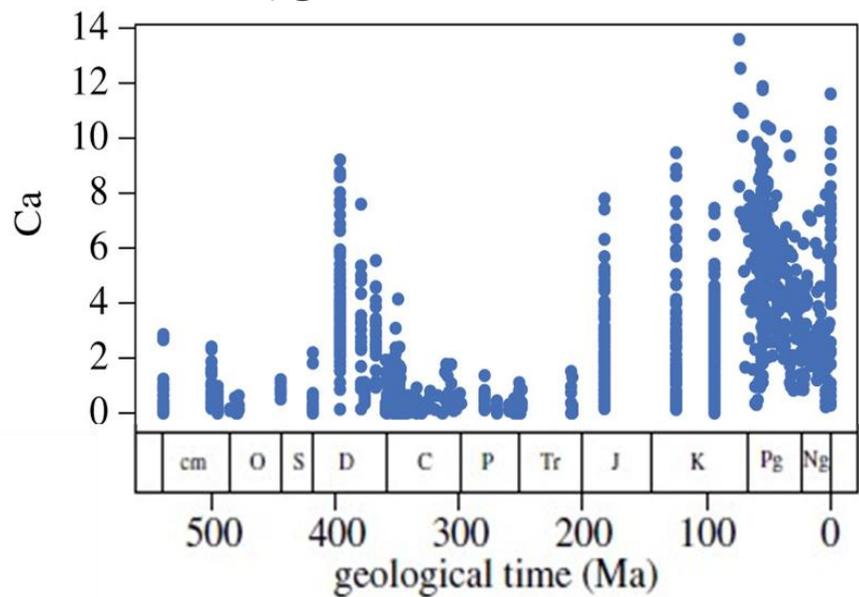


# THE EARTH SYSTEM THROUGH TIME

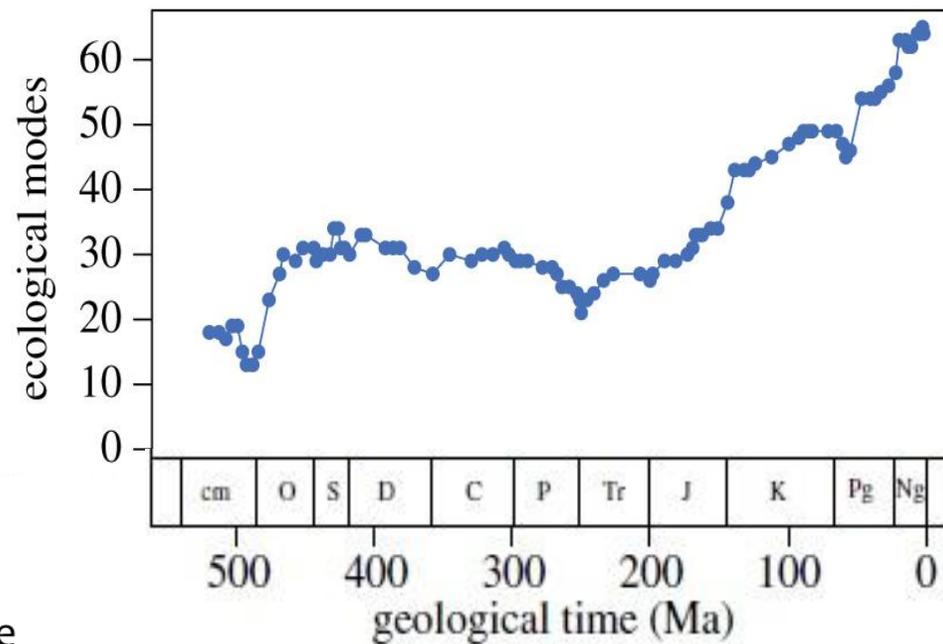


From Payne et al 2020

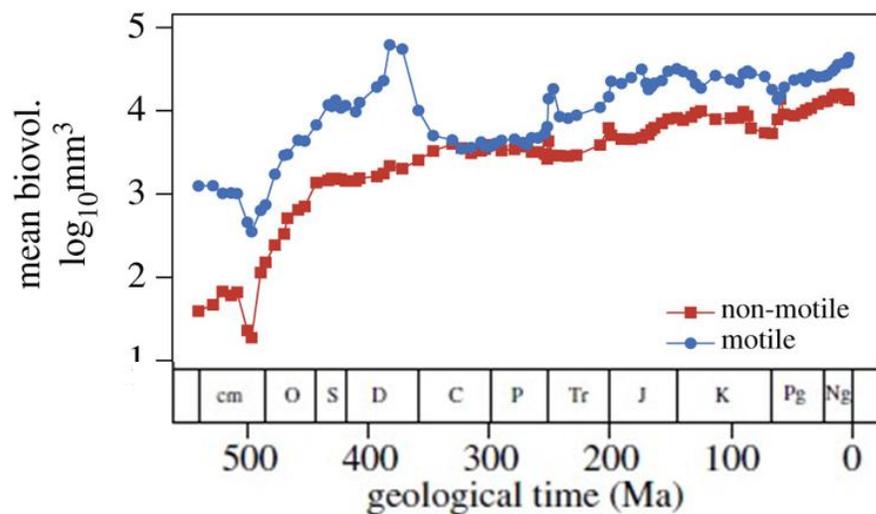
### Oxygenation of the oceans



### Marine ecological modes



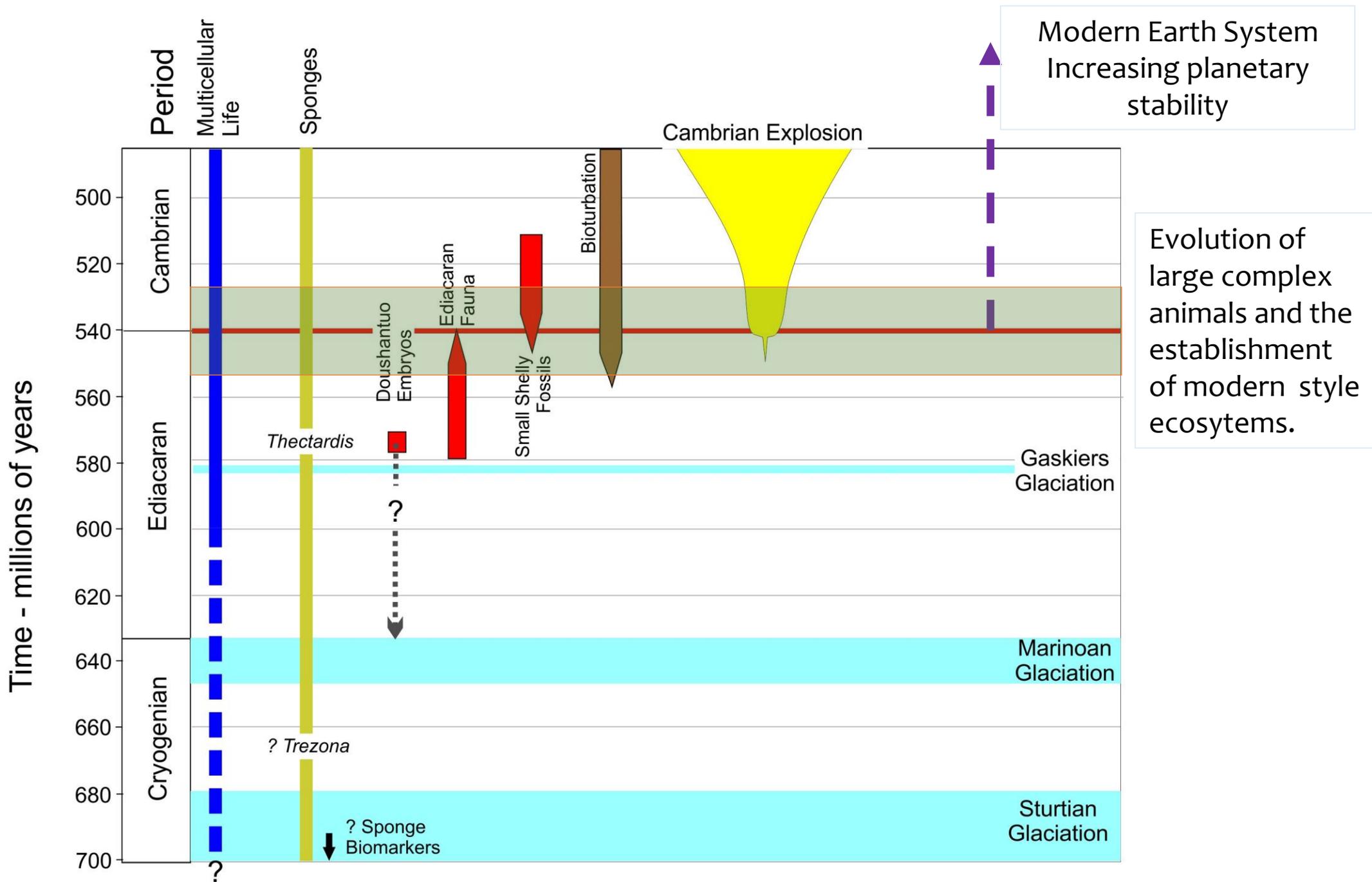
### Marine Animal Body size



## PAYNE ET AL - CONCLUSION:

*The increasing ecosystem stability of the planet and its ability to support complex life and are largely a consequence of biological processes that started in the Cambrian.*

**WHAT HAPPENED ~ 550 MYA?**



We shouldn't be surprised at the close association between the evolution of complex organisms and the Earth System because, as palaeontologist Nicholas Butterfield says,

*“they invented it”.*

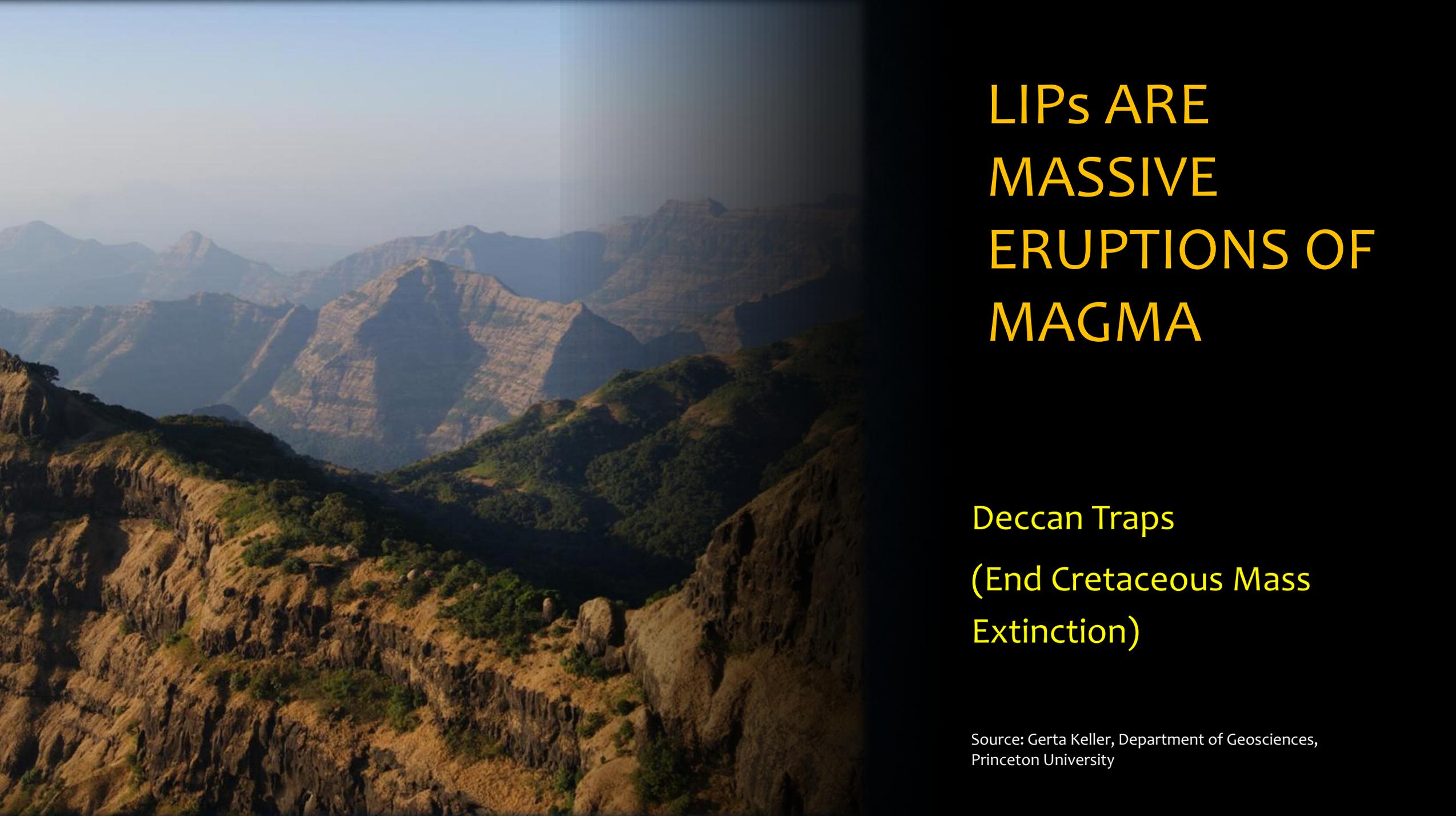
# THE ORIGIN OF THE EARTH SYSTEM

- The Earth System emerged as life evolved on the planet.
- It became fully operational as complex animals and modern style ecosystems evolved.
- In order for it to operate properly and maintain climatic equilibrium the system needs a diverse biosphere and complex ecosystems.

# MASS EXTINCTIONS - TRIGGERING A SHIFT IN THE EARTH SYSTEM

## LIPs

The eruption of *Large Igneous Provinces (LIPs)* are implicated in most mass extinctions over the last 500 million years.

A landscape photograph of a mountain range, likely the Deccan Traps, with a dark gradient overlay on the right side. The mountains are rugged and layered, with some peaks covered in green vegetation. The sky is clear and blue.

# LIPs ARE MASSIVE ERUPTIONS OF MAGMA

Deccan Traps  
(End Cretaceous Mass  
Extinction)

Source: Gerta Keller, Department of Geosciences,  
Princeton University



Ferrar Dolerite (Antarctica)  
Early Toarcian (Early Jurassic) mass extinction

Photo Mike Hannah

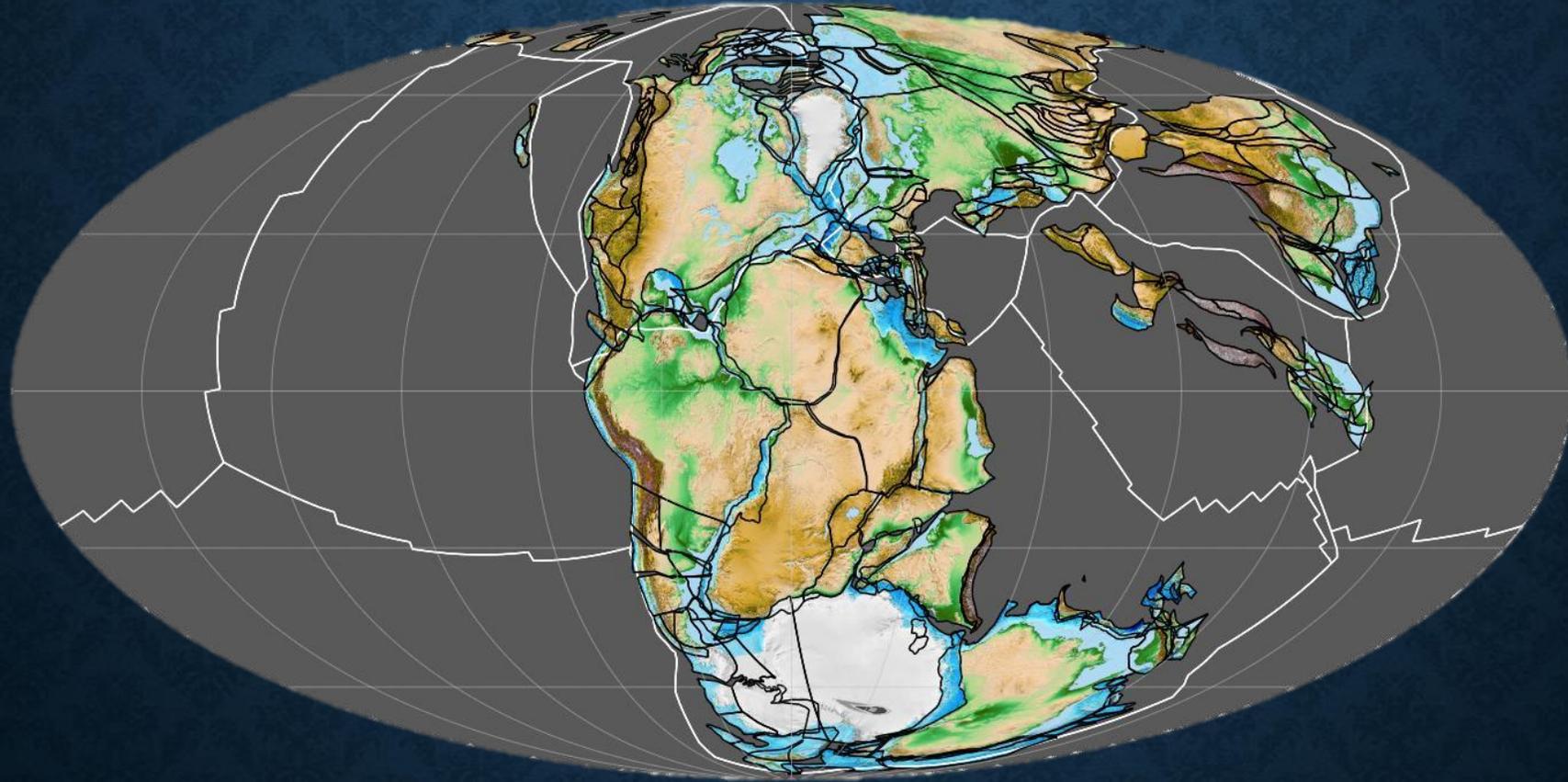
# LINKING A VOLCANIC ERUPTION, THE EARTH SYSTEM AND A MASS EXTINCTION.

*An example:*

**THE MOTHER OF ALL MASS EXTINCTIONS**

*the end Permian mass extinction*

AT THE END OF THE PERMIAN THINGS WERE VERY UNPLEASANT



BUT THEY WERE ABOUT TO GET A WHOLE LOT WORSE ...

# OVER A PERIOD OF ABOUT 48,000 YEARS

- *Up to 95% of all marine species went extinct.*
- *All coral reefs disappeared from the face of the planet.  
(It took twenty-seven million years for them to re-establish.)*
- *Many families of terrestrial vertebrates went extinct (up to 70% of species).*
- *Up to 40% of Insect families went extinct.*
- *Forests that had stretched from the North to the South Pole disappeared, replaced by low shrubby vegetation.*
- *No coal deposits for 10 million years.*

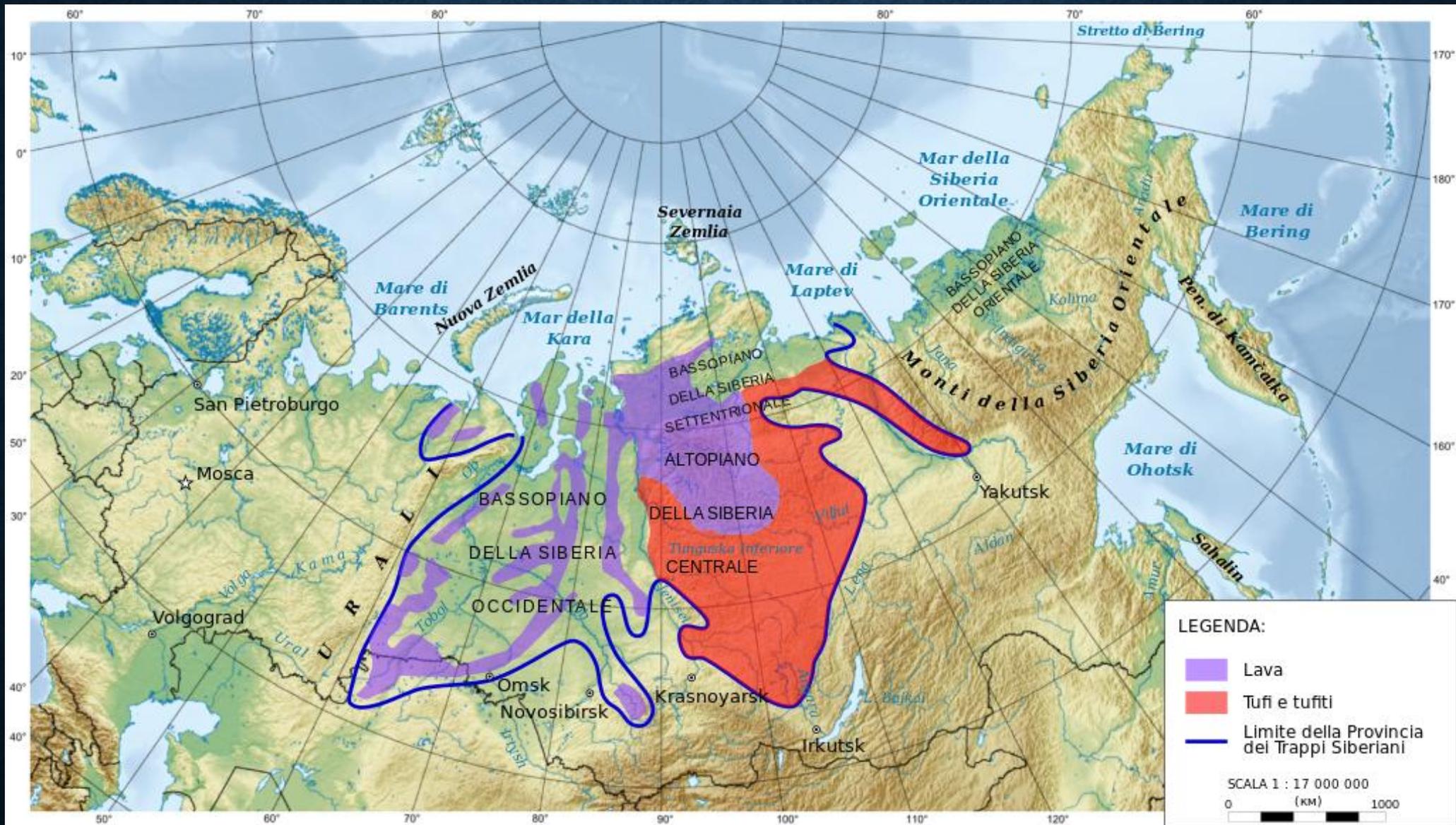


Siberian Traps –  
Taymyr Peninsula, Russia.



# SIBERIAN TRAPS

Trap is the Dutch word for stairs

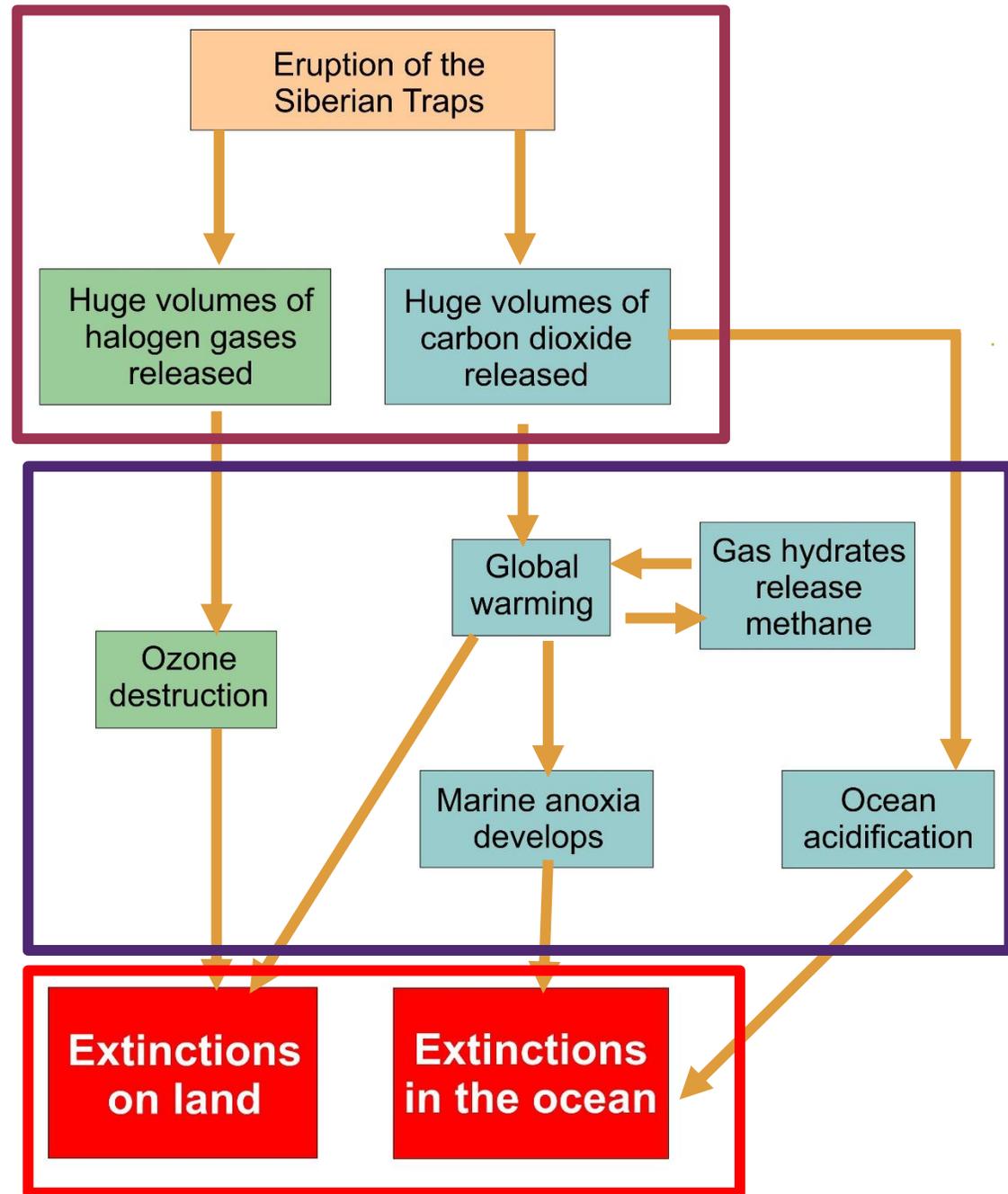


# THE SIBERIAN TRAPS – BY THE NUMBERS.

- *Today the Traps cover about 2.7 million km<sup>2</sup>. Original cover was up to 7 million km<sup>2</sup>.*
- *Up to 5 million km<sup>3</sup> of lava erupted over the 1 million years it took to emplace the Traps.*
- *The early stages of eruptions seem to have been very explosive, pushing gases and volcanic material high into the atmosphere.*
- *They released LOTS of gas.*

# THE SIBERIAN TRAPS – BY THE NUMBERS. (GASES)

- *Estimates suggest that the traps would release 170,000 giga tonnes of carbon dioxide.  
(That's  $170 \times 10^{12}$  or 170,000,000,000,000 tonnes.)*
- *Roughly 92 times all the carbon dioxide we've released since the industrial revolution.*
- *In addition, about 17,000 gigatonnes of halogen gases were pushed into the atmosphere.*



Adapted from Wignall, 2015



**Question 3:** Are we in the sixth extinction ?

## TRIVIAL ANSWER –

*There have been more than five previous mass extinctions. So technically, we're not in the sixth.*

*Perhaps the question should be how close are we to the ancient mass extinctions?*

# THE RATE AT WHICH SPECIES ARE GOING EXTINCT HAS INCREASED DRAMATICALLY SINCE THE APPEARANCE OF HUMANS

	Vertebrates	Mammals	Amphibians
Rate increase	55 x Pre-human	53 x Pre-human	100 x Pre-human

Data from Barnoski et al, 2011

# HAVE TODAY'S EXTINCTIONS REACHED THE LEVEL OF ONE OF THE ANCIENT MASS EXTINCTION ?

The data on the next two slides are from the red list <http://www.iucnredlist.org/>.

Managed by the International Union for Conservation of Nature, it is an attempt to assess the extinction status of all known species. It assigns each known species to a category of risk.

*We are interested in three categories:*

- Extinct
- Extinct in the wild
- Threatened

# EXTINCTION LEVELS

	Number of Species Assessed	% Extinct + Extinct in the Wild
Mammals	5899 (91%)	1.46%
Birds	11147 (100%)	1.47%
Reptiles	7833 (70%)	0.42%
Amphibians	6892 (84%)	0.54%
Insects	9793 (1%)	0.65%

# EXTINCTION LEVELS

	Number of Species Assessed	% Extinct + Extinct in the Wild	% Extinct, Extinct in the Wild + Threatened
Mammals	5899 (91%)	1.46%	23.48%
Birds	11147 (100%)	1.47%	14.8%
Reptiles	7833 (70%)	0.42%	18.37%
Amphibians	6892 (84%)	0.54%	33.56%
Insects	9793 (1%)	0.65%	19.23%

If we concentrate on EXTINCTION alone, we are being blinkered to the situation we are in.

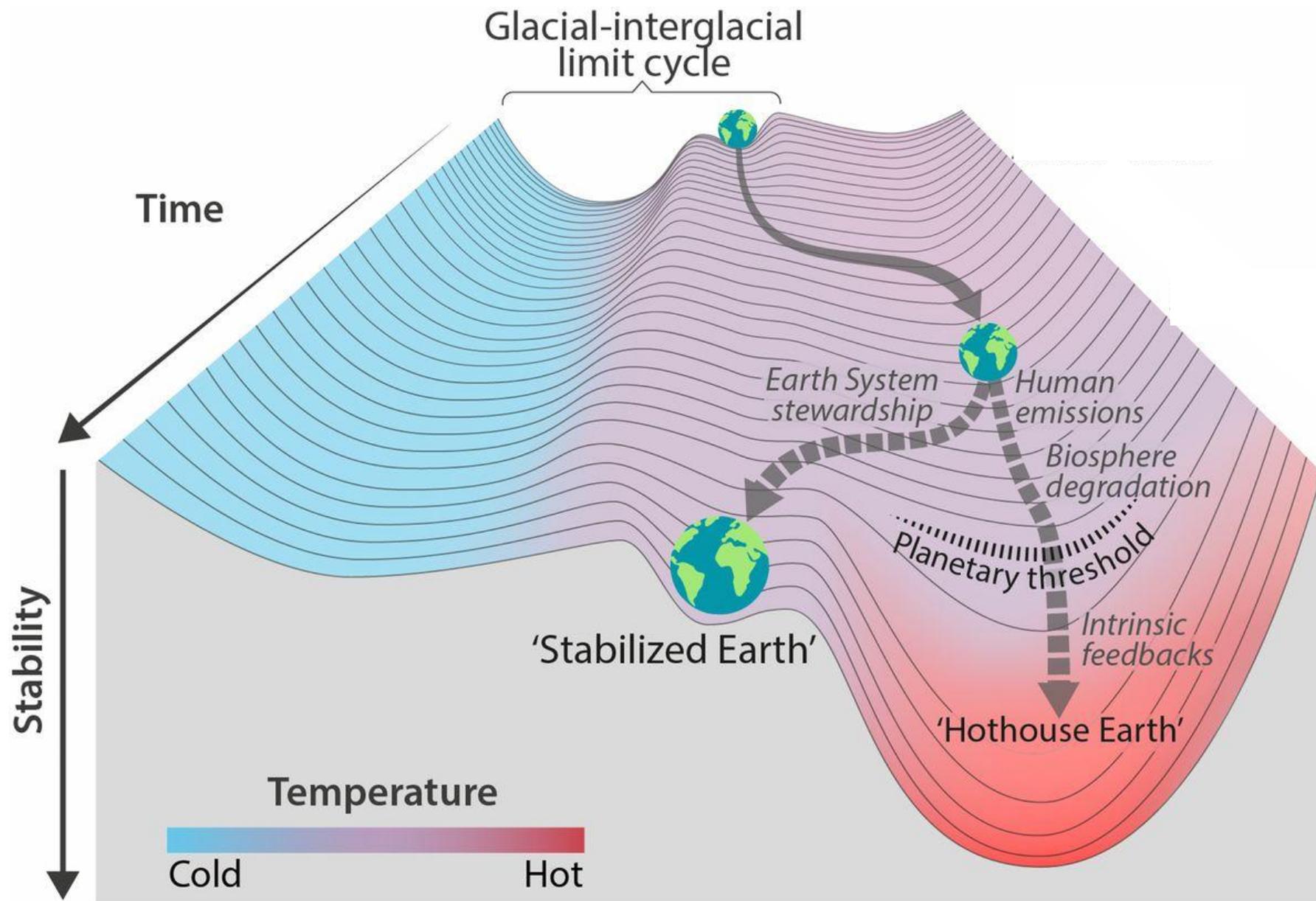
Perhaps we need a new word to describe it fully.

# DEFAUNATION

- *Not a perfect word, but it is meant to be an all-encompassing term that recognises that what's happening now is more than just extinction.*
- *We can't afford to let today's defaunation reach the level of an ancient mass extinction.*
- *We must act to preserve threatened species and maintain our biodiversity – halting the slide into a full mass extinction.*

A photograph of a lush tropical forest. The scene is filled with dense green foliage, including large ferns and various trees. Sunlight filters through the canopy, creating bright spots and a dappled light effect. The overall atmosphere is vibrant and natural.

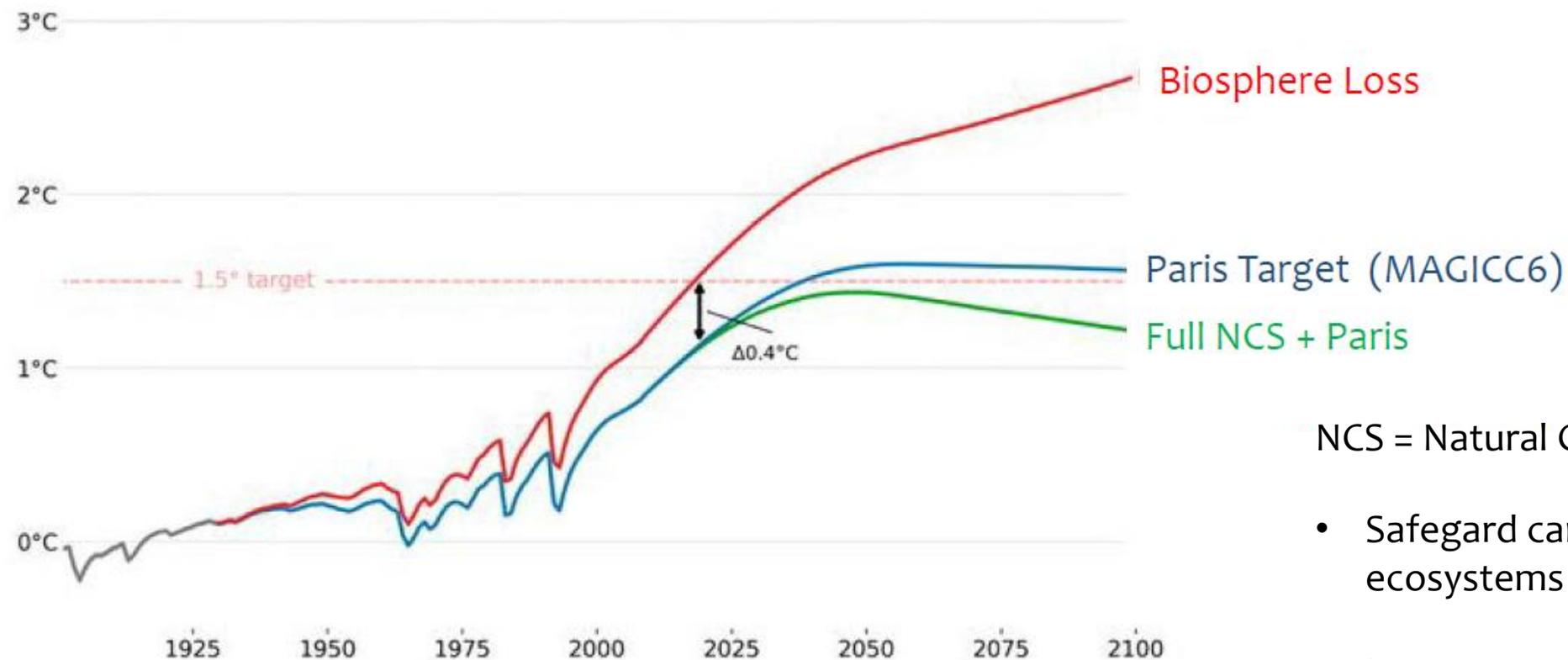
*THE HEART OF THE  
EARTH SYSTEM  
IS THE BIOSPHERE*



# BIOSPHERE STEWARDSHIP

“... the pursuit of social-ecological sustainability, from local to global scale the ensures the health and resilience of the Earth’s life support systems”

Steffen et al 2018



NCS = Natural Climate Solutions

- Safeguard carbon stocks in vulnerable ecosystems
- Increase uptake of carbon in agricultural areas
- Restore and regenerate degraded native ecosystems



*IF WE ARE TO AVOID A CATASTROPHIC  
SHIFT IN THE EARTH SYSTEM AND AVERT  
A MASS EXTINCTION, WE MUST:*

- 1. REMOVE THE FORCING*
- 2. PRESERVE AND RESTORE OUR  
BIODIVERSITY TO ALLOW THE  
EARTH SYSTEM TO RECOVER*

I don't know what word in the English language – I can't find one – that applies to people who are willing to sacrifice the literal existence of organized human life so they can put a few more dollars into highly overstuffed pockets. The word evil doesn't begin to approach it.

Noam Chomsky

Drill, Baby, Drill

Donald J Trump