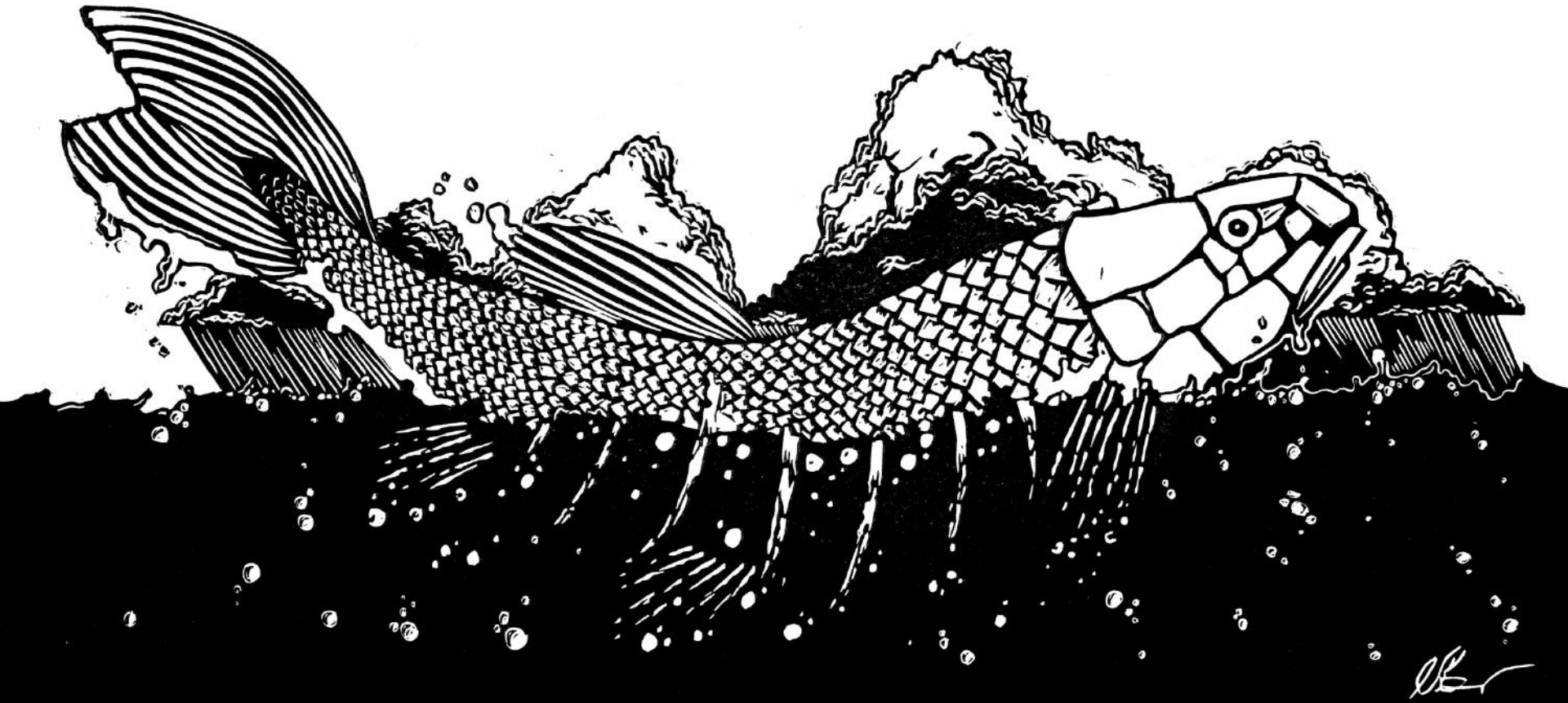


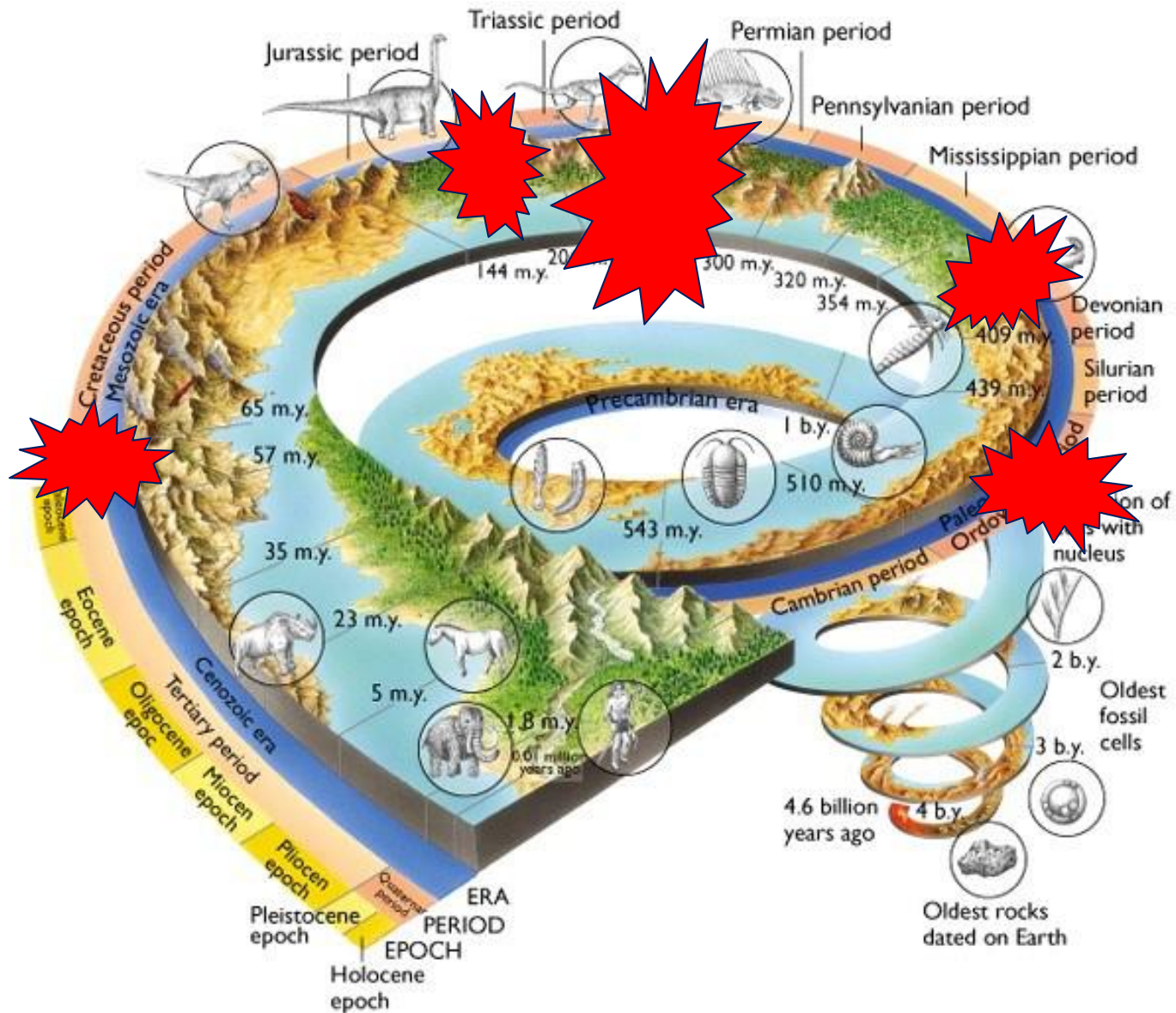
# Mass extinction, climate change, and ocean acidification

*Rachel Wood*

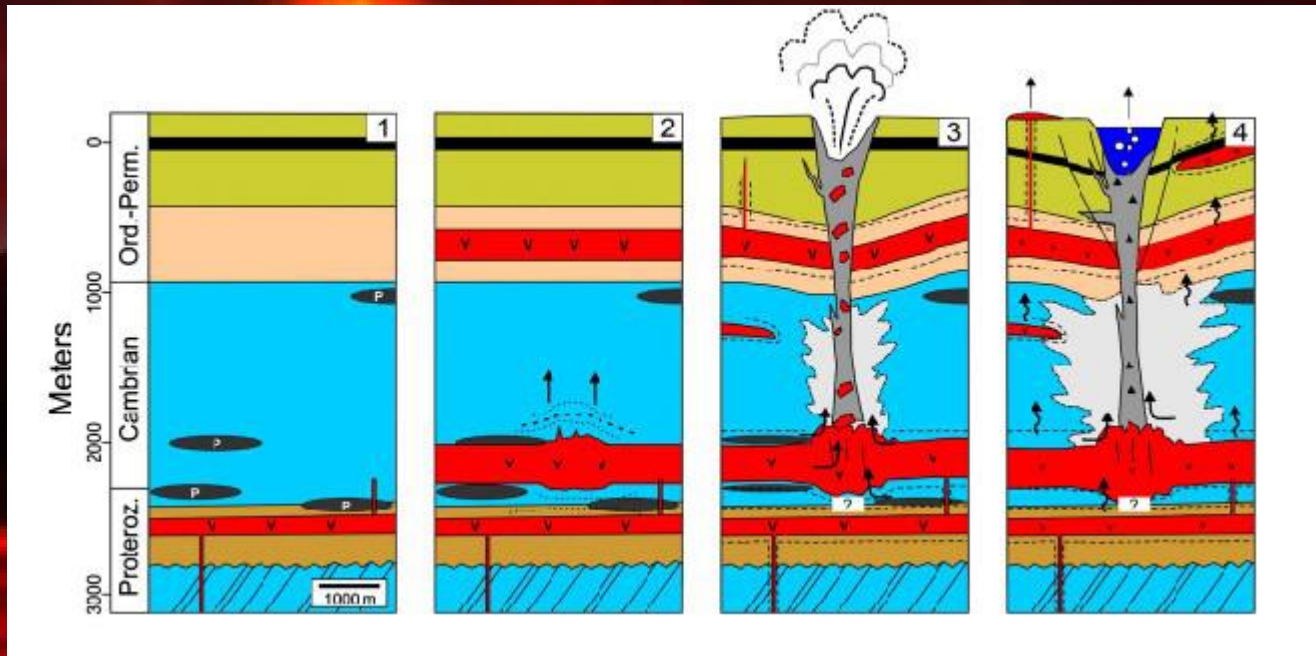
M. O. Clarkson, S. A. Kasemann, T. M. Lenton, S. J. Daines, S. Richoz, F. Ohnemüller,  
A. Meixner, S. W. Poulton, E. T. Tipper



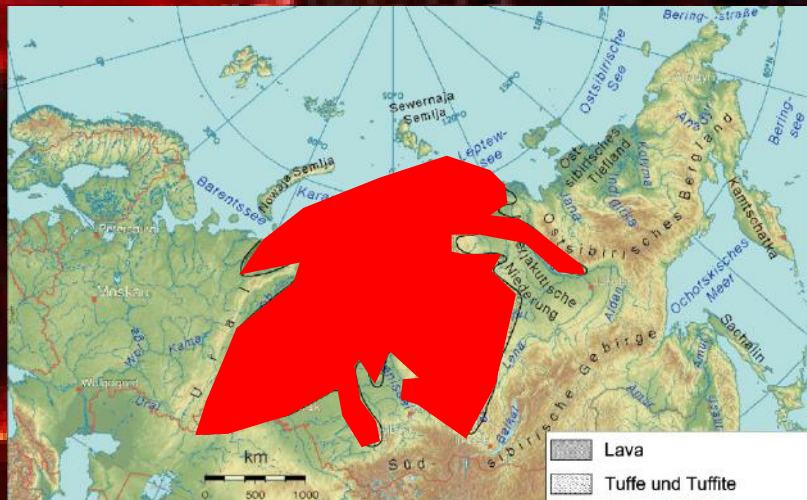
# The end-Permian Mass Extinction: ~252 million years ago



# Siberian Traps: a Large Igneous Province



Magmatic  
&  
carbonate  
-derived  
CO<sub>2</sub>



# In the sea...before



*Permian diorama at the University of Michigan's Museum of Natural History*

# In the sea...after



# On land...before



*Credit: Davide Bonadonna*

# On land...after



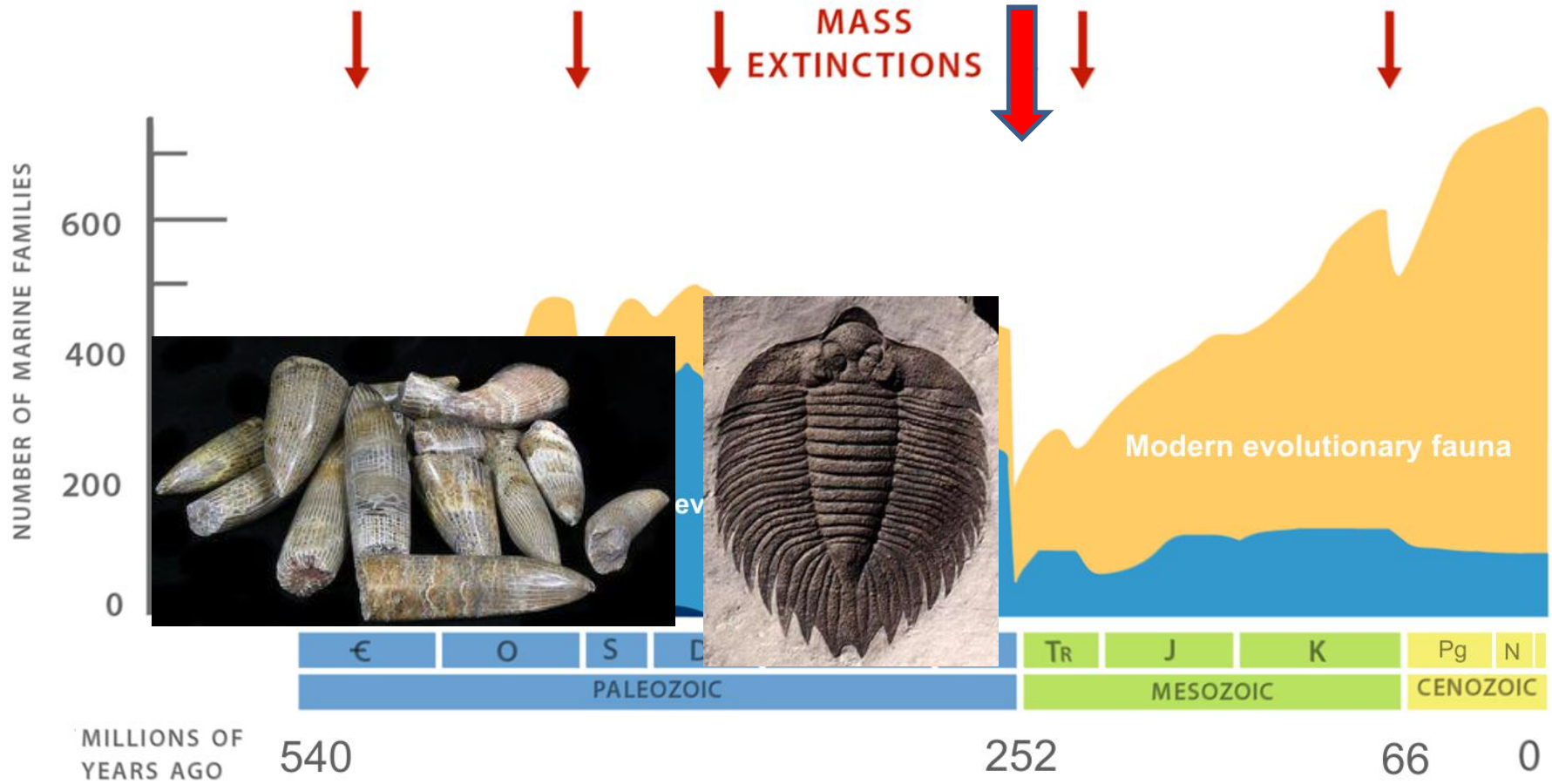
*National Geographic*



© Jonathan Blair/CORBIS

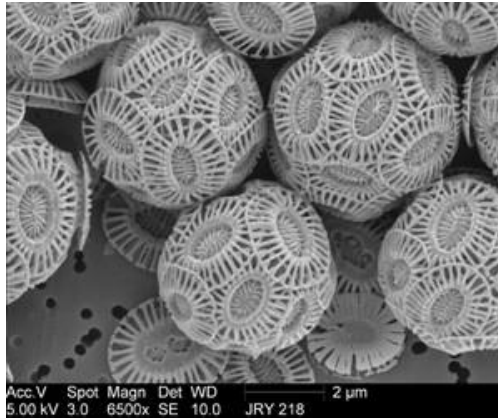
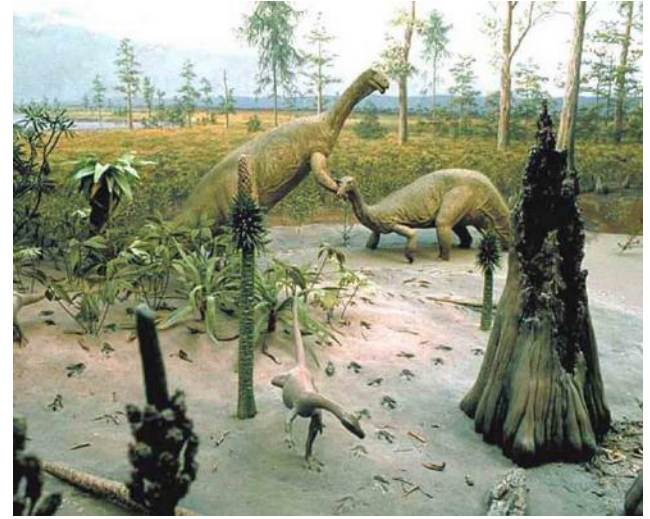
*Dinogorgon*

# Removed 'incumbents'

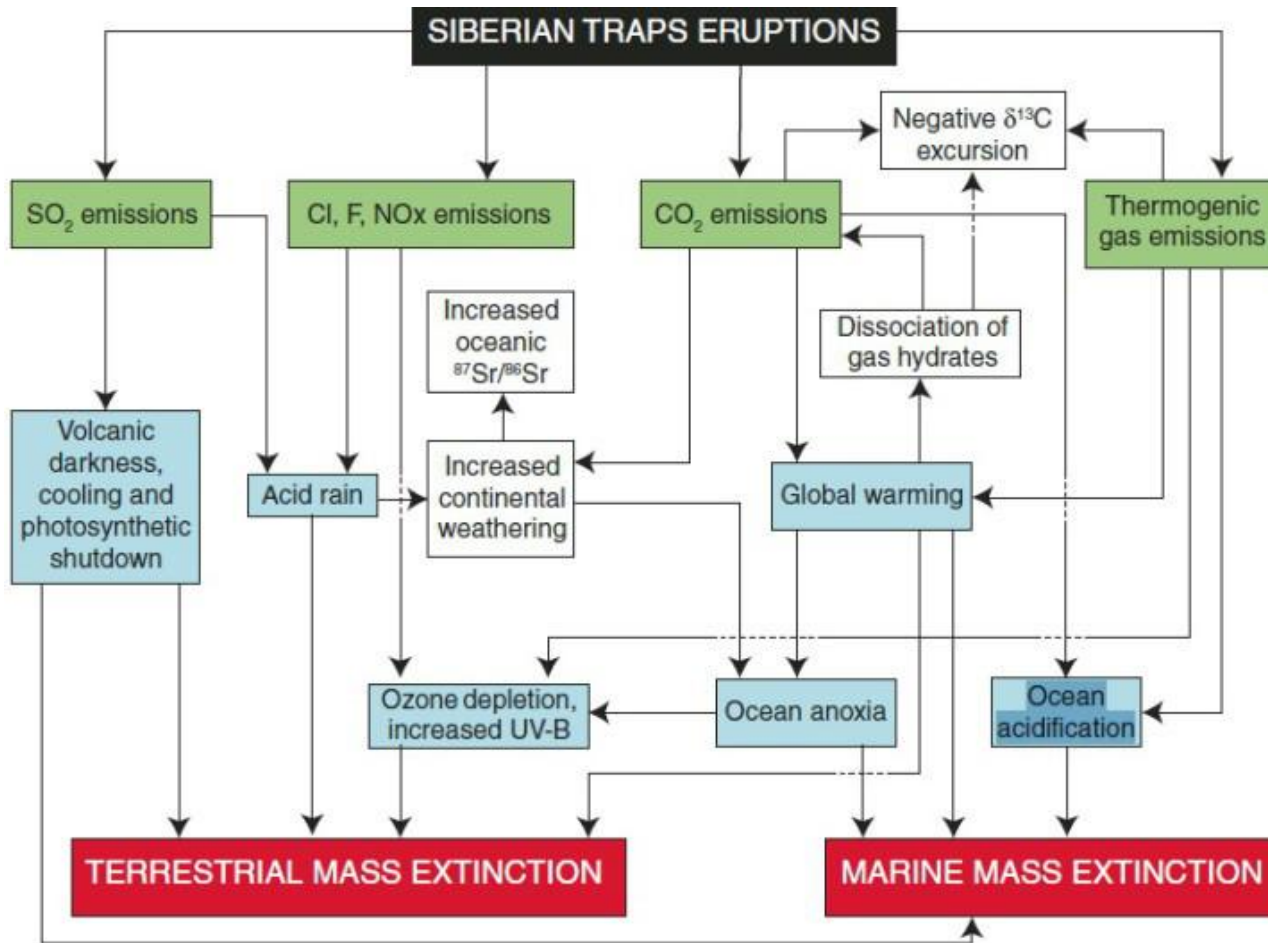




# Ushered in the Modern world



# A runaway greenhouse?

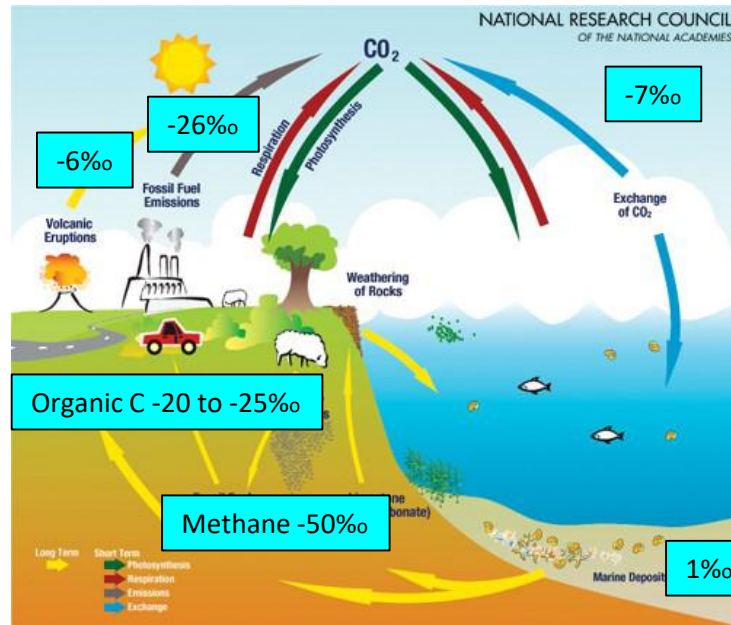


Time-lapse image of methane hydrate mound.

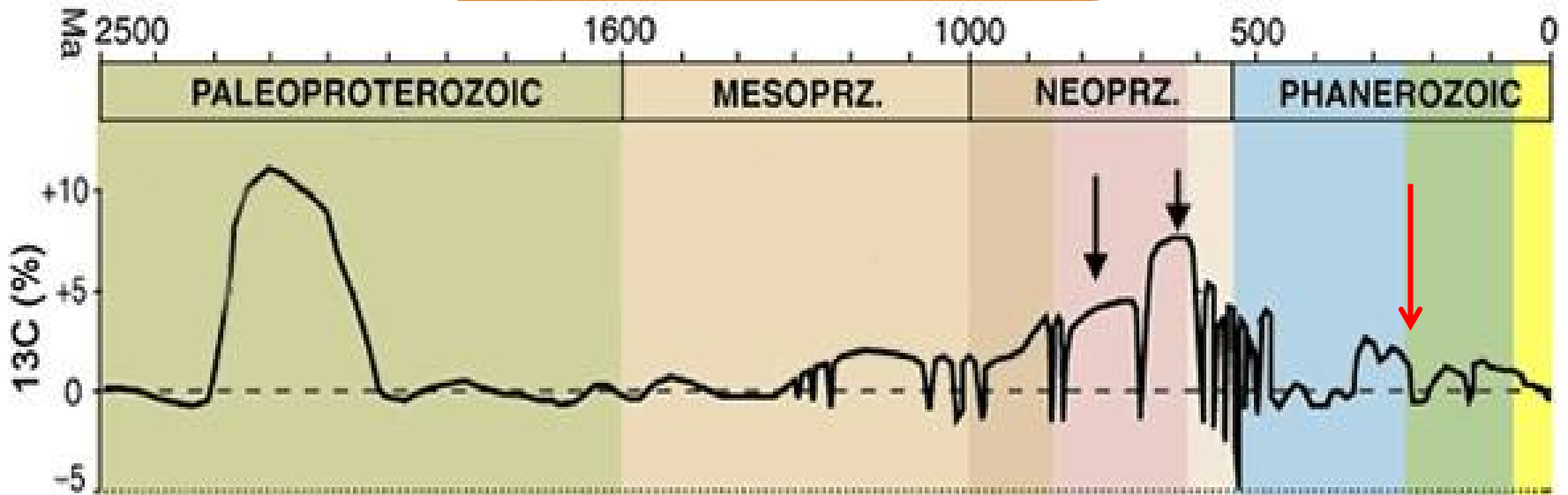
Image by DOE



# Changes in the Carbon cycle

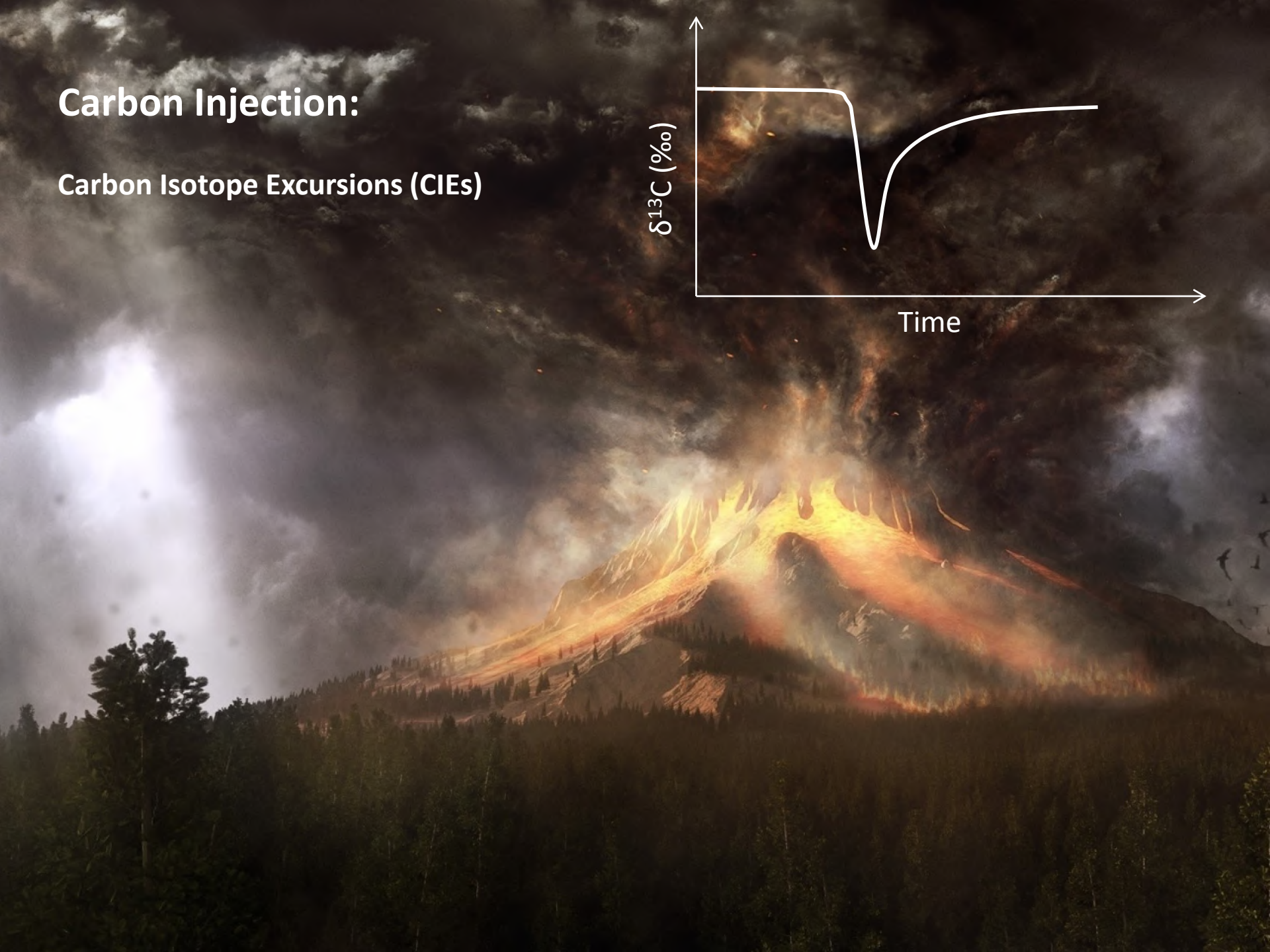
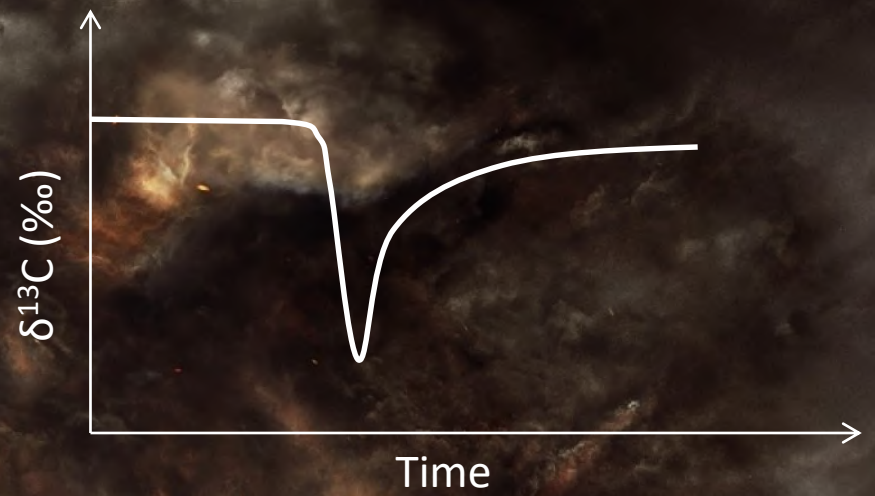


$^{12}\text{C}$  vs  $^{13}\text{C}$   
 $\delta^{13}\text{C}$

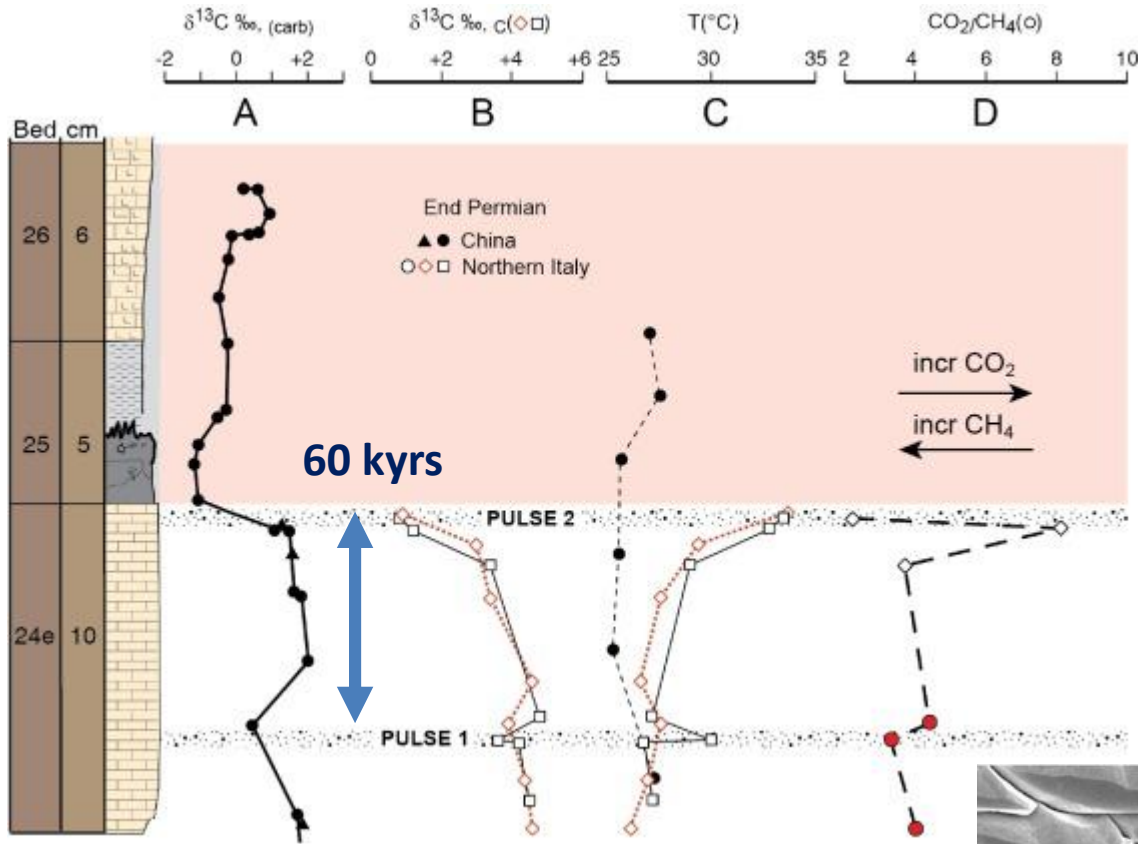


# Carbon Injection:

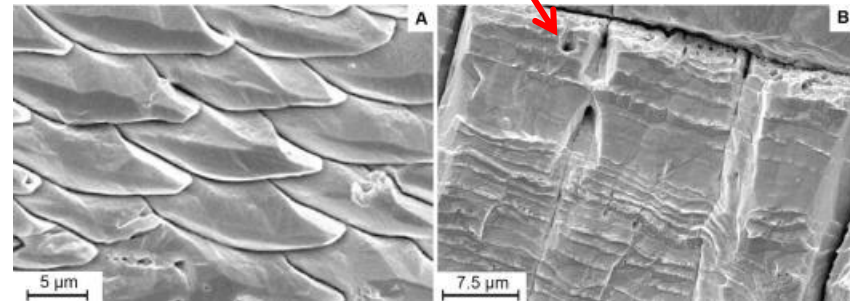
Carbon Isotope Excursions (CIEs)



# Rapid global warming: CO<sub>2</sub> + CH<sub>4</sub>



Seawater & Gas inclusions



Brand et al., 2016



Triassic

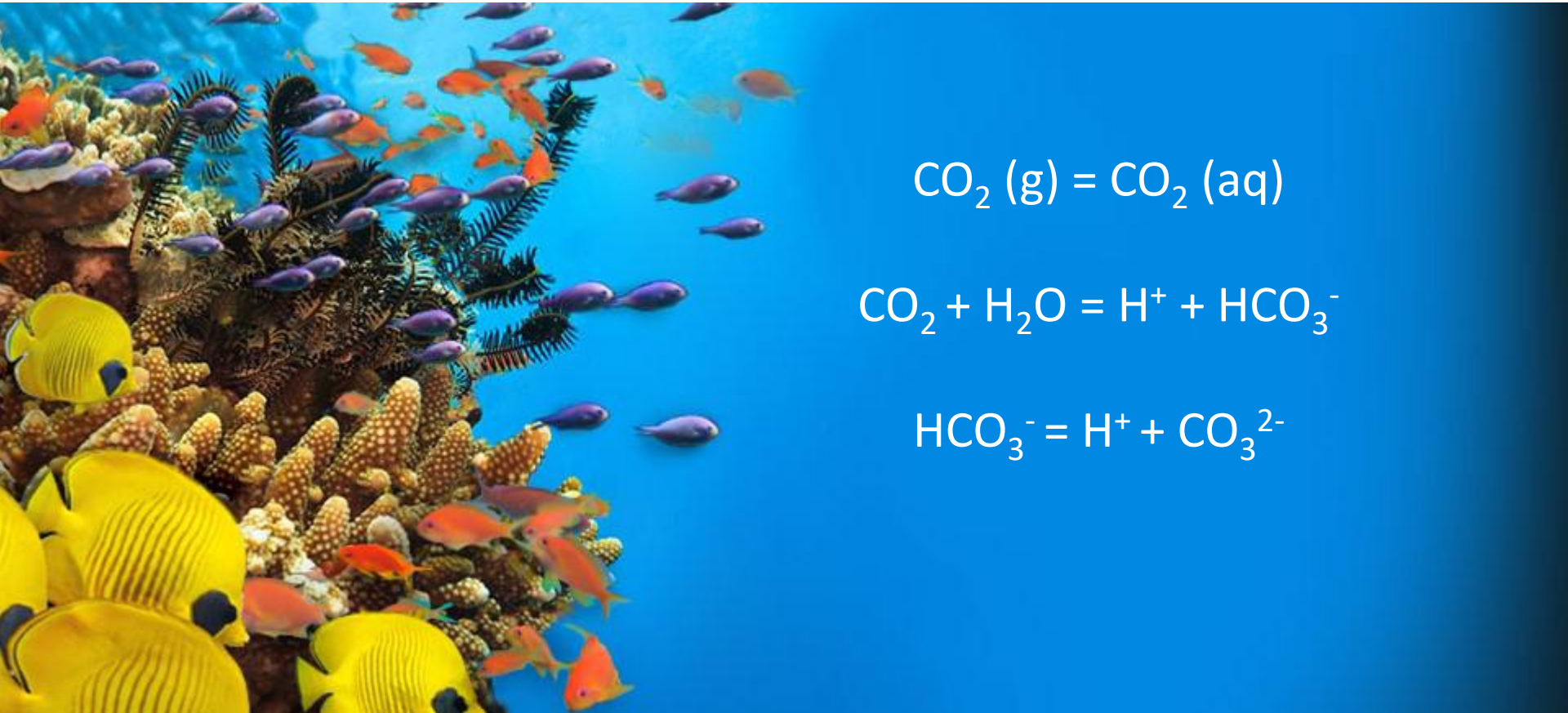
Permian

2015  
PERM  
PTB-106

2015  
PERM  
PTB-107

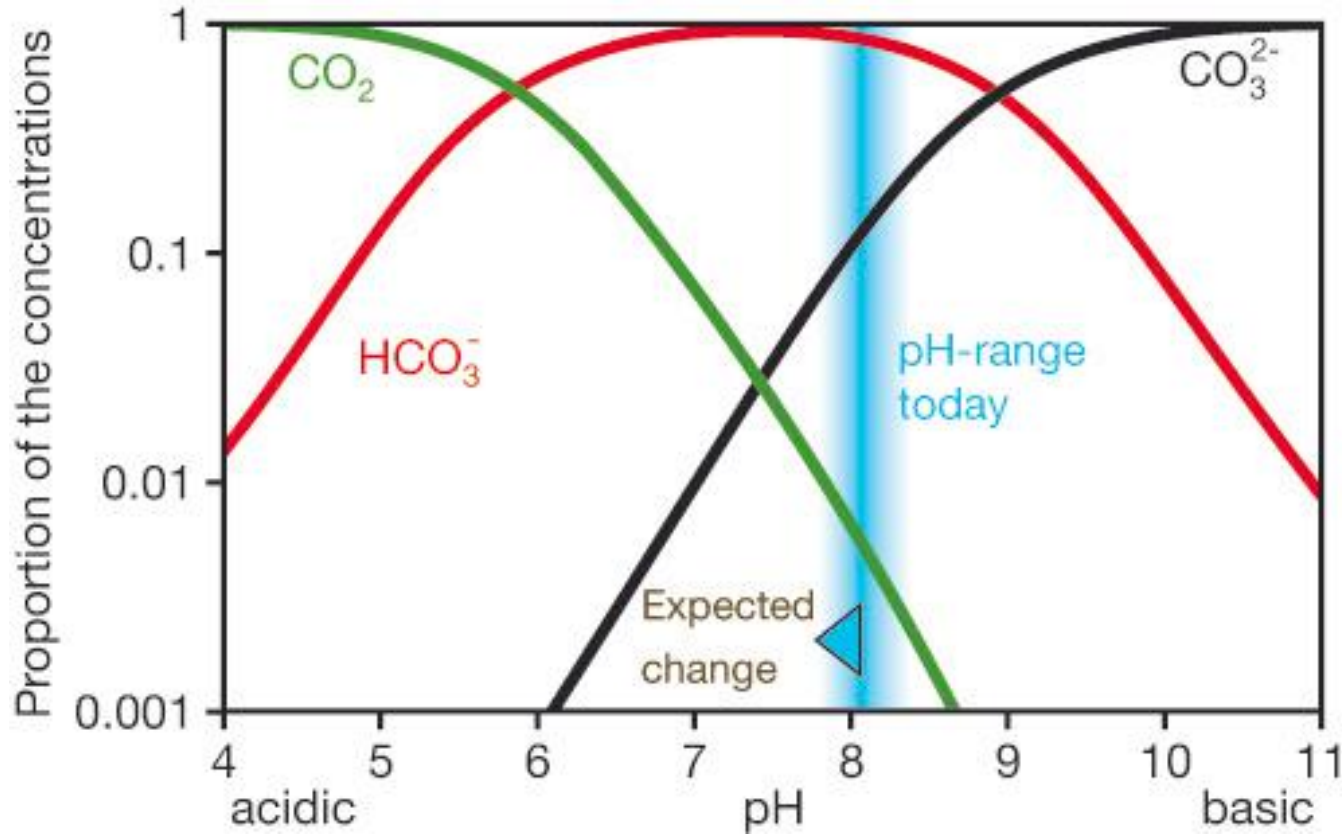


# Ocean Acidification: the basics and why it's bad





# Carbon in the oceans



$p\text{CO}_2$  on geological timescales – rate, not absolute amount – is critical

# Bad news.....

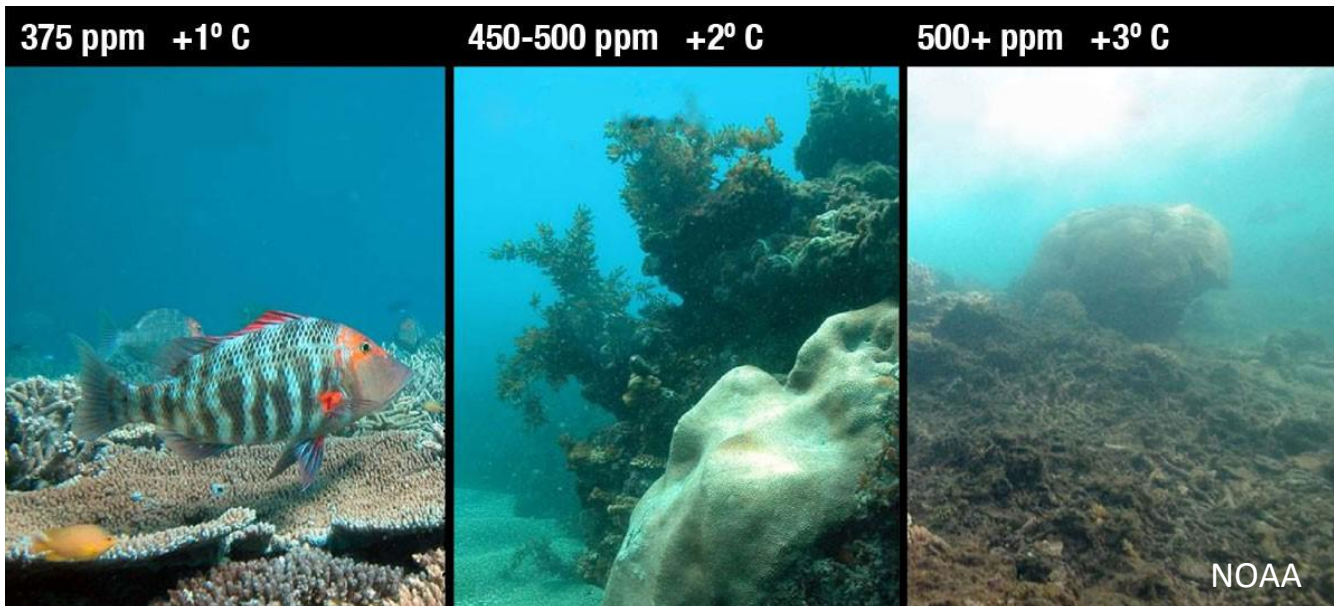
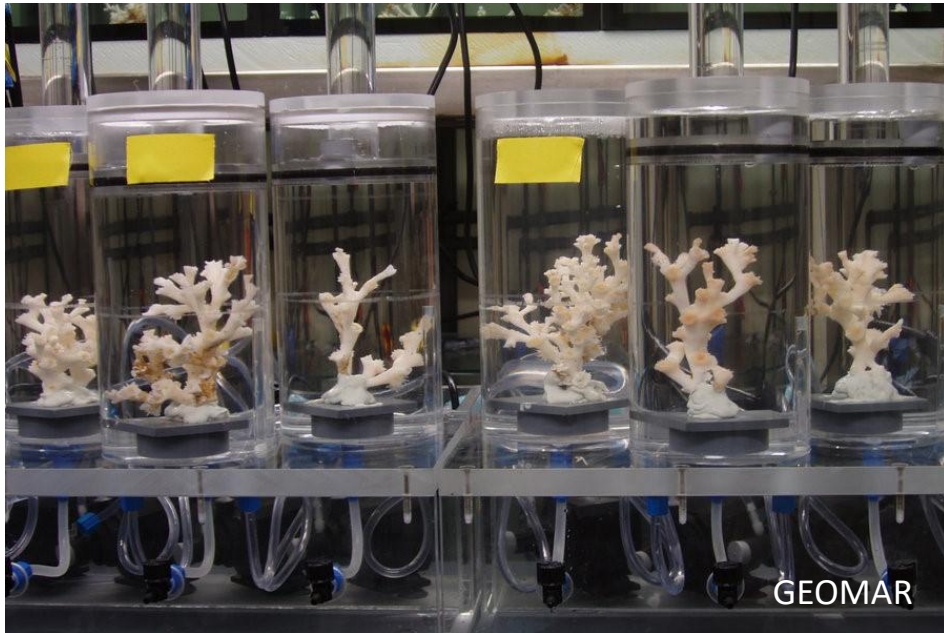


## Direct effects:

- ✓ Shell dissolution
- ✓ Hypercapnia and mortality
- ✓ Chronic metabolic suppression
- ✓ Sense disruption
- ✓ Reproductive disruption

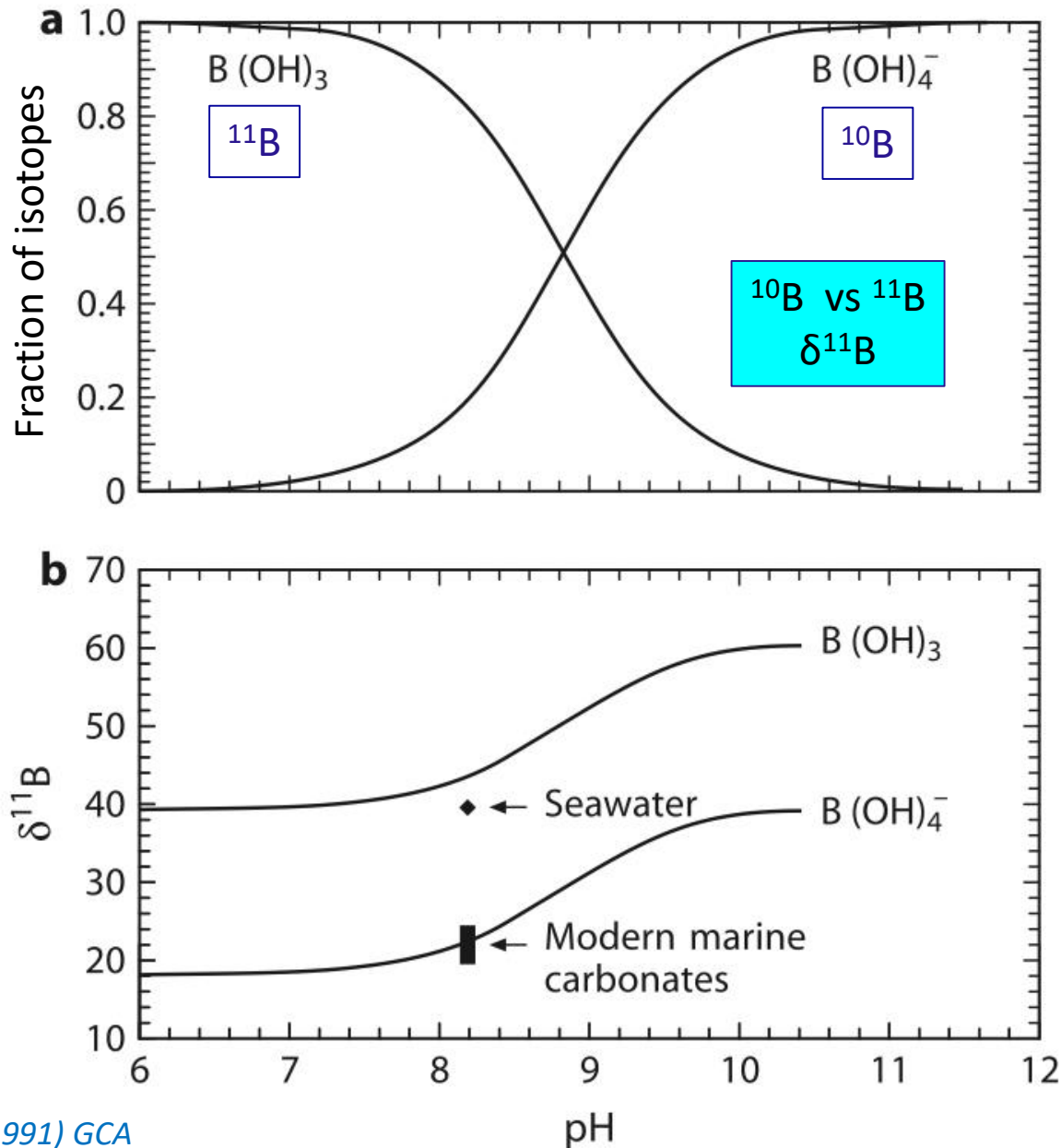
## Plus synergistic pressures:

- ✓ High temperature
- ✓ Ecosystem collapse

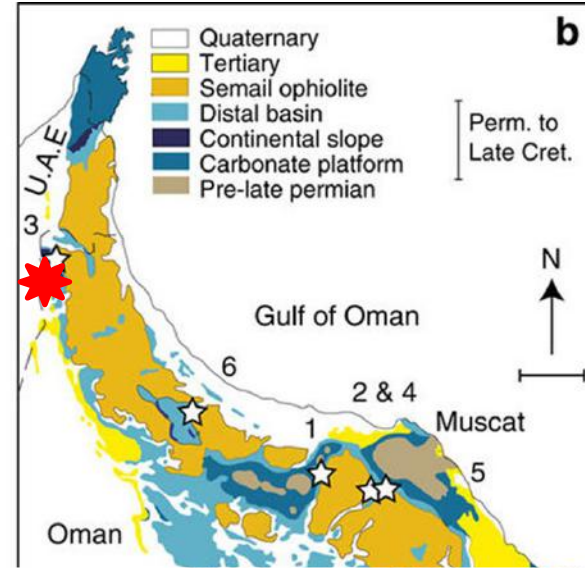
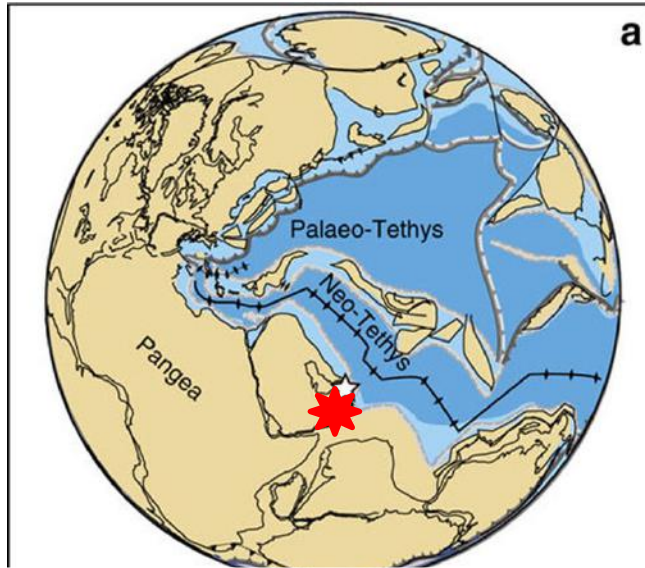




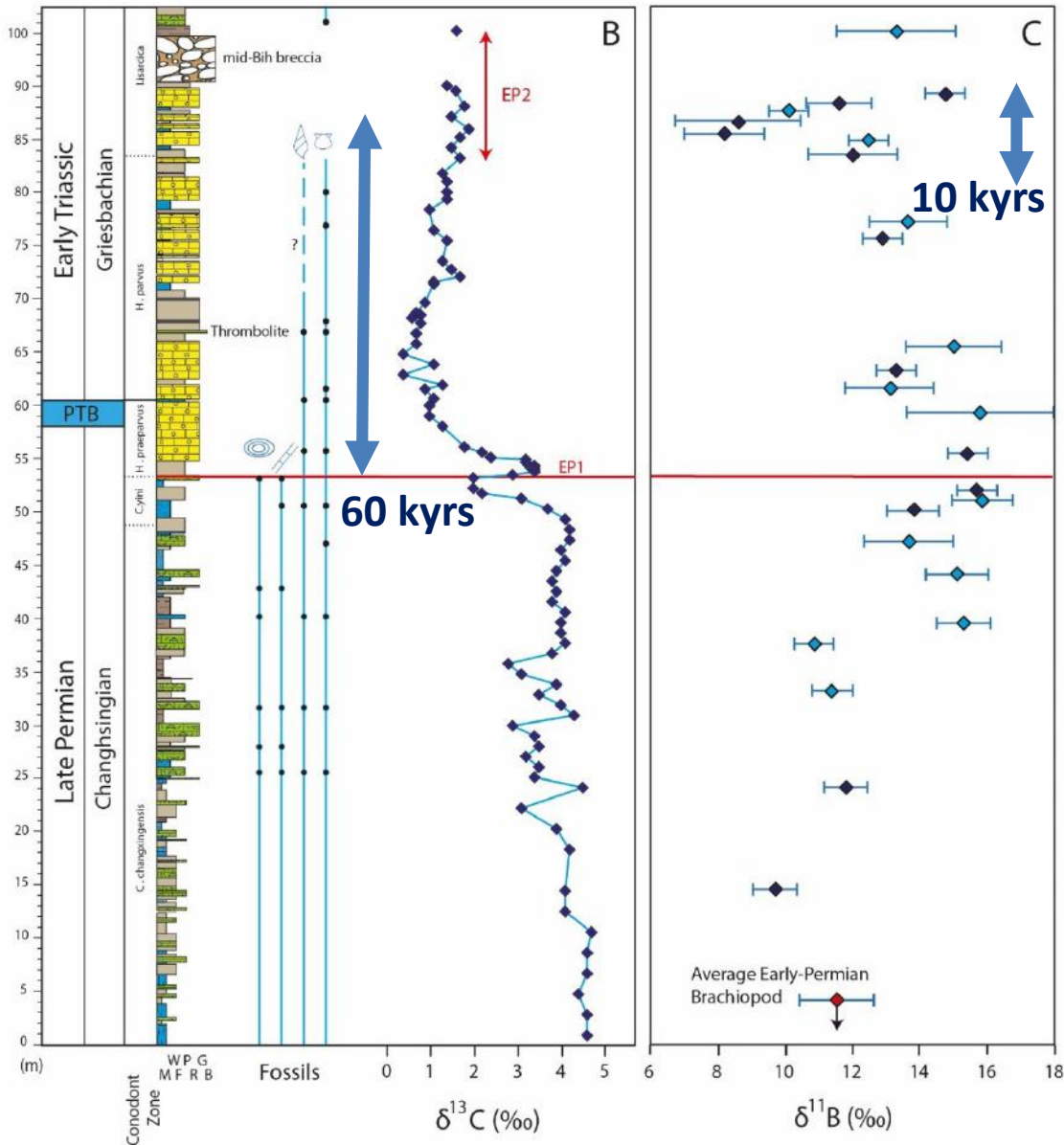
# A more direct proxy for pH – Boron isotopes



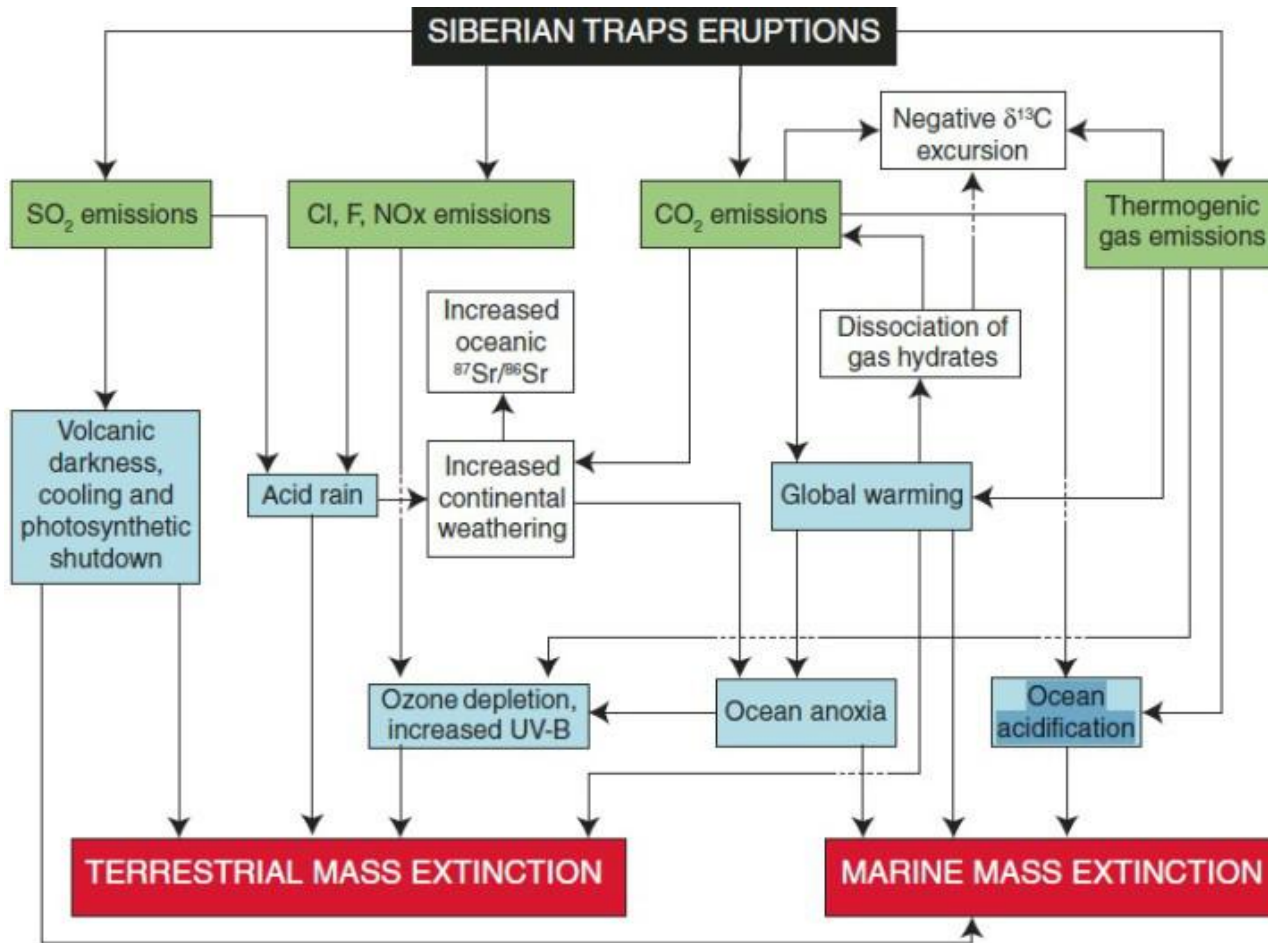
# Ocean Acidification?



# Ocean Acidification!



# A runaway greenhouse



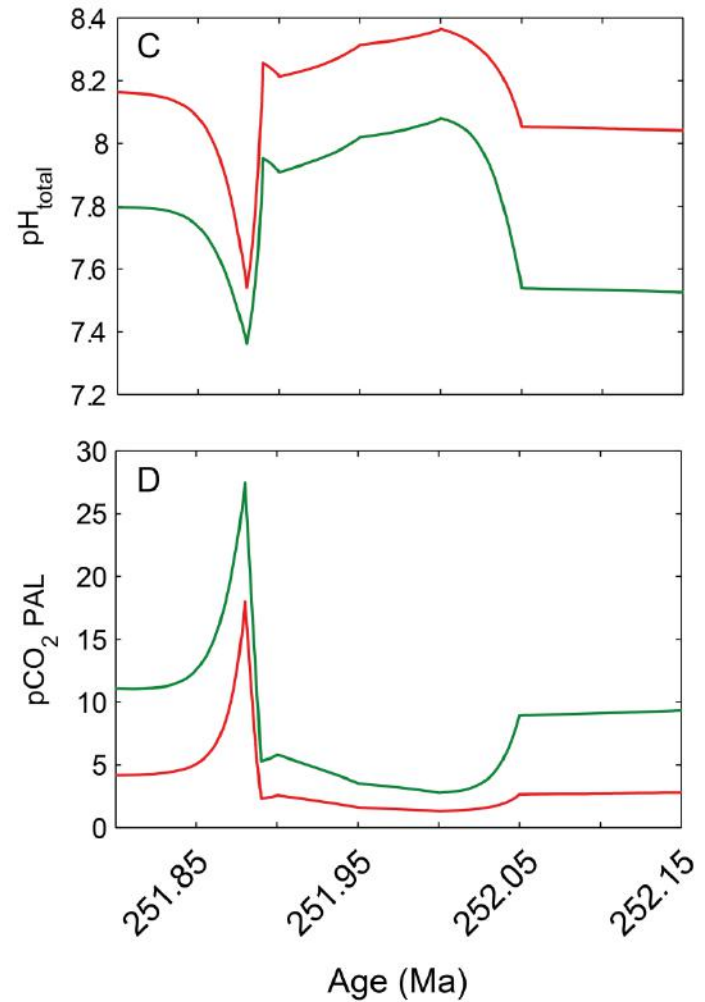
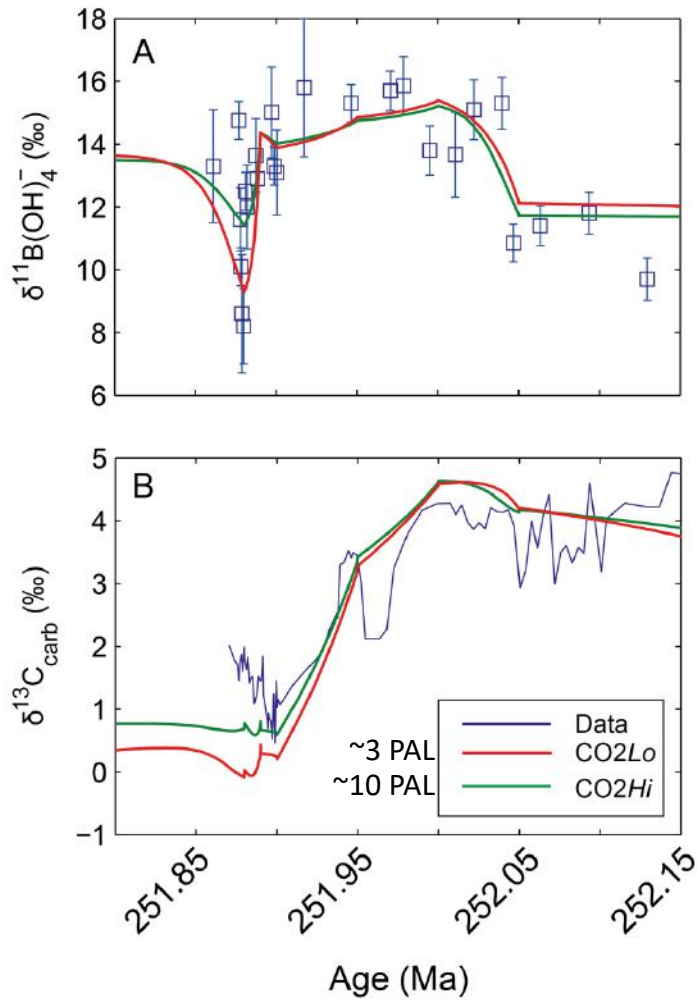
Time-lapse image of methane hydrate mound.

Image by DOE



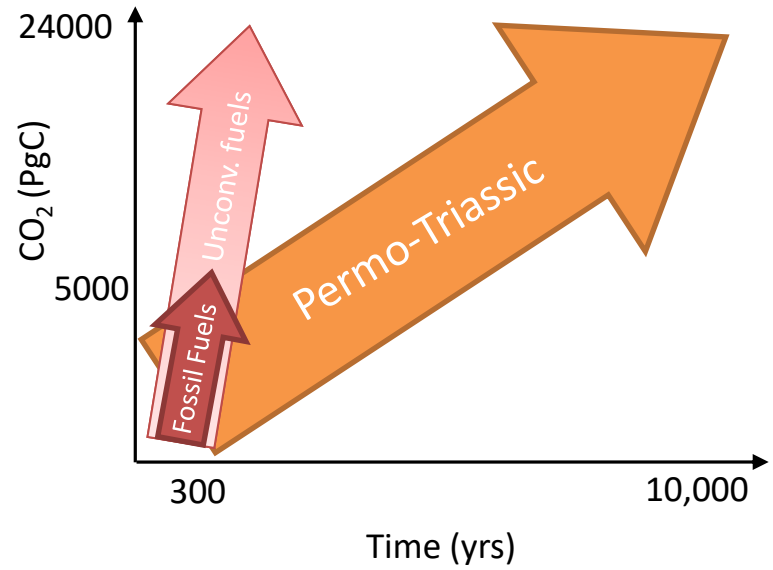


# Model outputs

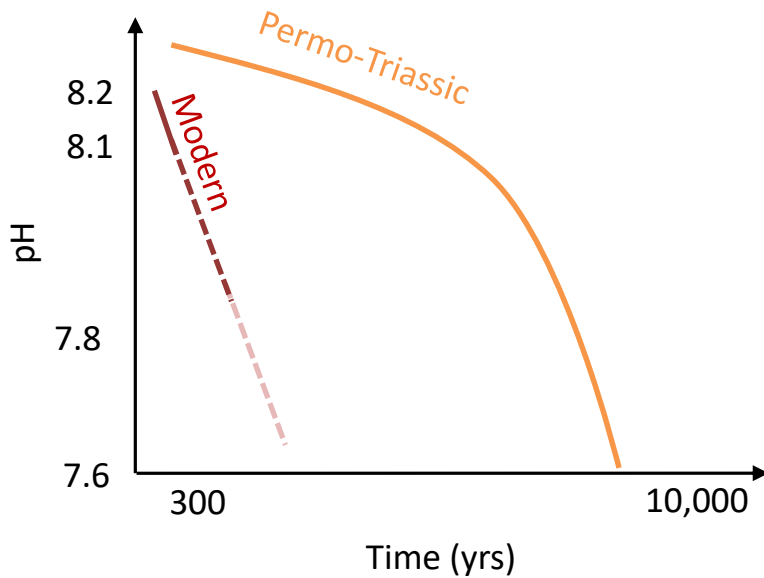


*Clarkson et al., 2015*

# Future analogue or “Doom-mongering”?



Vs.



# Future analogue or “Doom-mongering”?

Global mean temperature near-term projections relative to 1986–2005

