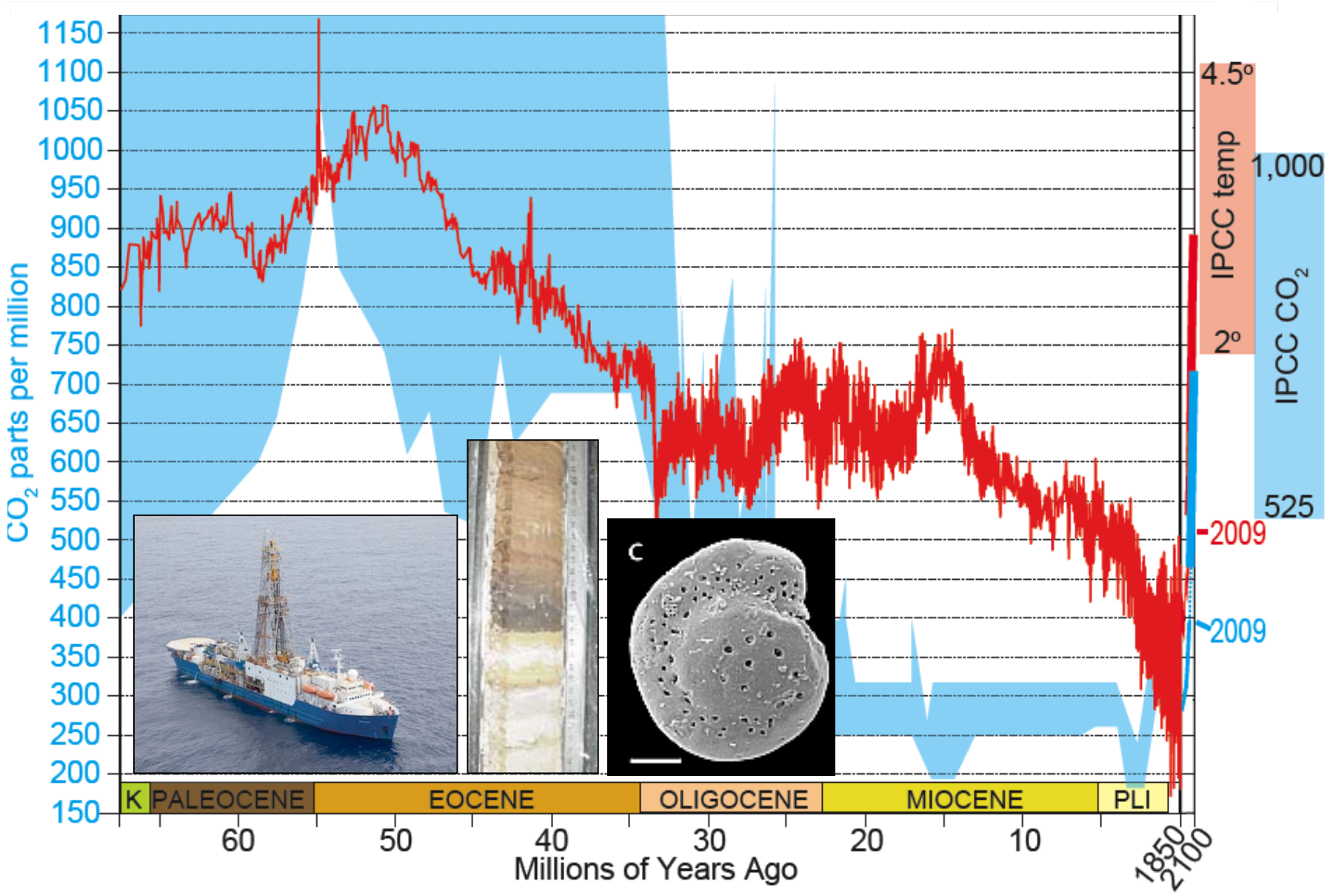
# Terrestrial ecosystem response to 'transient' global warming 56 million years ago

Scott L. Wing
Dept. of Paleobiology
Smithsonian Institution

# An Even Longer Context

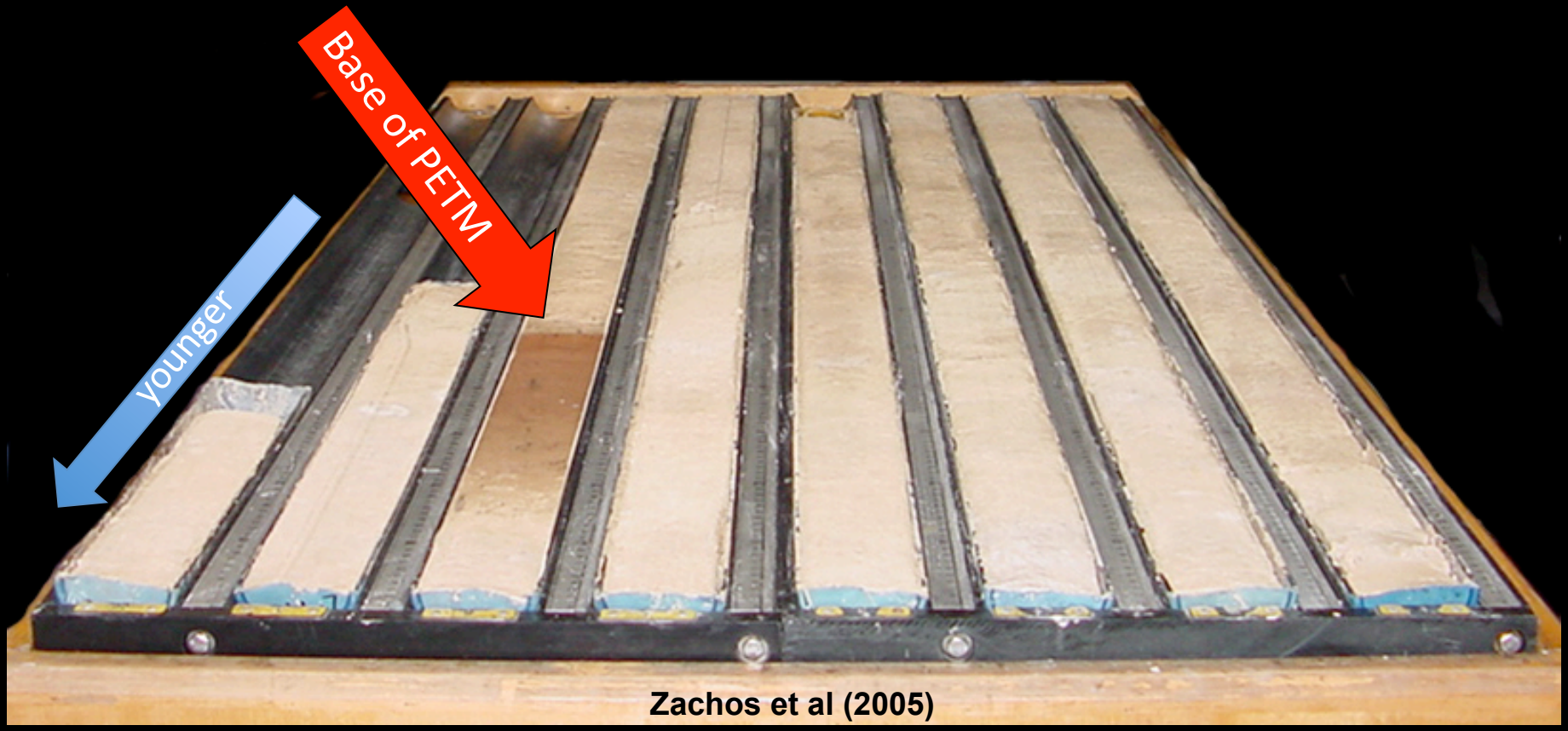


# Paleocene-Eocene Thermal Maximum (PETM)

- Release of ~4,000-7,000 Gt carbon in (inferred from carbon isotope excursion of -4 to -5‰ and extensive marine carbonate dissolution)
- Duration of onset 10-20 ky (orbital calibration of sediment cores)
- Large increase in atmospheric $CO_2$
- Global warming of 5 to 8 °C
- Total duration ~200 ky

# Dissolution of deep ocean chalk

http://www-odp.tamu.edu/publications/208_IR/208ir.htm



# PETM carbon & temperature

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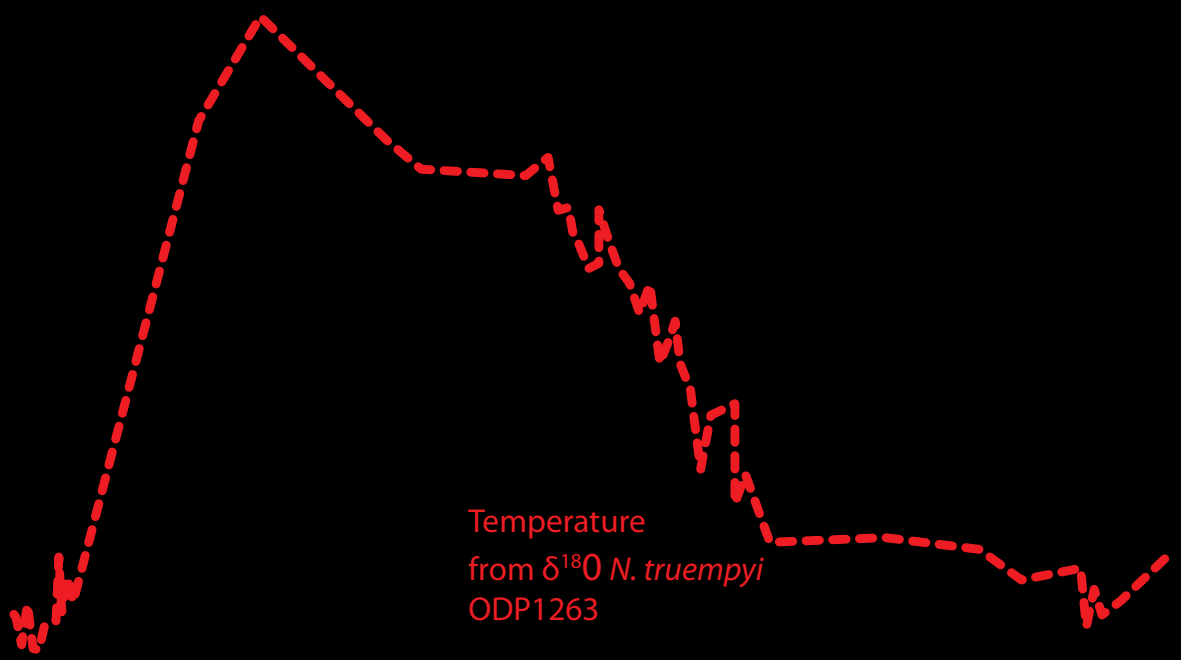
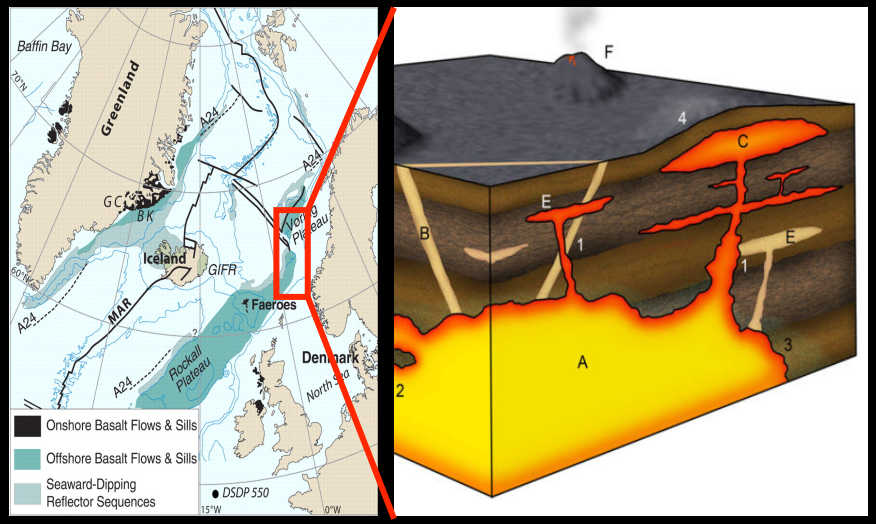



Murphy et al. 2010

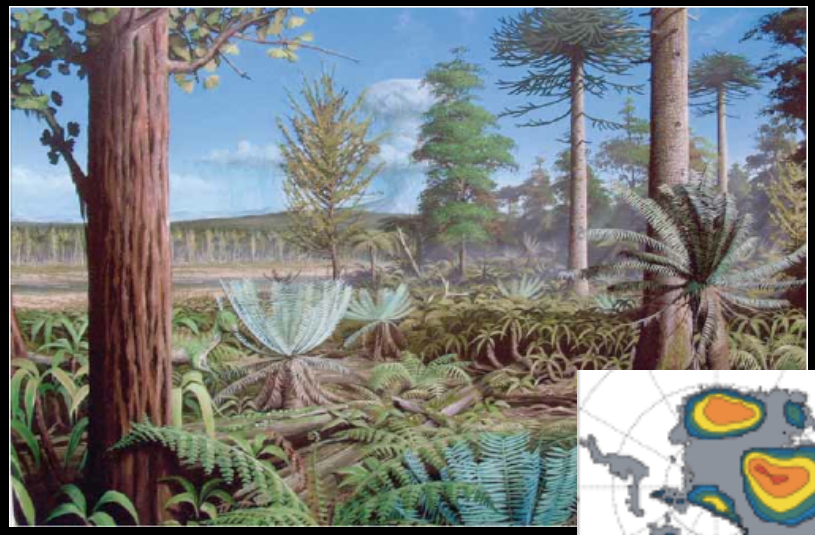
# Where did the carbon come from?


Methane Hydrates

Wildfire

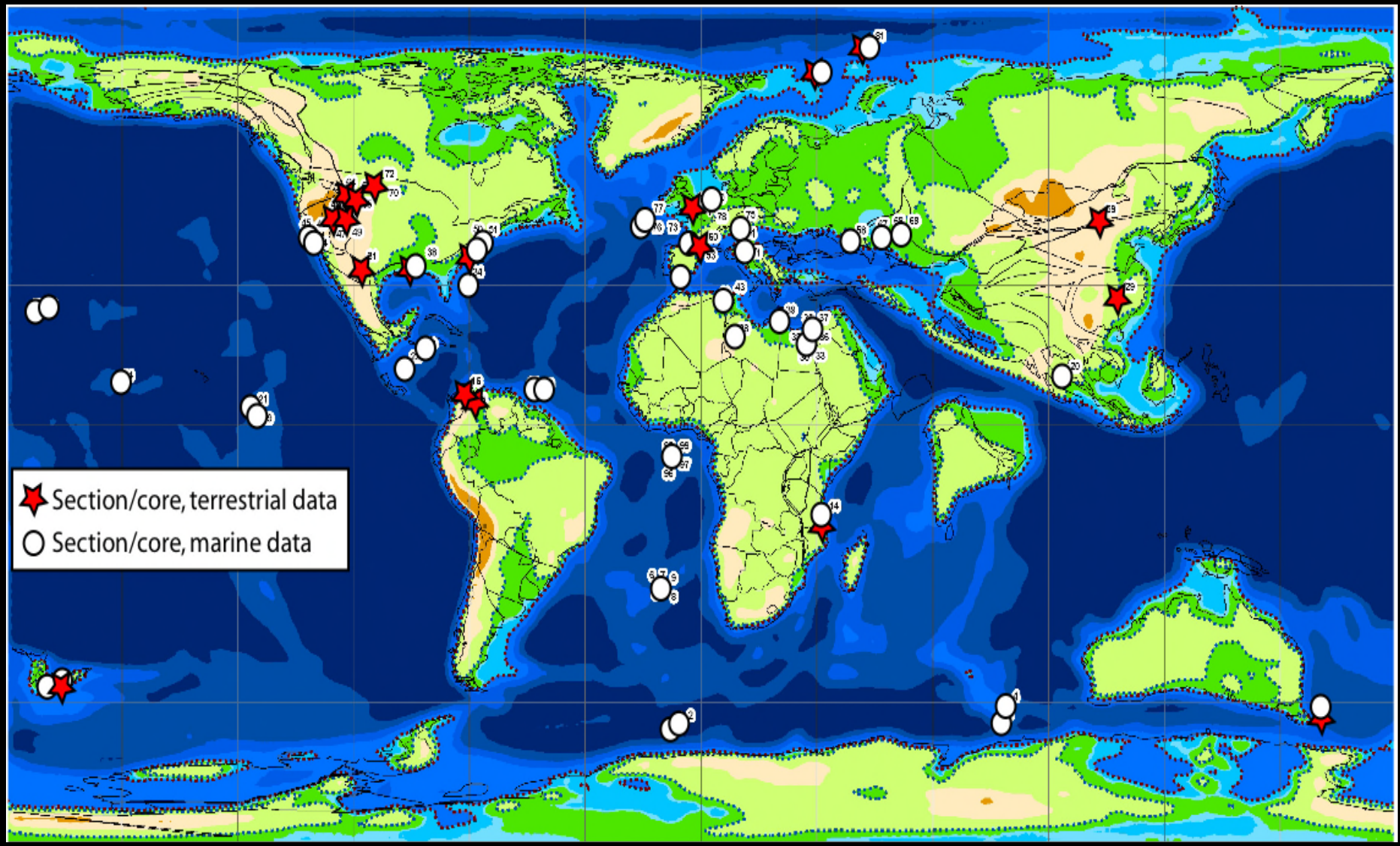



Thermogenic Methane

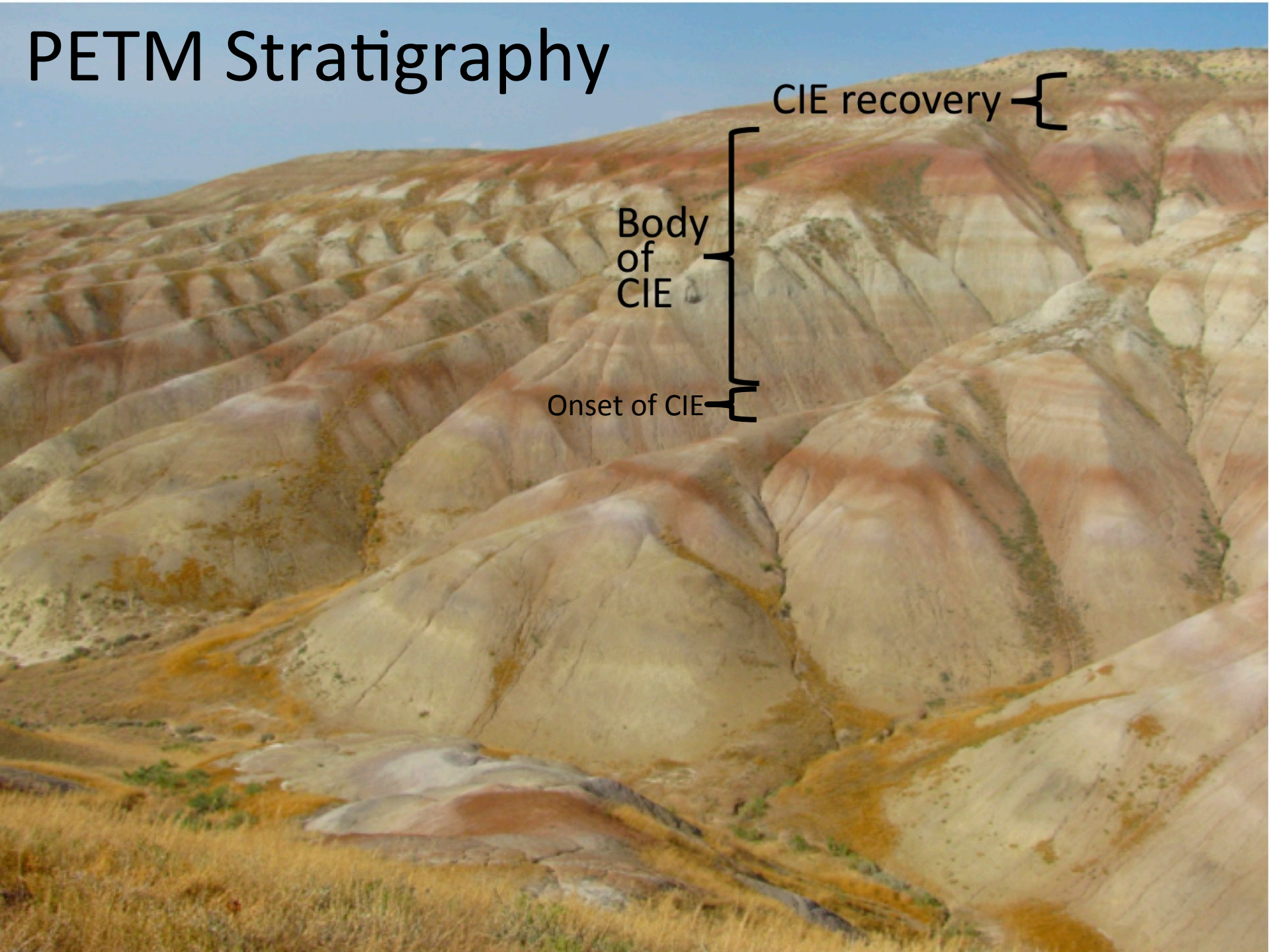


Antarctic Peat

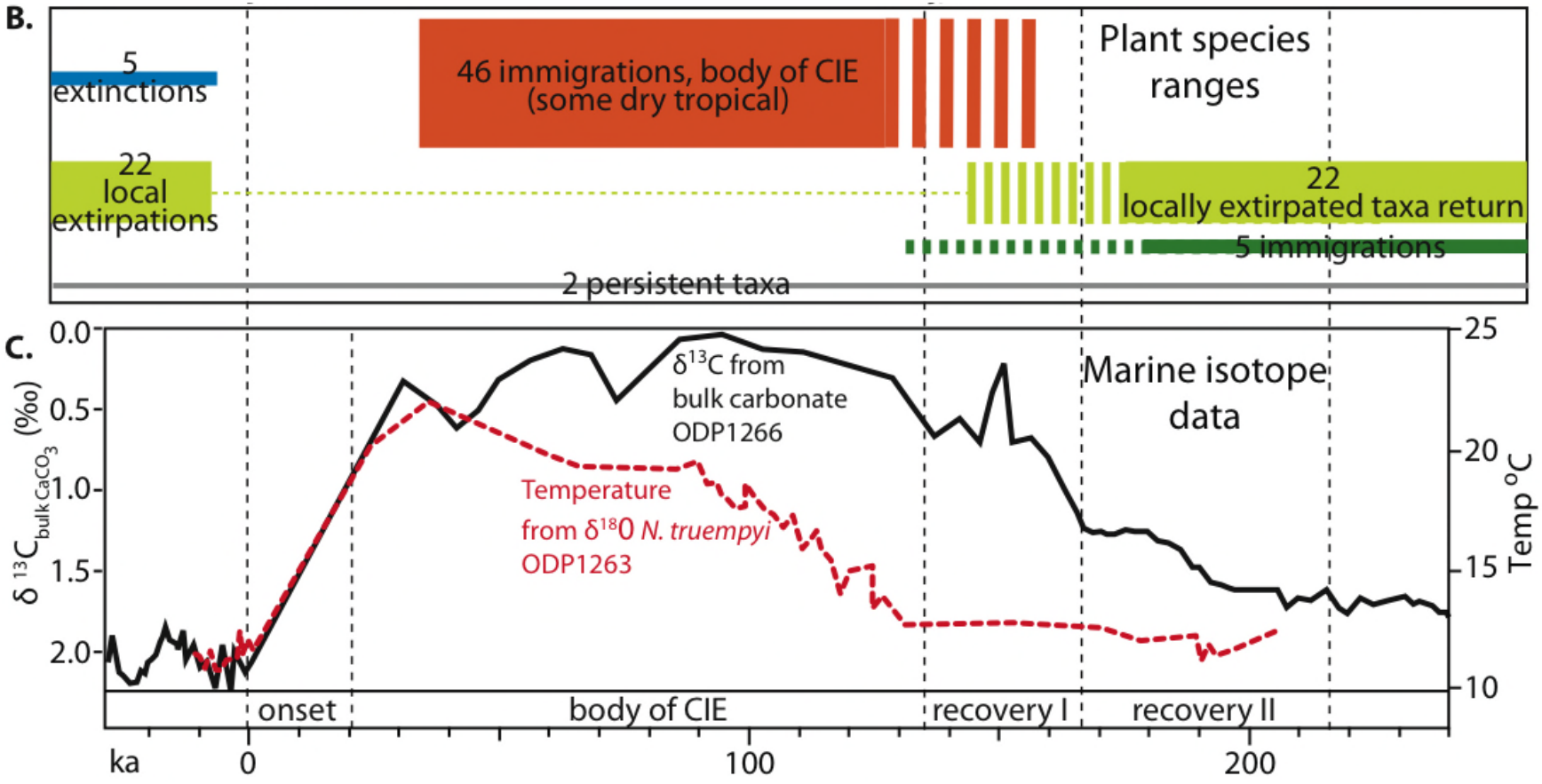
# P-E boundary records




Paleogeography by C.R. Scotese, PALEOMAP Project

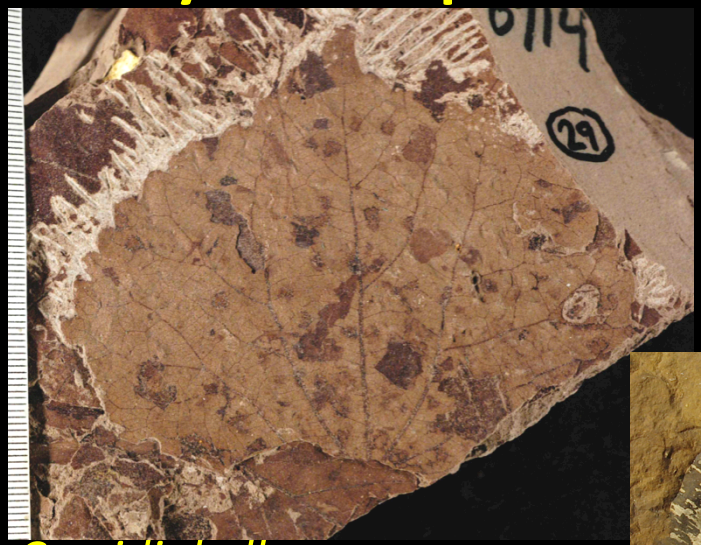

PETM Stratigraphy
CIE recovery
Body of CIE
Onset of CIE

# PETM - change in plant species



# Locally extirpated

*Fagopsiphyllum*

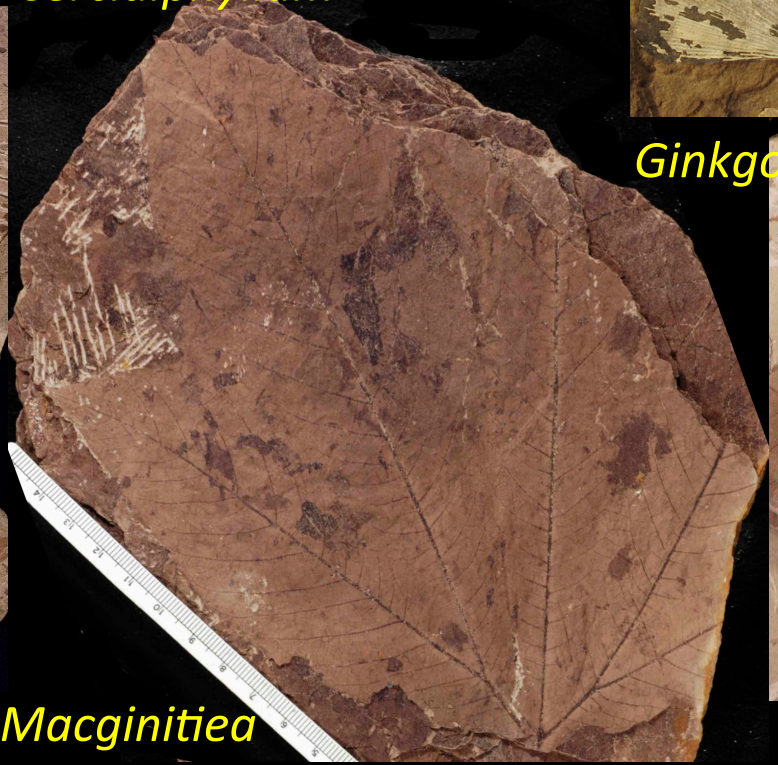


*Cercidiphyllum*

*Metasequoia*

*Ginkgo*

*Corylites sp.*



*Macginitiea*

*Platanus raynoldsii*

# PETM only

1.

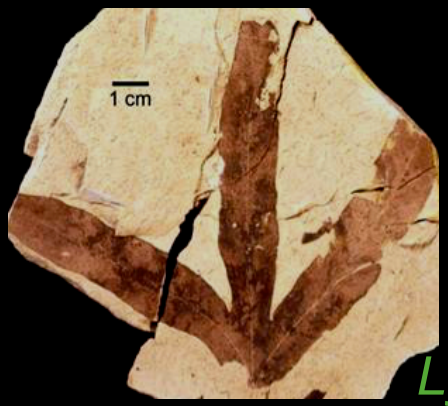
2.

3.

4.

5.

# Early post-PETM flora



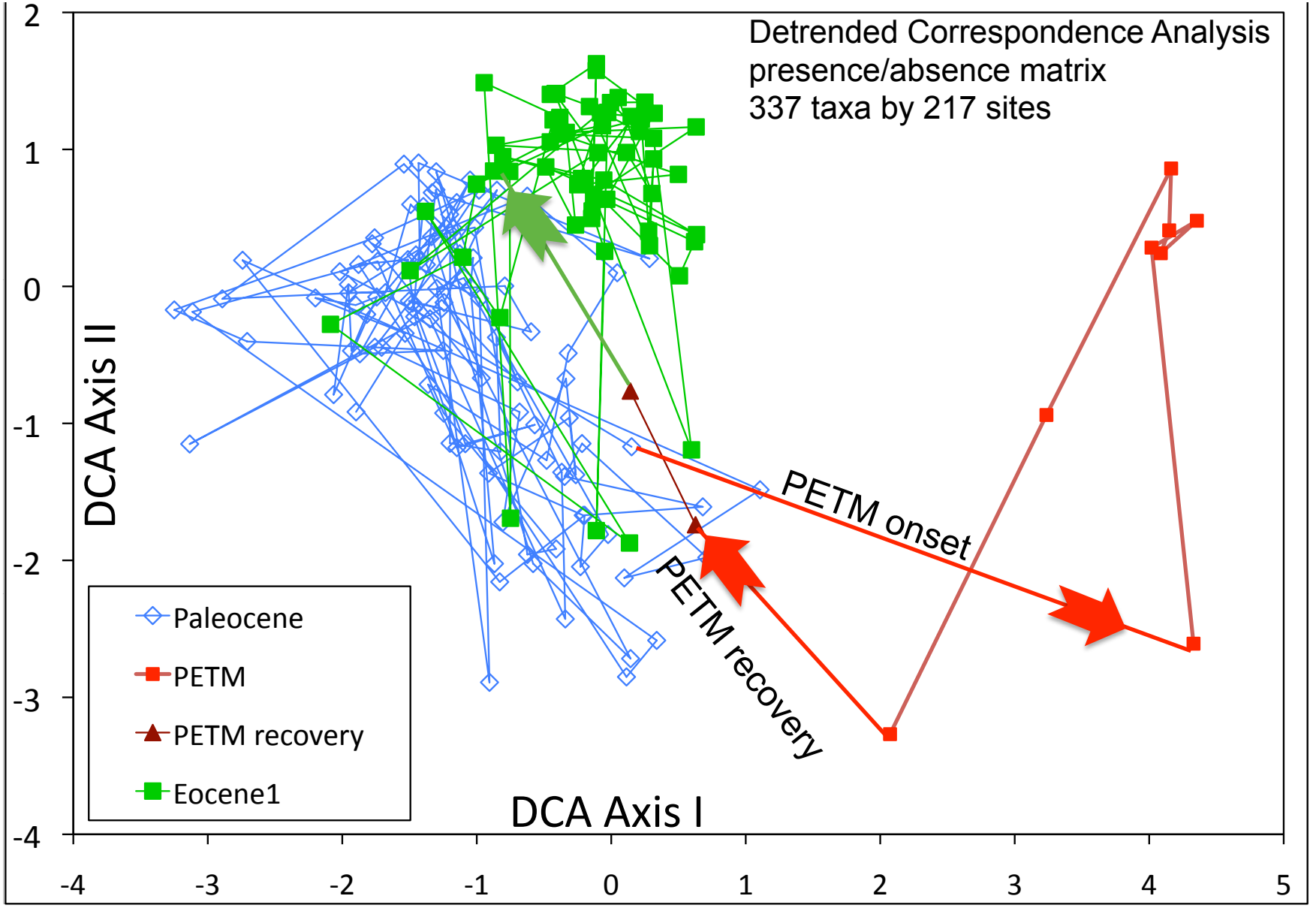

*Lygodium*

Tiliaceae


*Alnus*


*Platycarya*

# Paleocene-Eocene Floral Change



# PETM in Wyoming

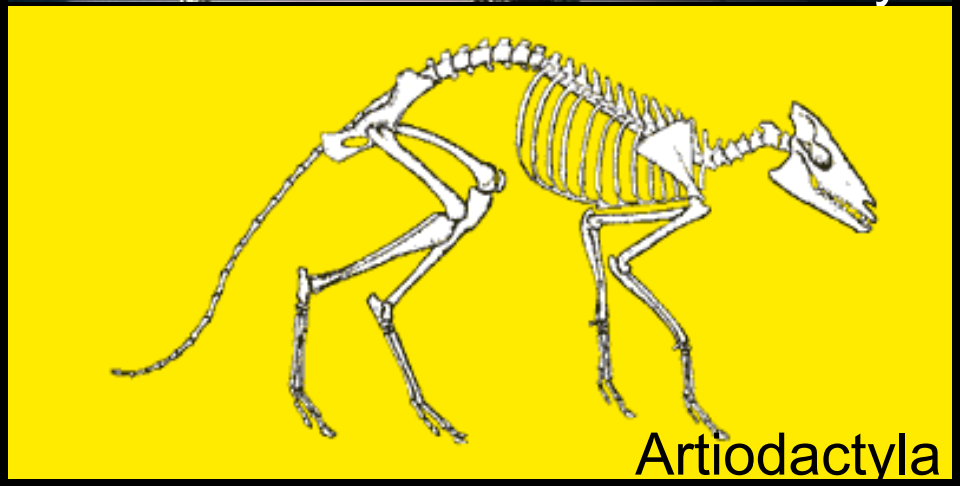
Latest Paleocene

Paleocene-Eocene Thermal Maximum

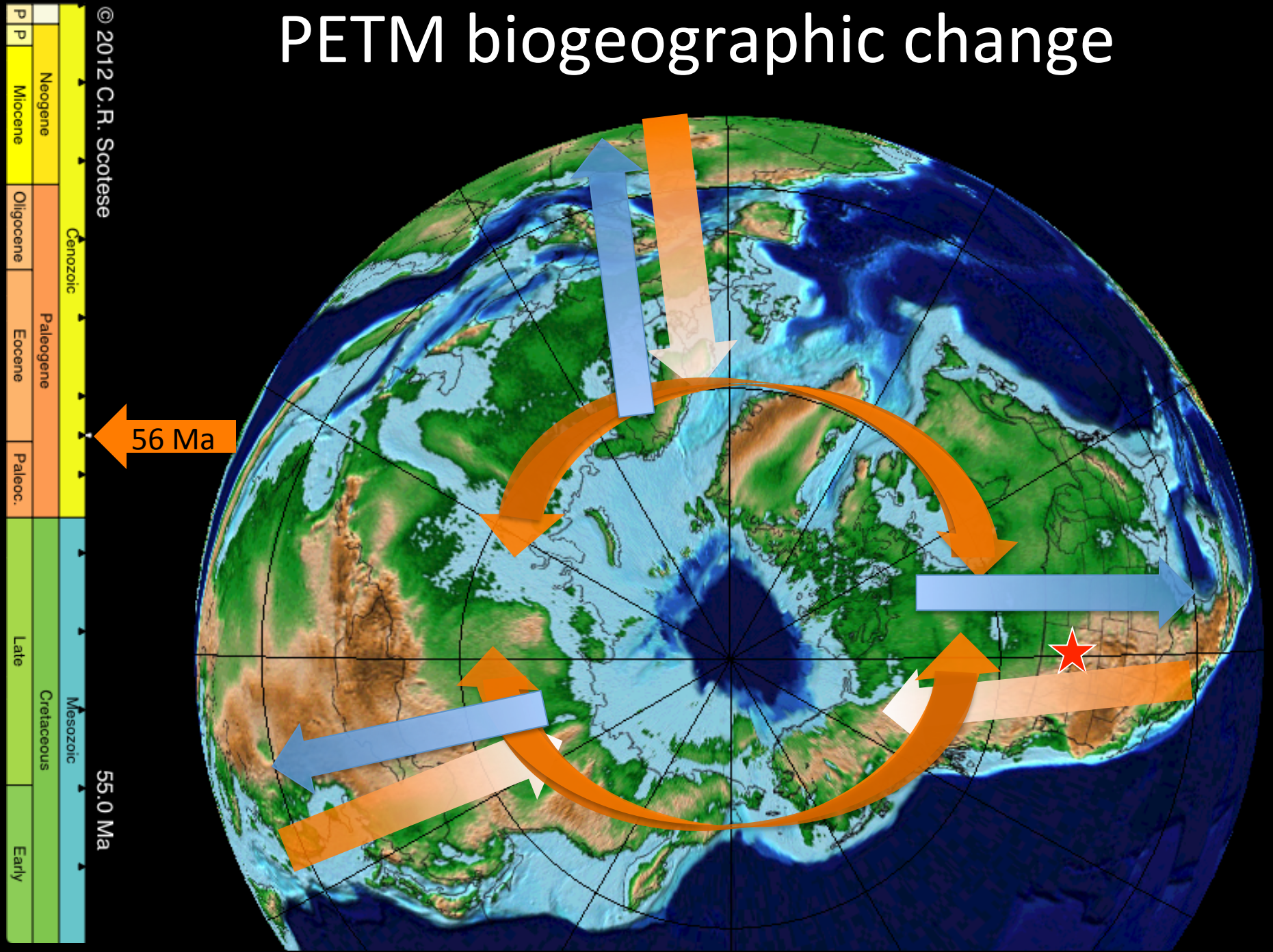
Earliest Eocene

painting by Aldo Chiappe
*National Geographic* Oct. 2011

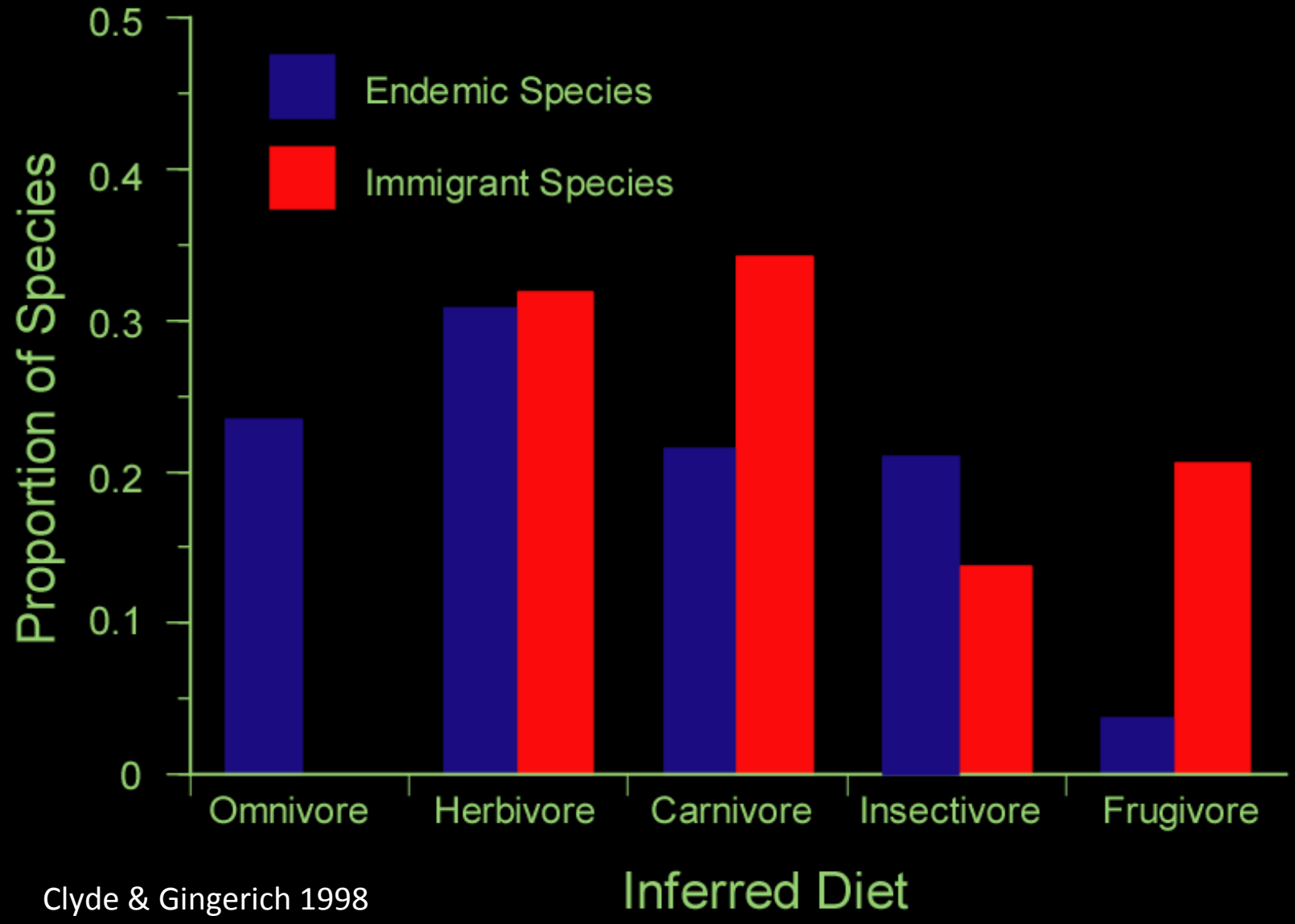
# PETM mammal migrants


# PETM biogeographic change

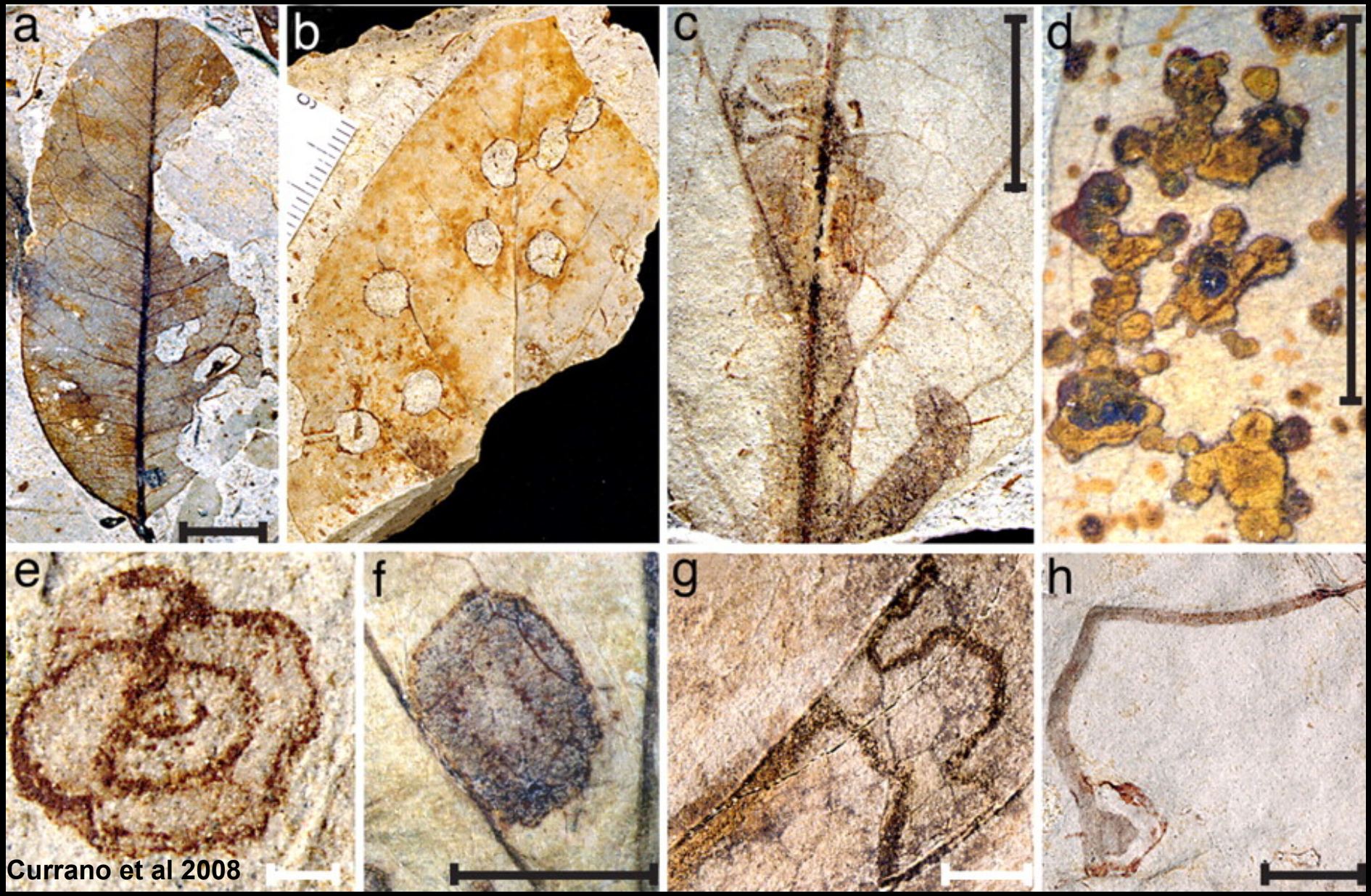


# Diet of PETM immigrant & endemic mammals

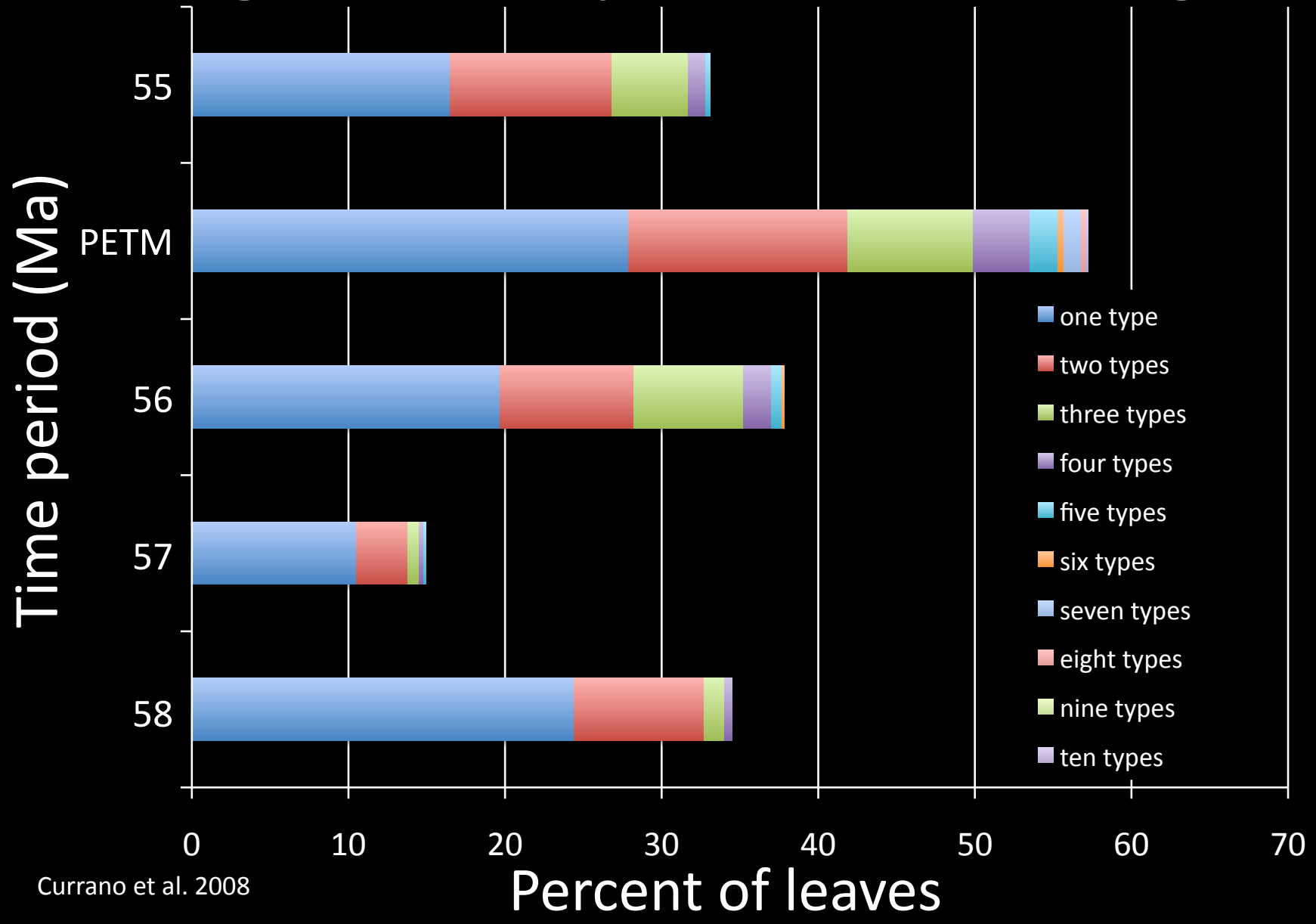



Clyde & Gingerich 1998

# PETM – abundant insect damage

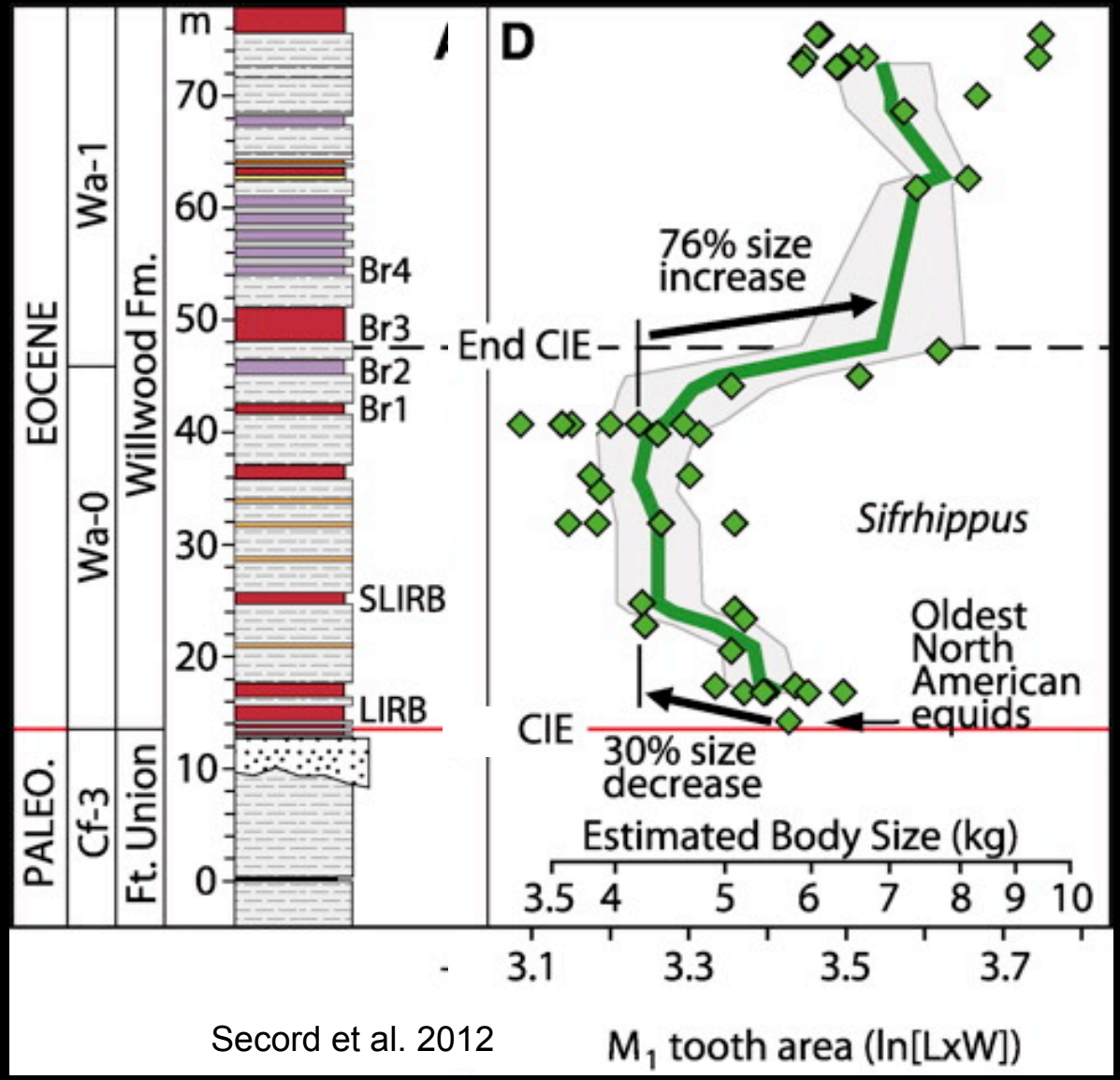


# High diversity of insect damage




Currano et al. 2008

# Rapid evolution of small body size in mammals (dwarfing)

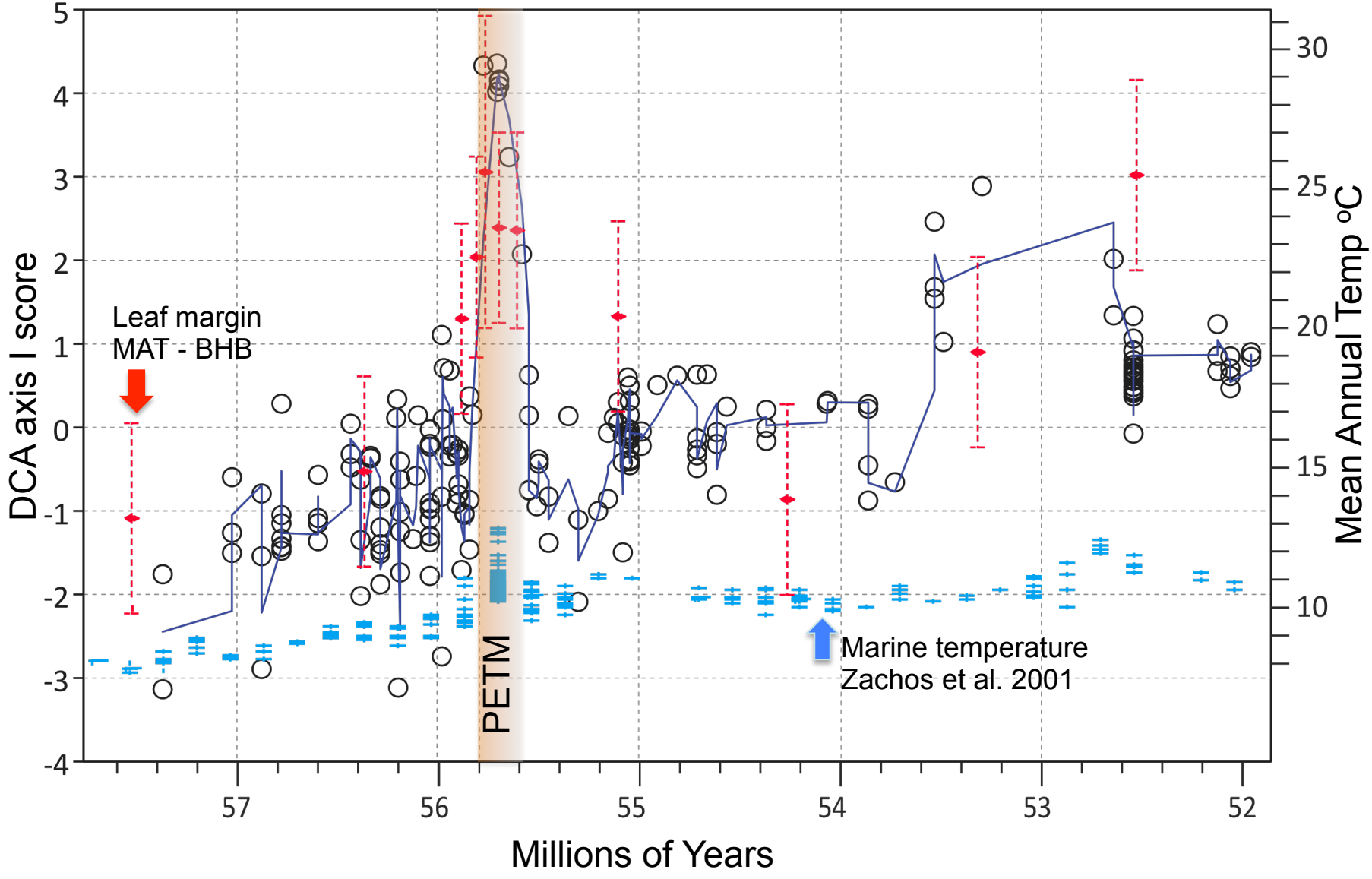



Secord et al. 2012

# PETM lessons

- Temperature change – yes
- Precipitation change – yes
- Range change – yes
- Rapid evolution – yes
- Changes in trophic interactions – yes
- Long duration of climatic/ecological change – yes
- Extinction – not much

# Floral Composition and Temperature



# Timescales of processes

EARTH SYSTEMS

------$CO_2$ weathering------

---$CO_2$ surface ocean---

---$CO_2$ deep ocean---

---------ice sheet dynamics---------

-full Earth system climate sensitivity-

ECOLOGICAL-EVOLUTIONARY

--------continent-scale dispersal--------

-evolve by 2 StDev ➔

-evolutionary radiation ➔

-human lifespan- ➔

SOCIAL-POLITICAL-ECONOMIC

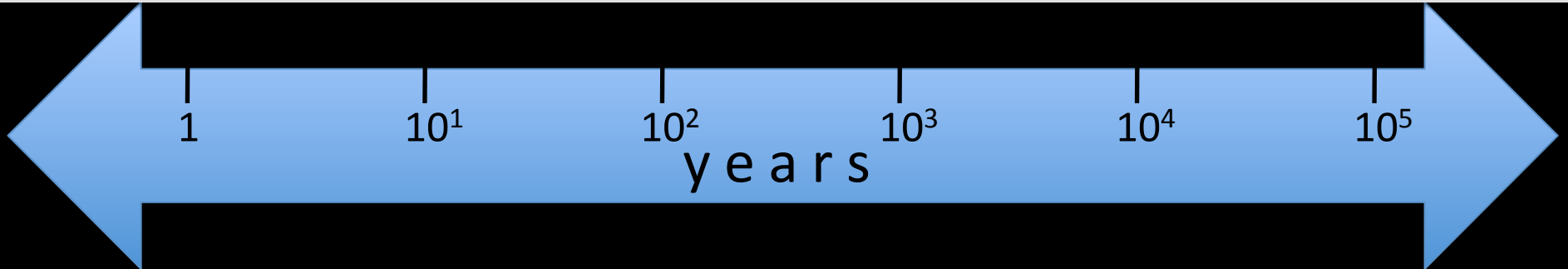
-IPCC "long-term"- ➔

-elections-

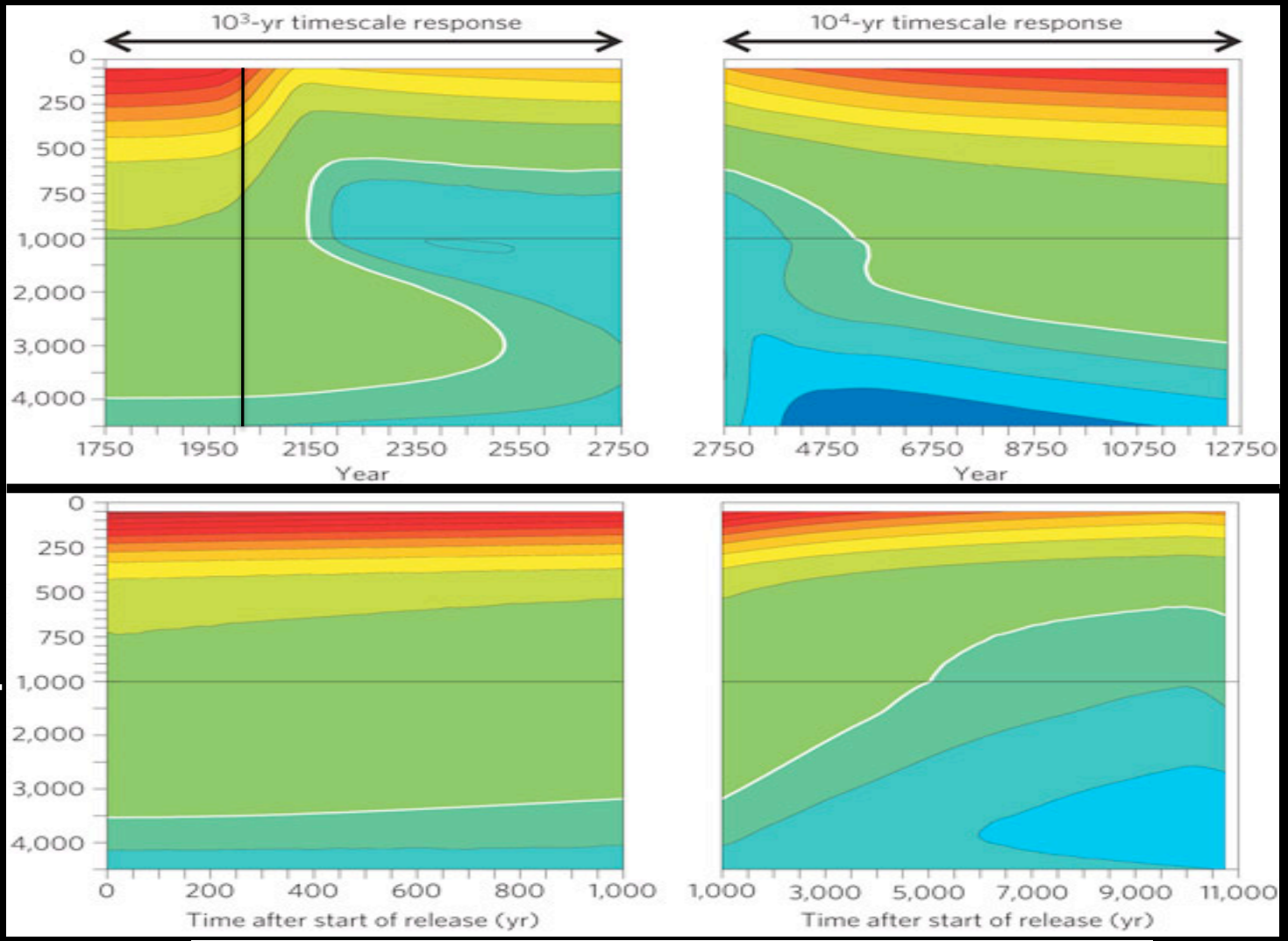
$10^9$ ➔ $10^3$ at 4% annual future discount- ➔

time to exhaustion of fossil fuels- ➔

Japanese monarchy ➔



# Carbon release rate affects carbonate dissolution




Ridgwell & Schmidt 2010

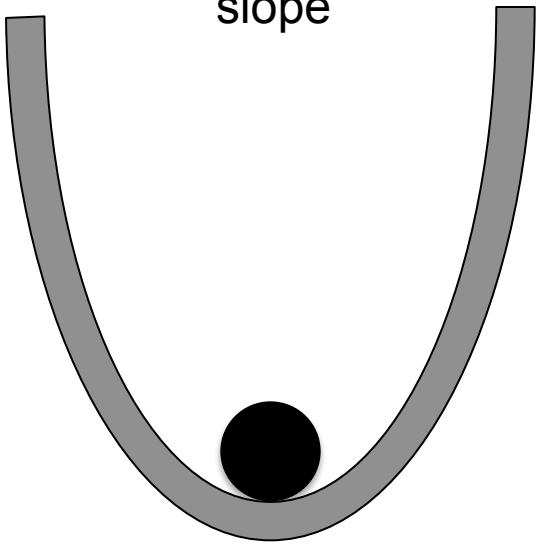
The farther backward you can look, the farther forward you are likely to see.

Winston Churchill

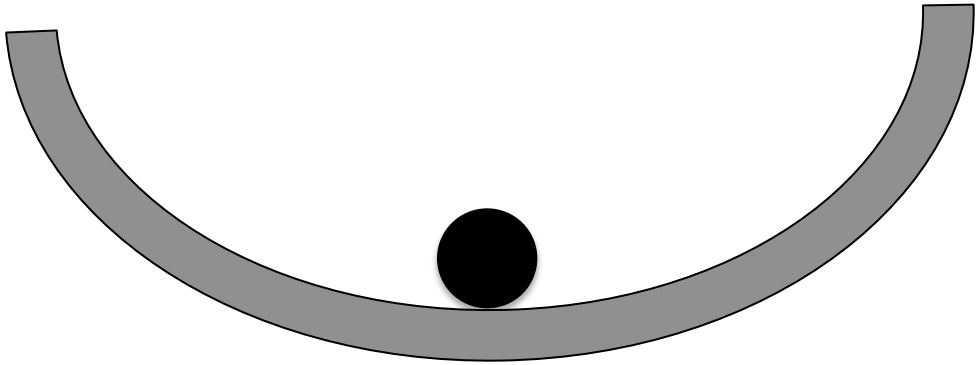
# *Can Societies Plan for the Long Term?*

# Ecological Resilience

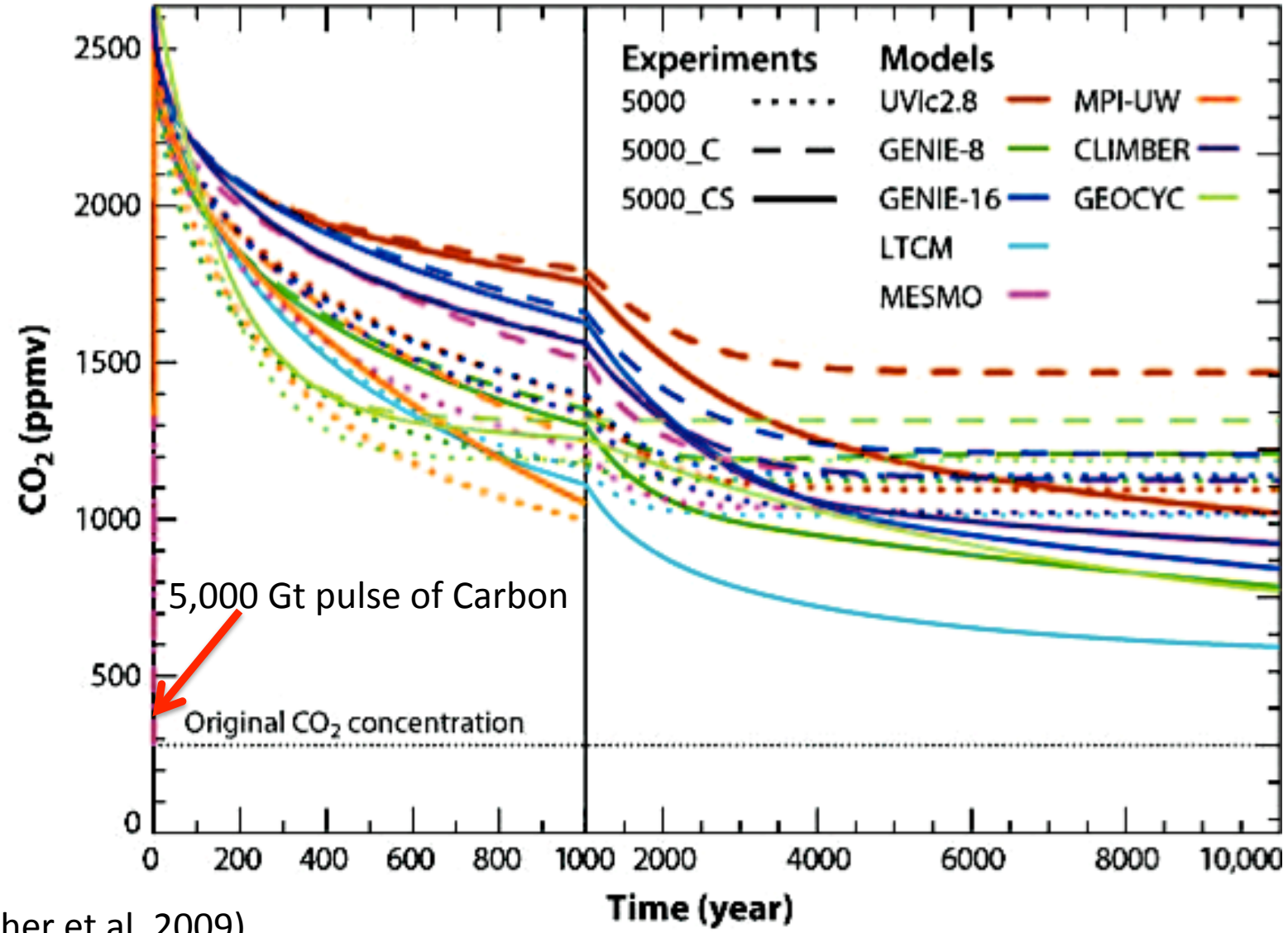
return time to a stable state following a perturbation – "slope"



the amount of disturbance that an ecosystem can withstand without changing self-organized processes and structures – "breadth"

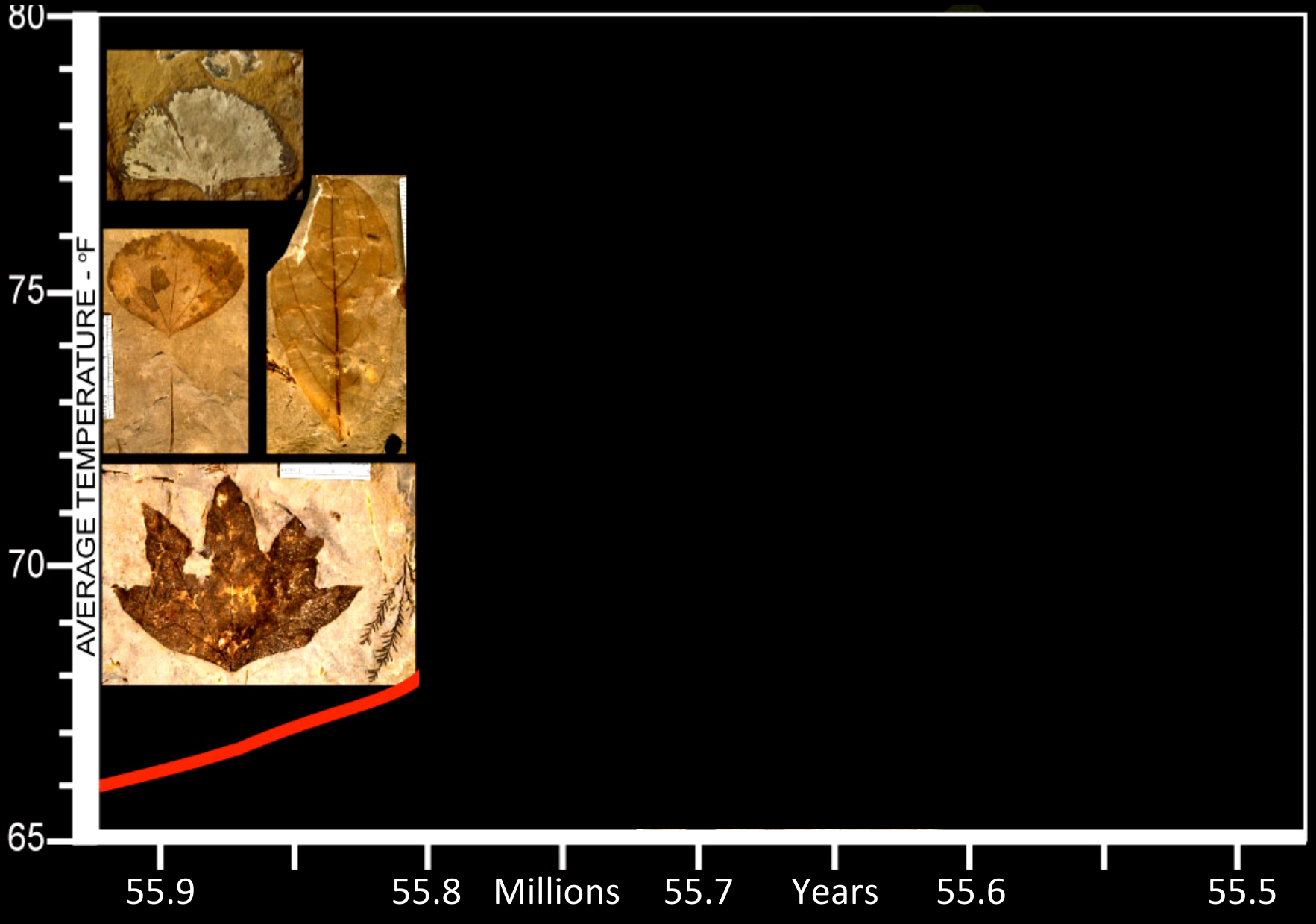


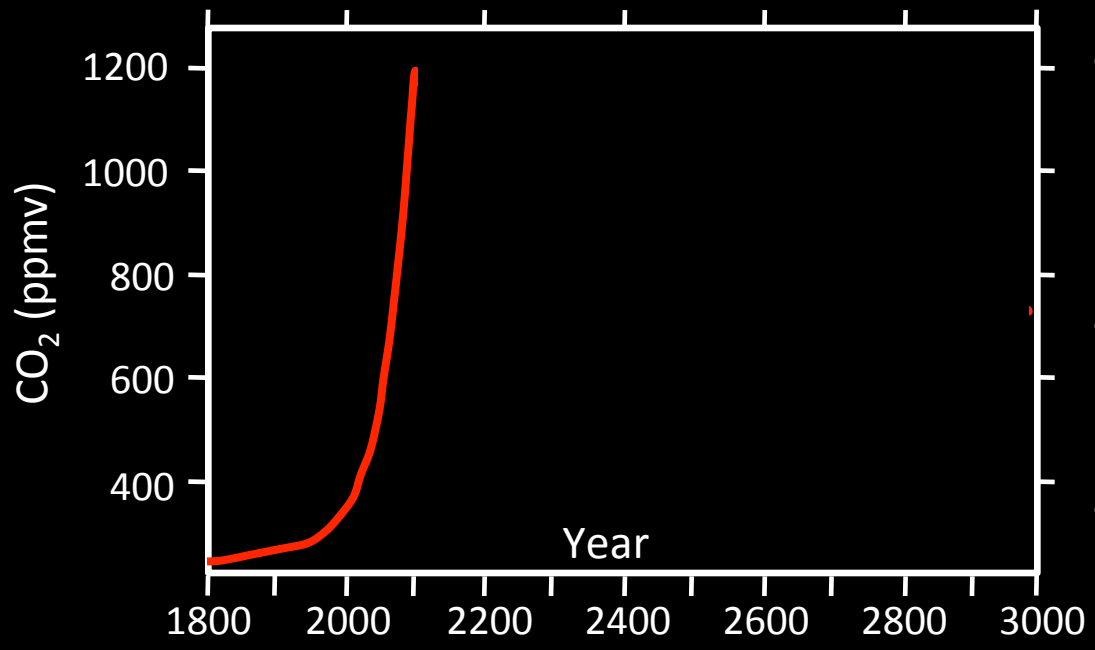
# $CO_2$ uptake takes geological time

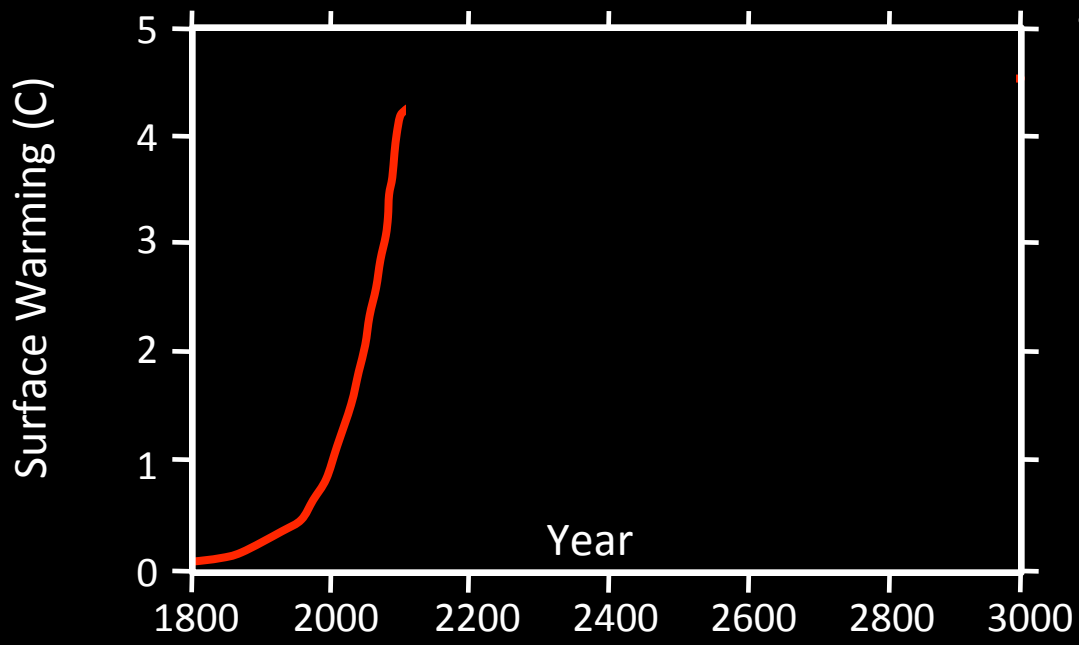



(Archer et al. 2009)

# PETM floral change






Solomon et.al. PNAS 2009

- Anthropogenic carbon emissions currently ~7 Gt/yr
- Total fossil fuel reservoir ~5,000 Gt
- Consumption increasing ~2%/yr
- In 100 years yields peak atmospheric $CO_2$ of ~1200 ppm, ~4.5 °C