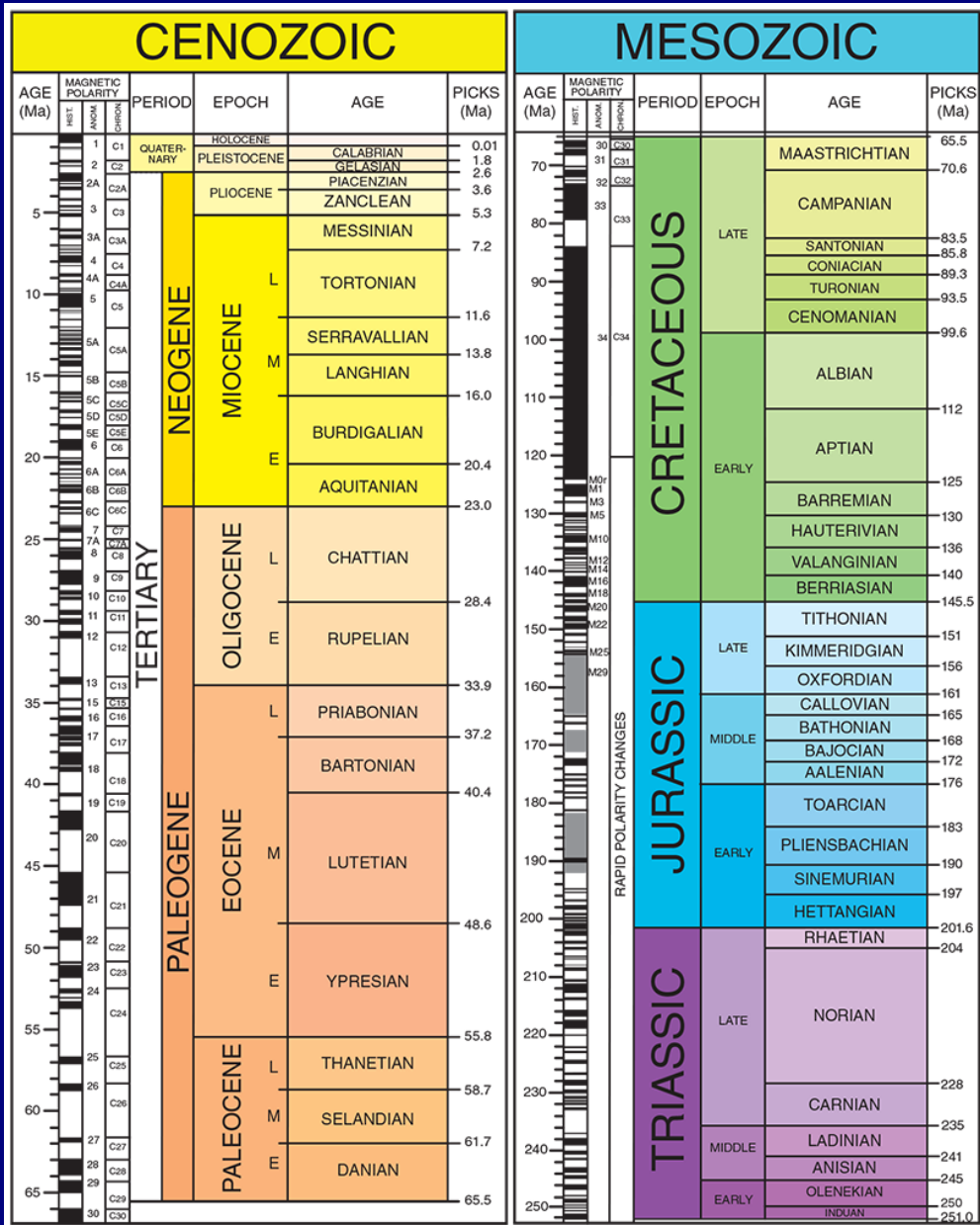


# What punctuates the geologic time scale?



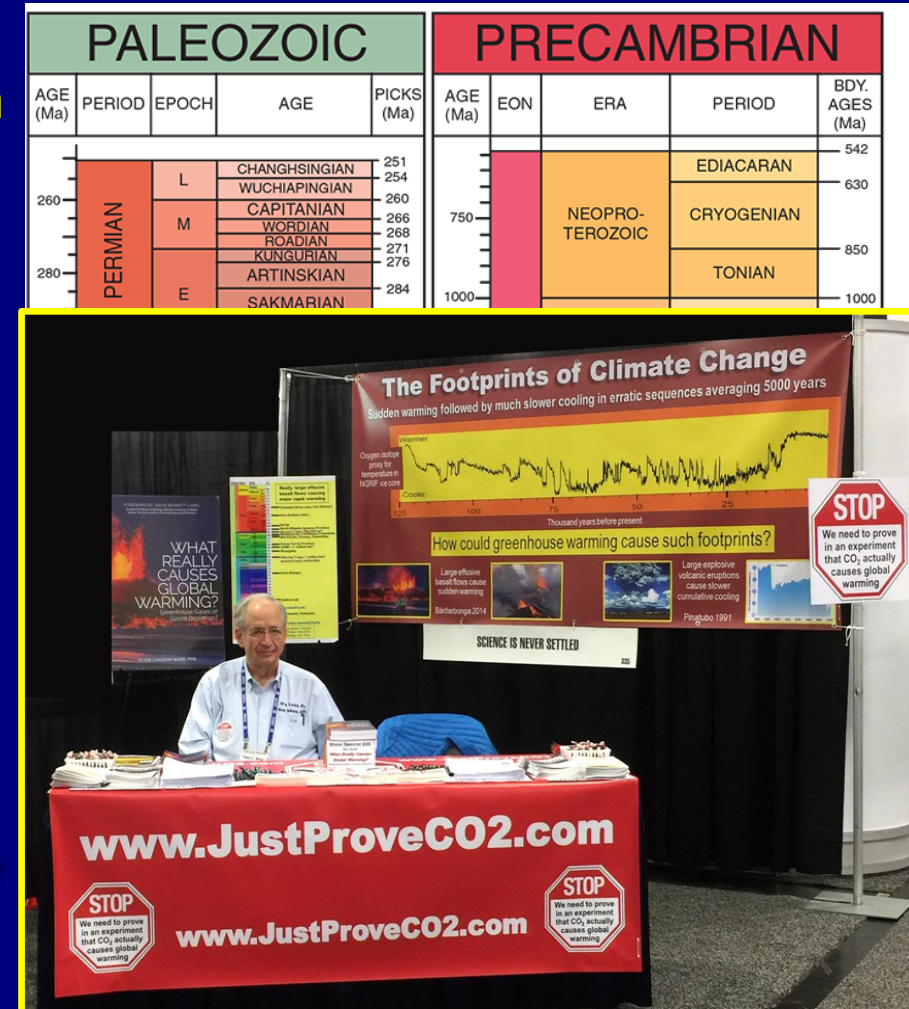
Why are there sudden changes in rock types, sedimentation, and fossils between geologic Eons, Eras, Periods, Epochs, and Ages?

**Peter L. Ward**

United States Geological Survey  
Retired

peward@Wyoming.com

Geologists of Jackson Hole  
June 6, 2017



**Geologic Society of America**  
**American Geophysical Union**  
**American Meteorological Society**



DID YOU KNOW THAT  $\text{CO}_2$  WARMING THEORY  
HAS NEVER ACTUALLY BEEN FLIGHT TESTED?



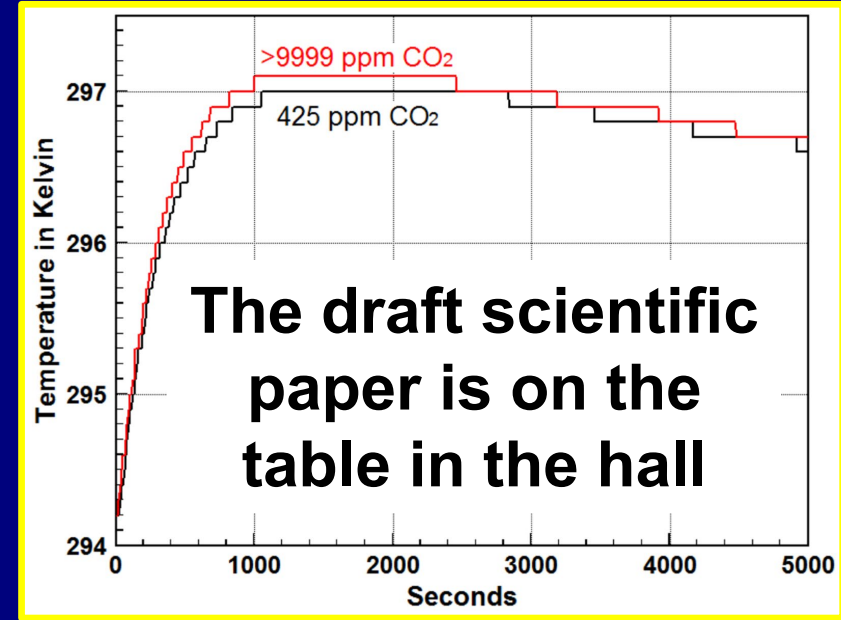
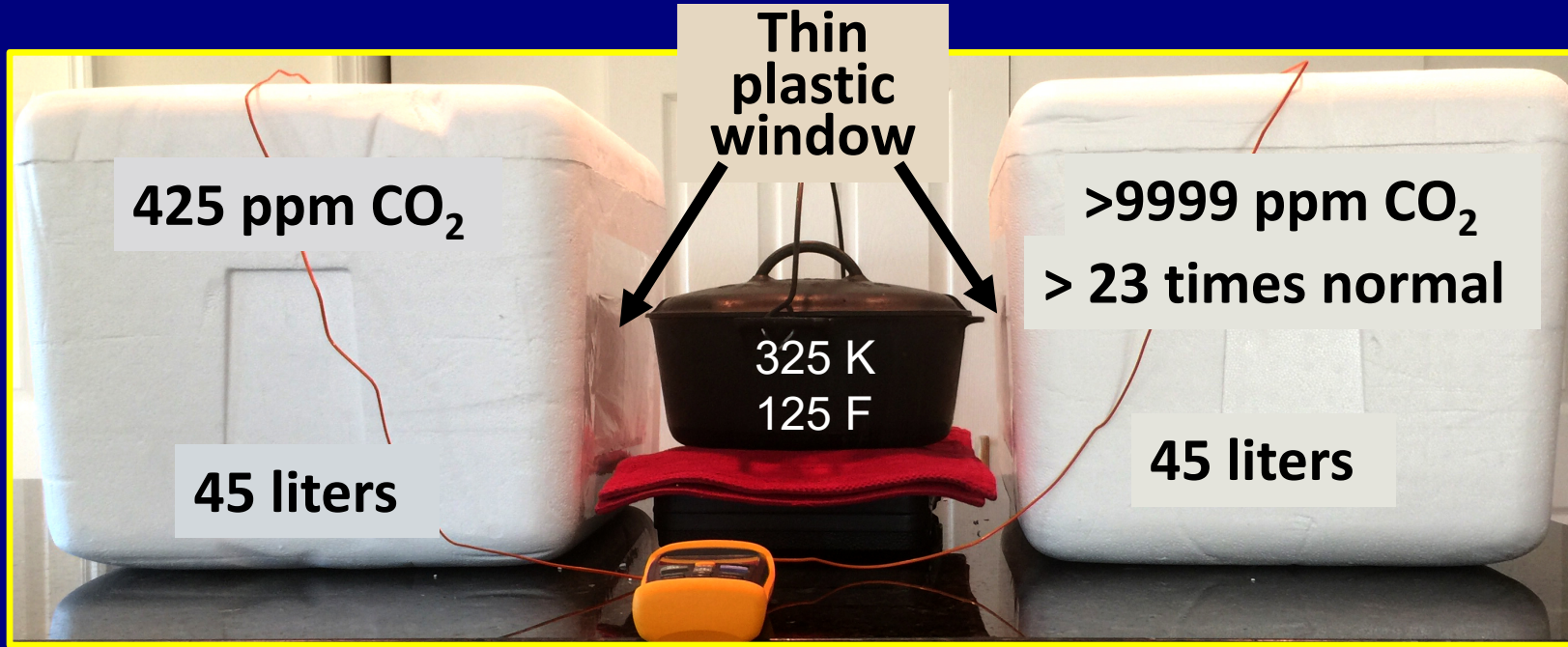
**“The final arbitrator  
of any point of view  
are experiments  
that seek the  
unbiased truth”**

**Steven Chu  
Nobel prize in Physics 1997  
Former Secretary of Energy**

**JustProveCO2.com**



# A simple negative demonstration



CO<sub>2</sub> simply does not absorb enough heat to warm Earth

There is a fundamental problem in the way computer models calculate heat flux

Atmospheric concentration of CO<sub>2</sub> may simply be a proxy for ocean temperature

Greenhouse-warming theory could be the greatest, most costly mistake in science

CO<sub>2</sub> cannot explain most periods of warming throughout the geologic record



**Kaibab Limestone**

**Toroweap Formation**

**Coconino Sandstone**

**Hermit Shale**

**Supai Group**

**Redwall Limestone**

**Muav Limestone**

**Supai  
Group**

**Redwall  
Limestone**

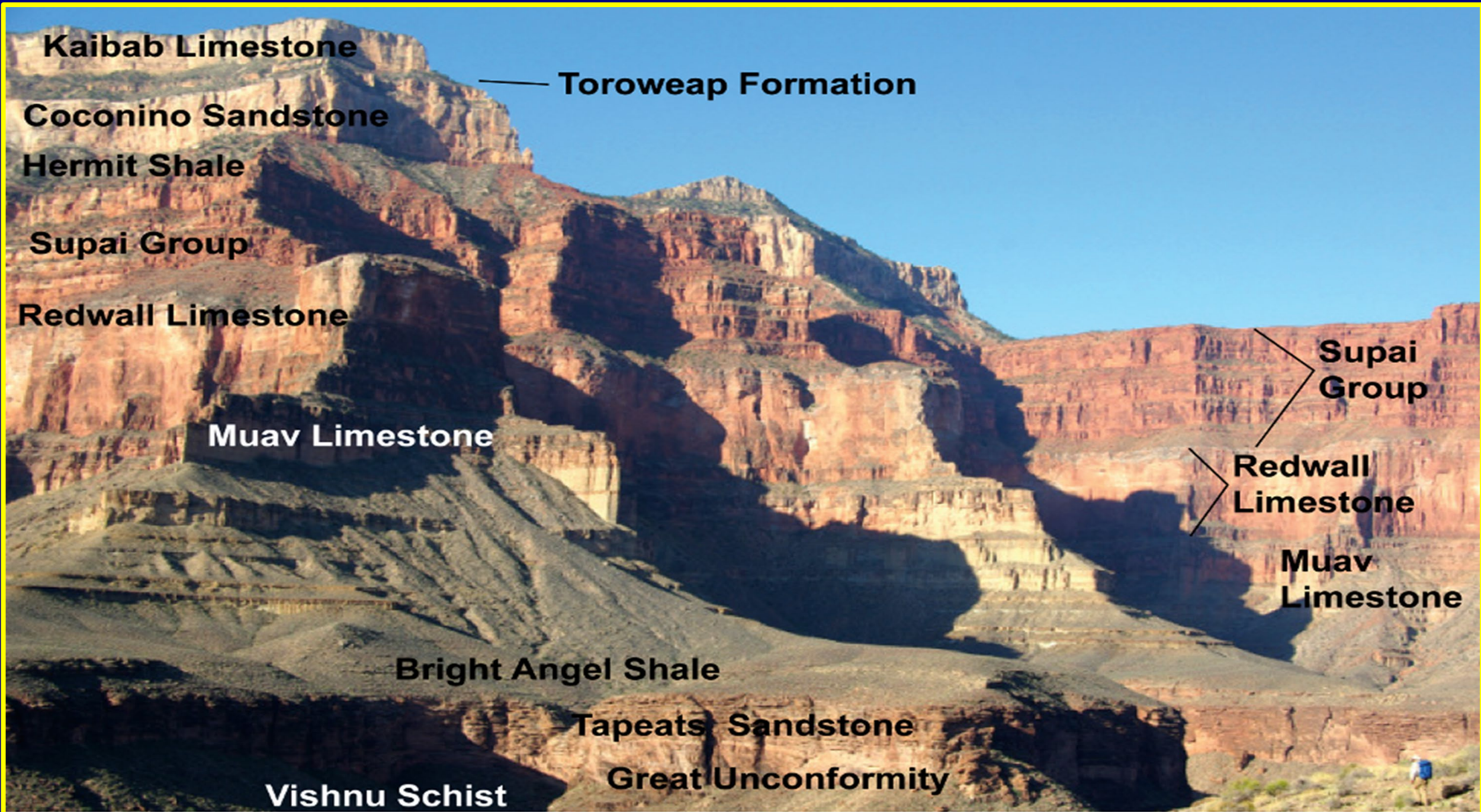
**Muav  
Limestone**

**Bright Angel Shale**

**Tapeats Sandstone**

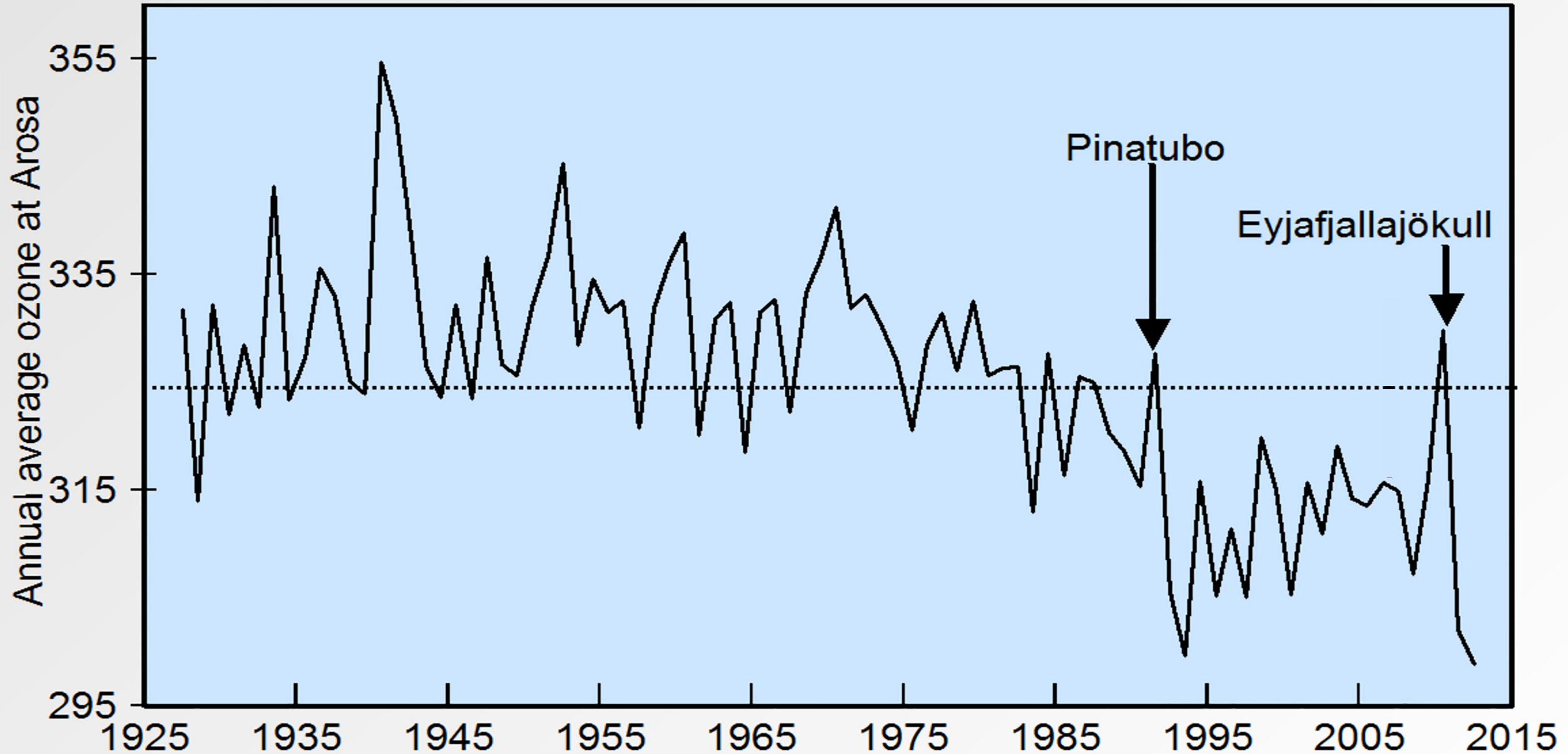
**Vishnu Schist**

**Great Unconformity**

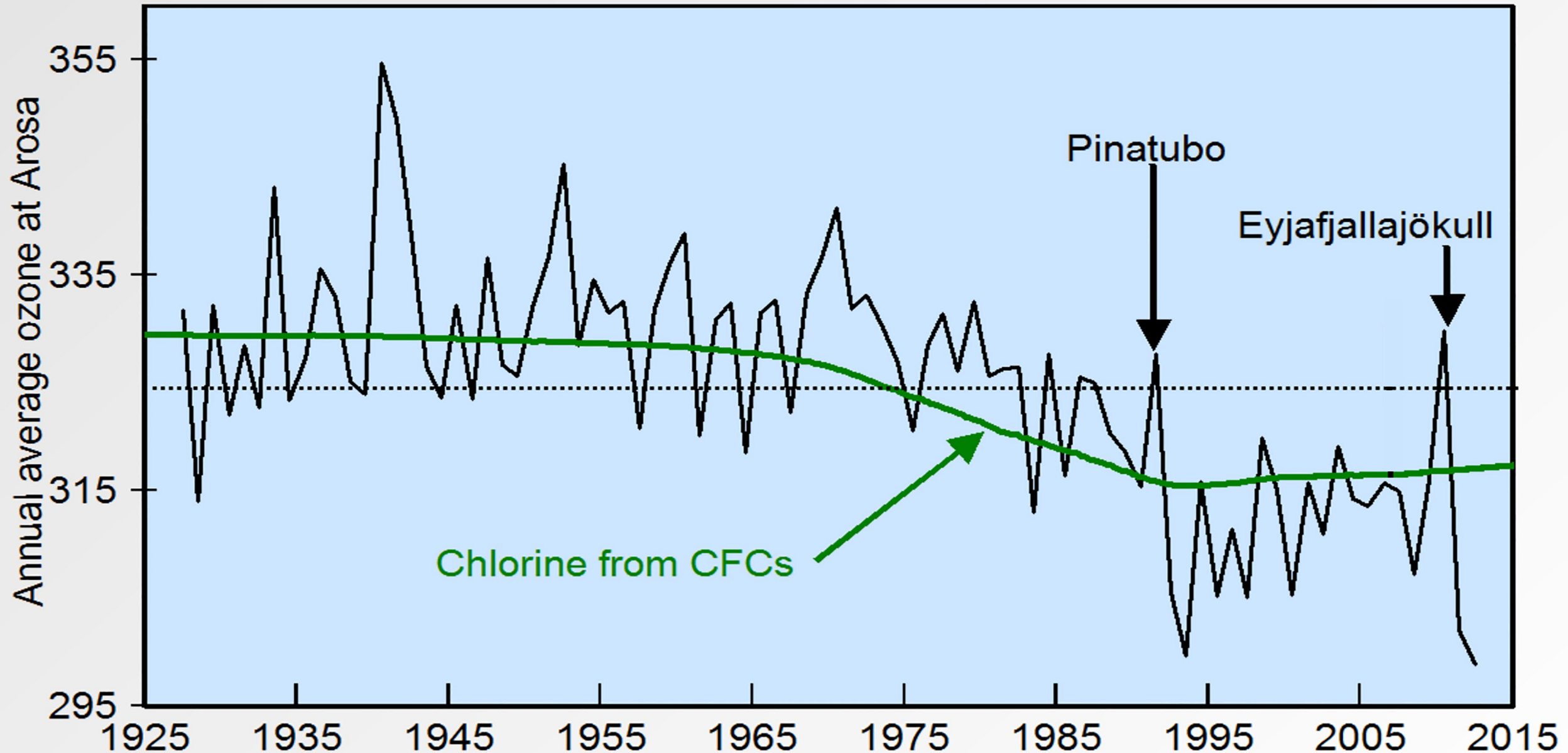




# Volcanic eruptions deplete the ozone layer



# Chlorofluorocarbons (CFCs) also deplete the ozone layer





Sun

UV-a

UV-b

UV-c

Ozone  
layer

Lower  
energy

High  
energy

Very  
high  
energy

5% UV-a  
absorbed

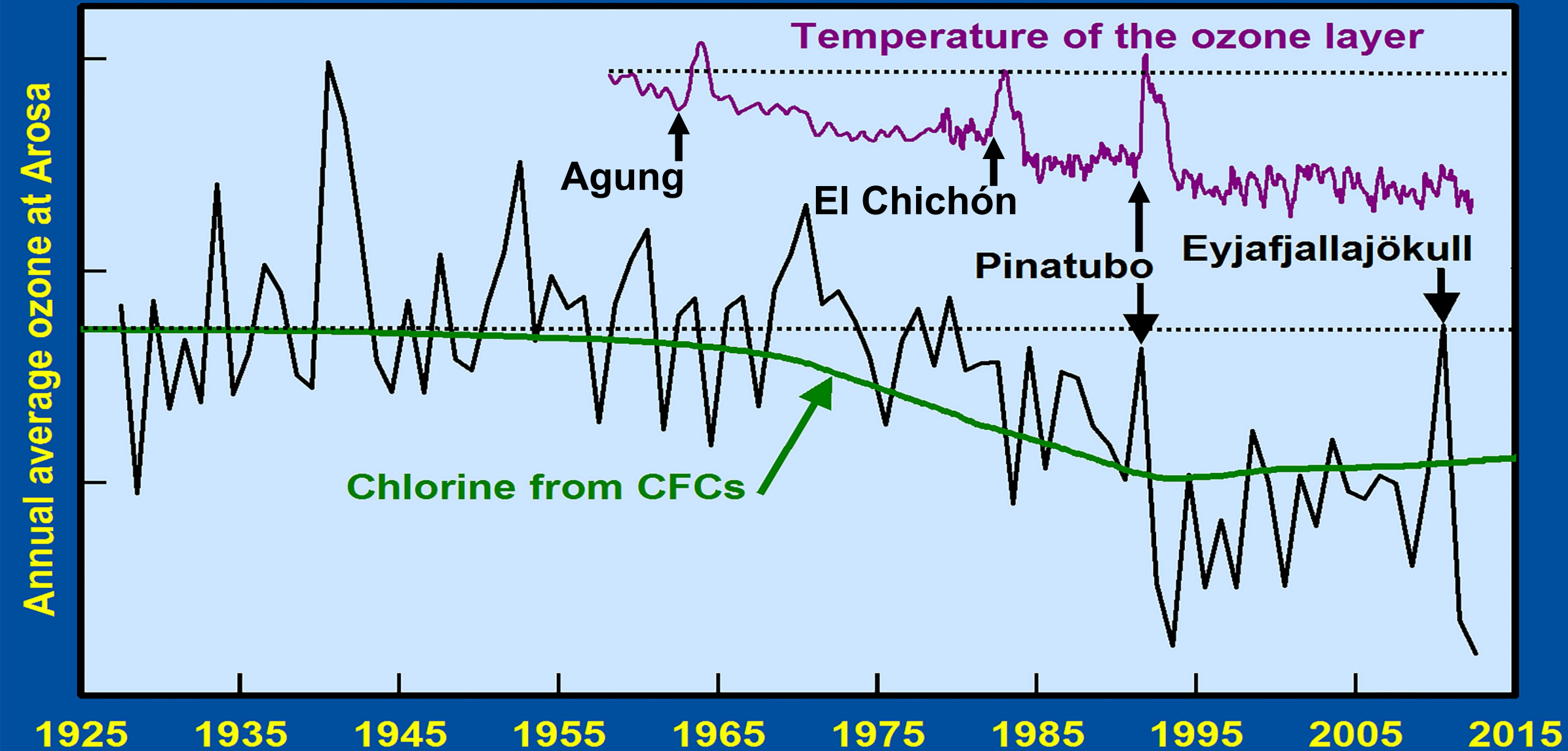
95% UV-b  
absorbed

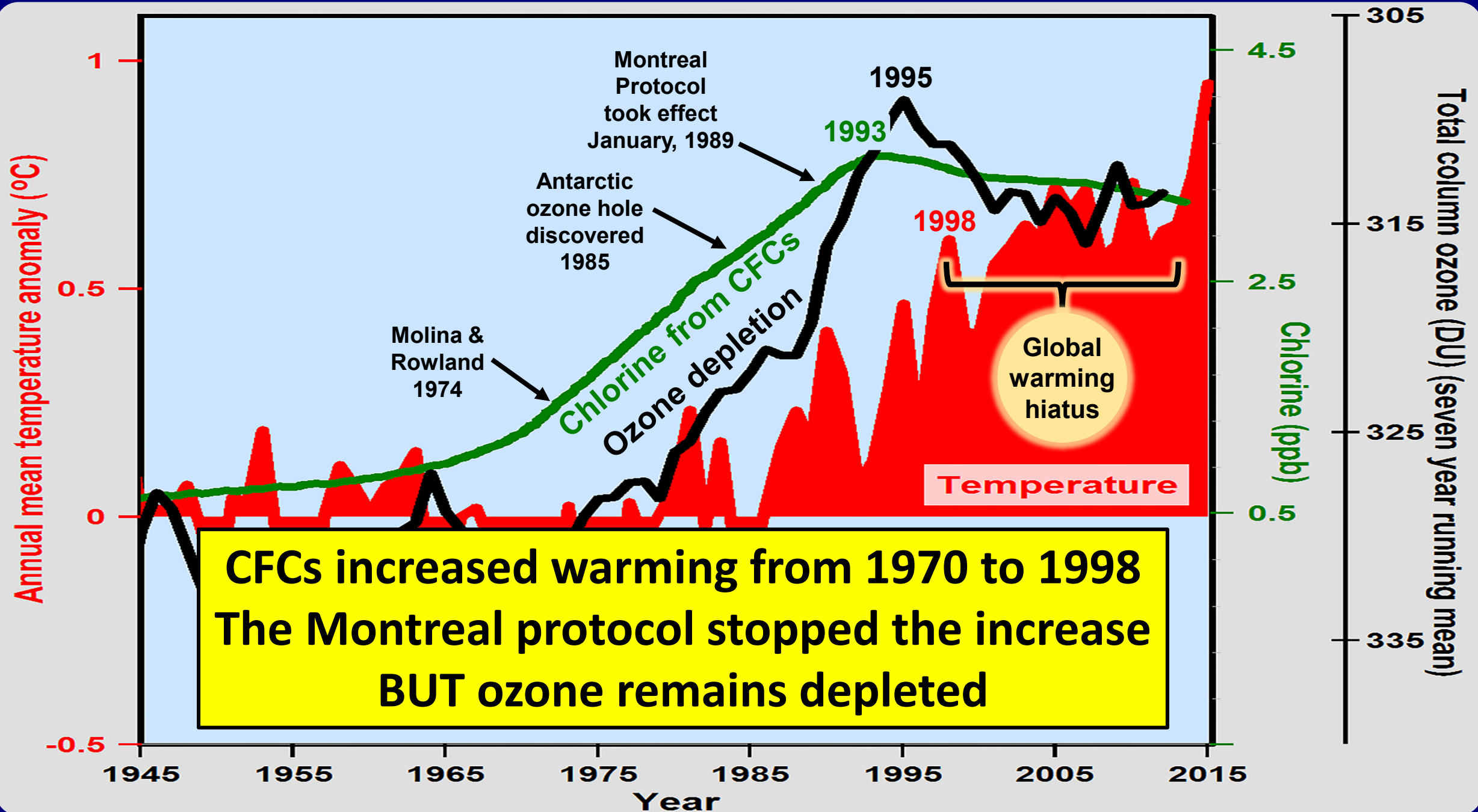
100% UV-c  
absorbed

Sunburn  
Skin cancer  
Cataracts  
Vitamin-D

Less ozone absorbs  
less UV-B

# Less ozone causes ozone layer to cool and Earth to warm







# Explosive, aerosol forming, volcanic eruptions



Pinatubo June 1991

USGS

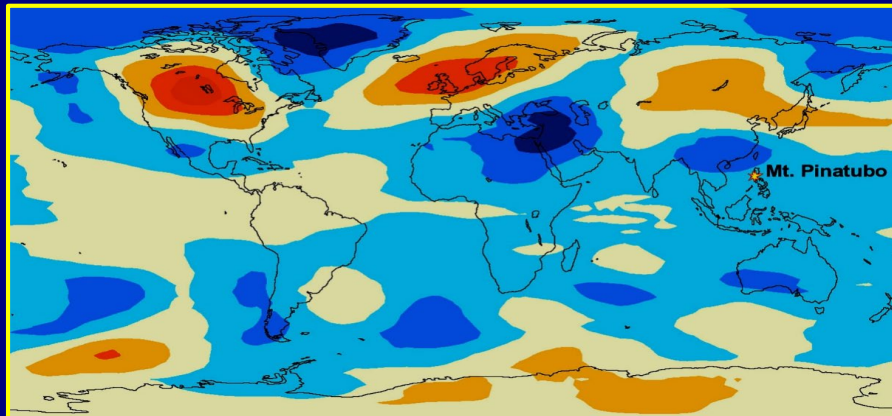
Typical above subduction zones

Erupt for days, may recur within 500 to 1000 years

Deplete ozone causing short-term warming

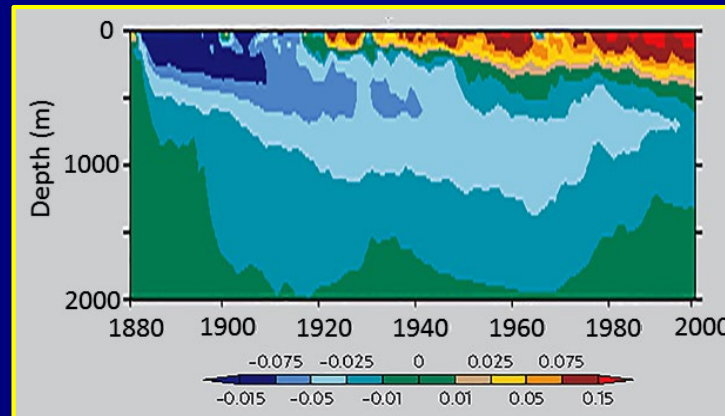
Form aerosols in the lower stratosphere that last for 2-4 years, scattering and reflecting solar energy, causing net global cooling of  $0.5^{\circ}\text{C}$

Pinatubo warmed  $3.5^{\circ}\text{C}$  world  
Dec 1991 to Feb 1992



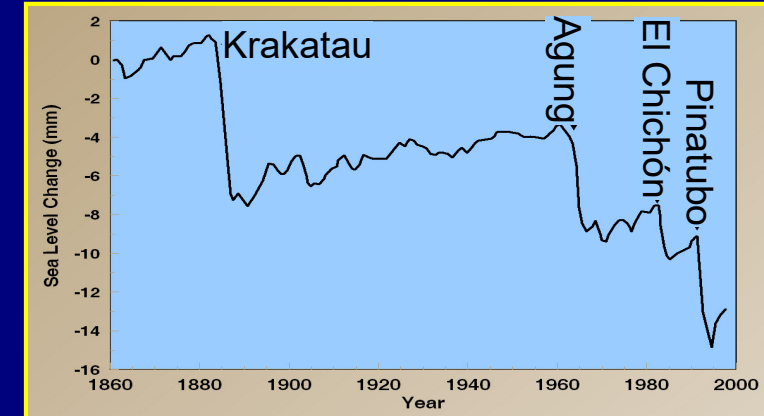
Robock, 2002

Krakatau (1883) cooled ocean  
for more than 100 years



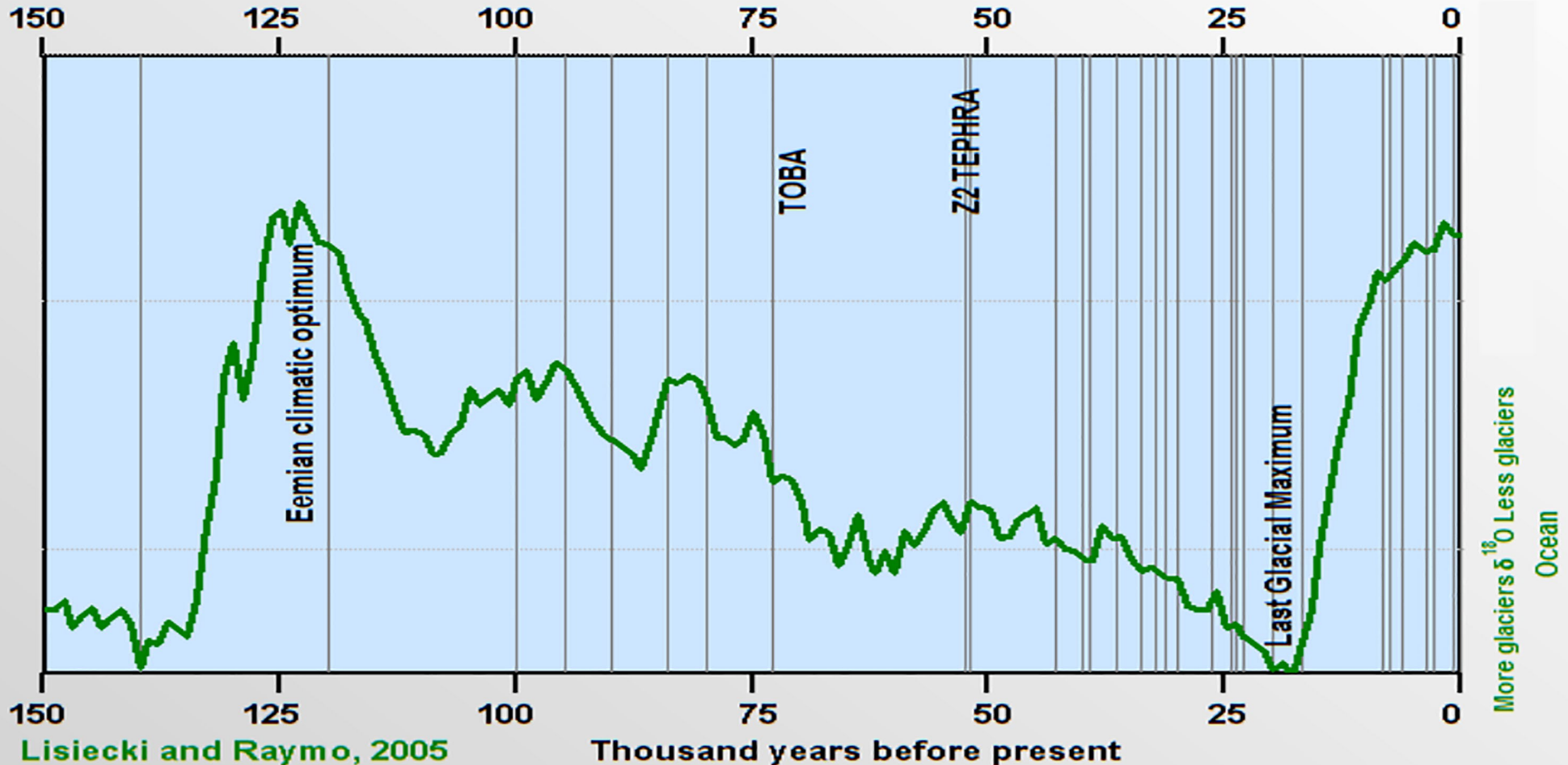
Gleckler et al., 2006

Multiple eruptions increment world  
into an ice age

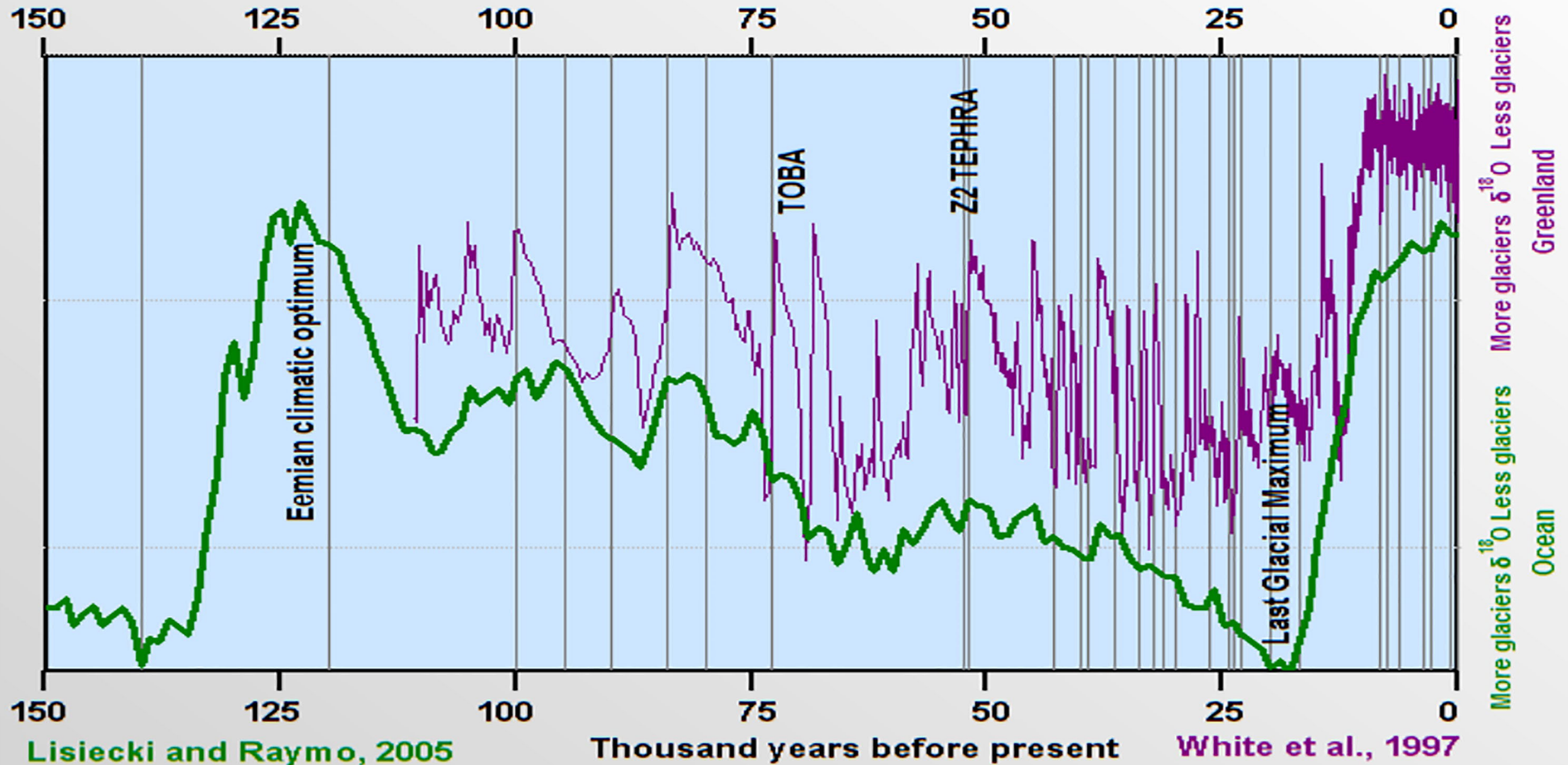


Gregory et al., 2006

# Stack of 57 globally distributed benthic $\delta^{18}\text{O}$ records

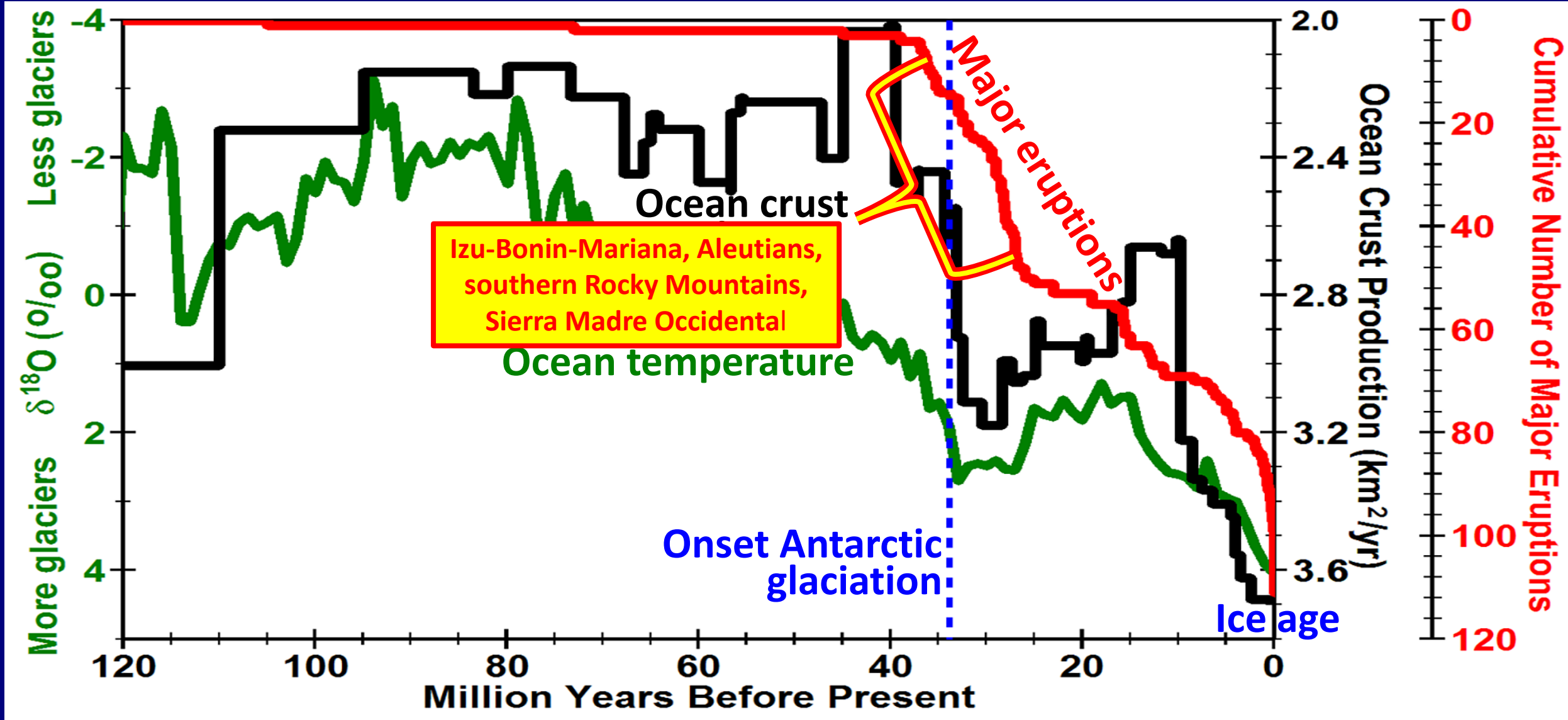


# Greenland ice core $\delta^{18}\text{O}$ records

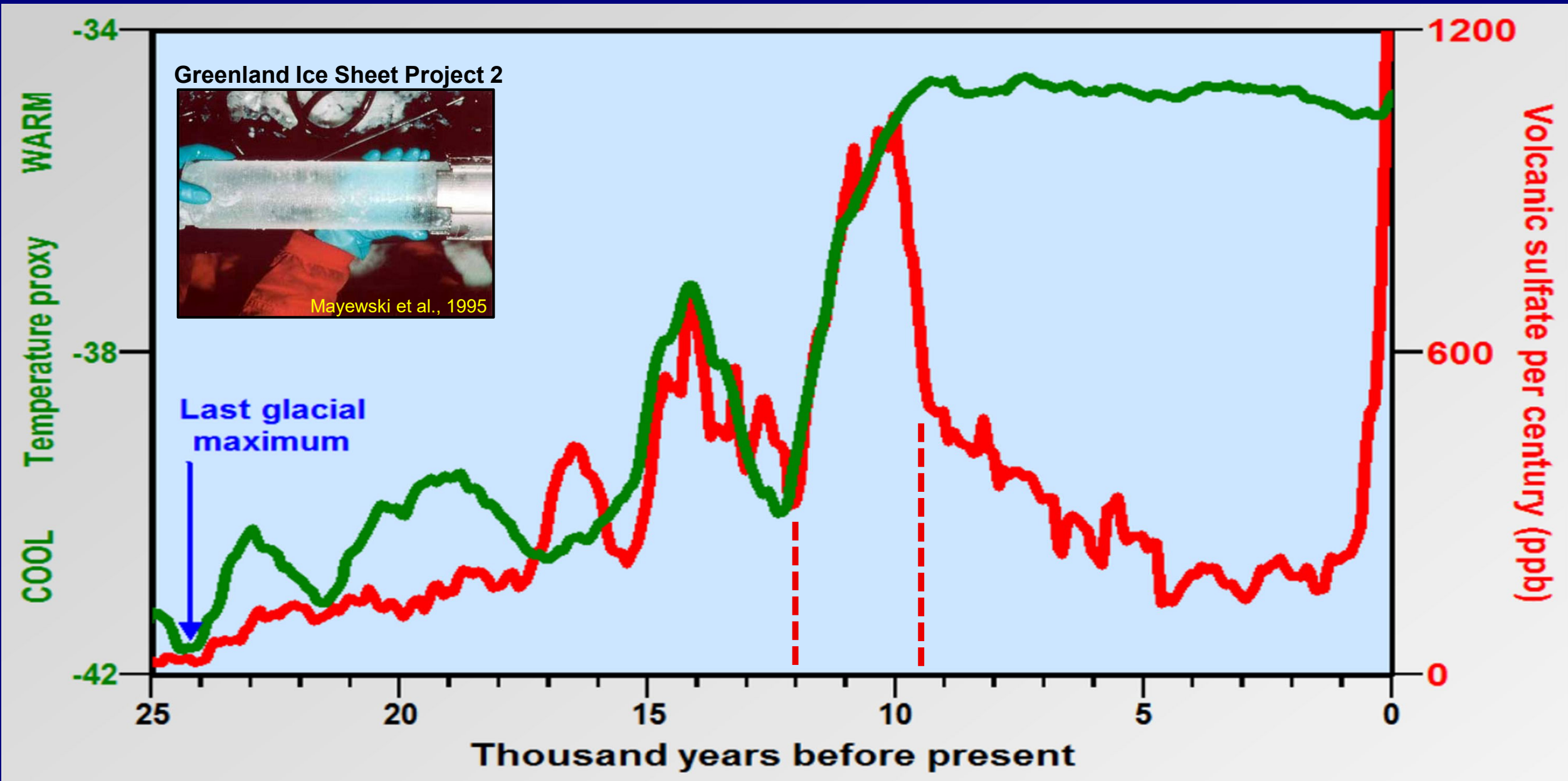




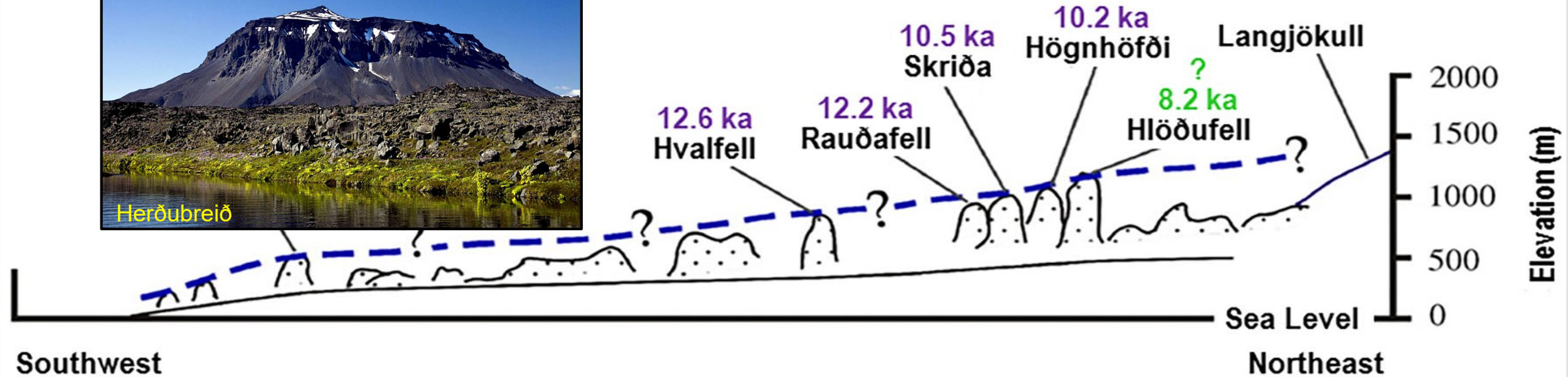
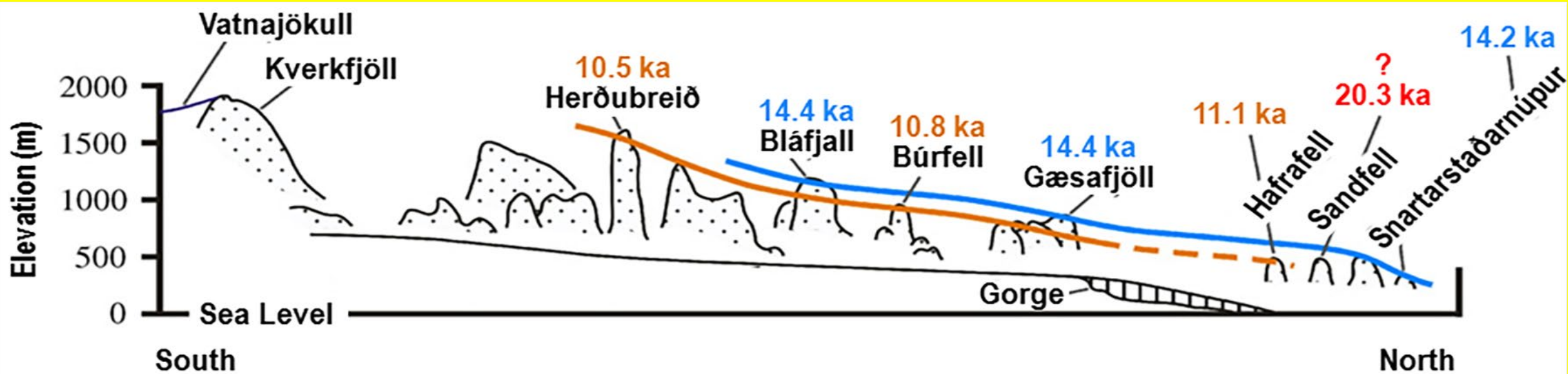
# Explosive volcanism led to onset Antarctic glaciation and the recent ice age



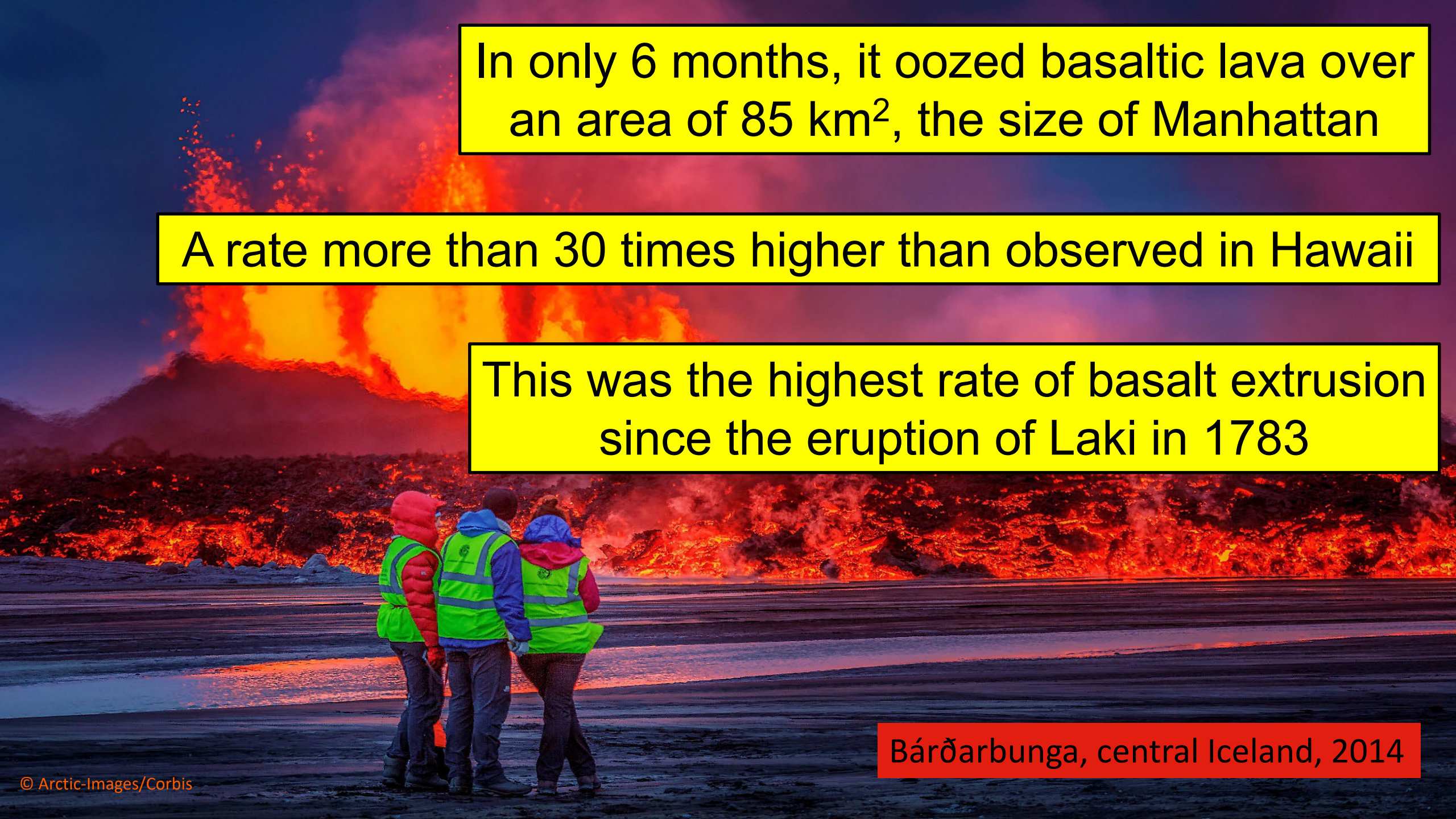
# Basaltic volcanism warmed the world out of the last ice age



# Basaltic volcanism in Iceland at the end of the last ice age







In only 6 months, it oozed basaltic lava over an area of 85 km<sup>2</sup>, the size of Manhattan

A rate more than 30 times higher than observed in Hawaii

This was the highest rate of basalt extrusion since the eruption of Laki in 1783

Bárðarbunga, central Iceland, 2014



## Laki 1783 (Iceland)

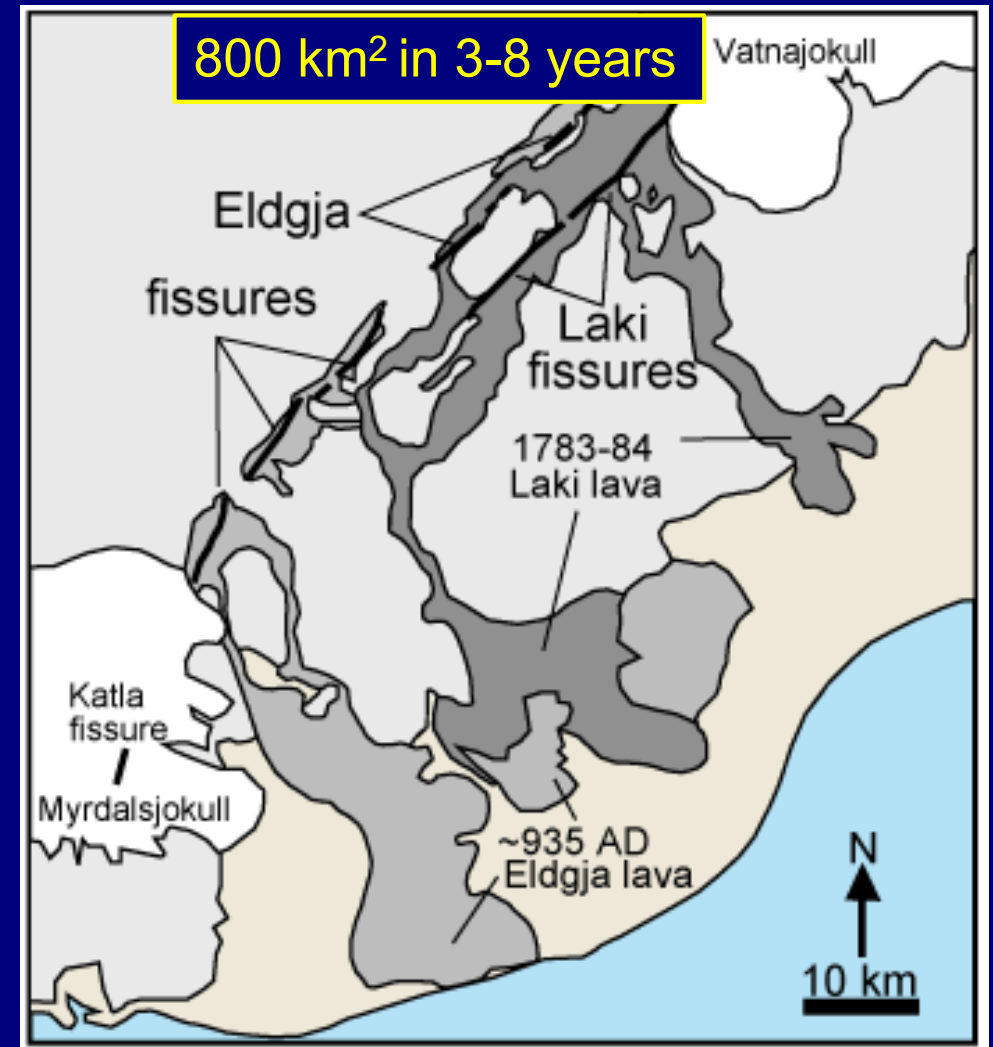
565 km<sup>2</sup> in 8 months



Temperatures in Europe raised 3.3°C, tens of thousands killed primarily by the effects of SO<sub>2</sub>, sulfuric acid, and resulting famine

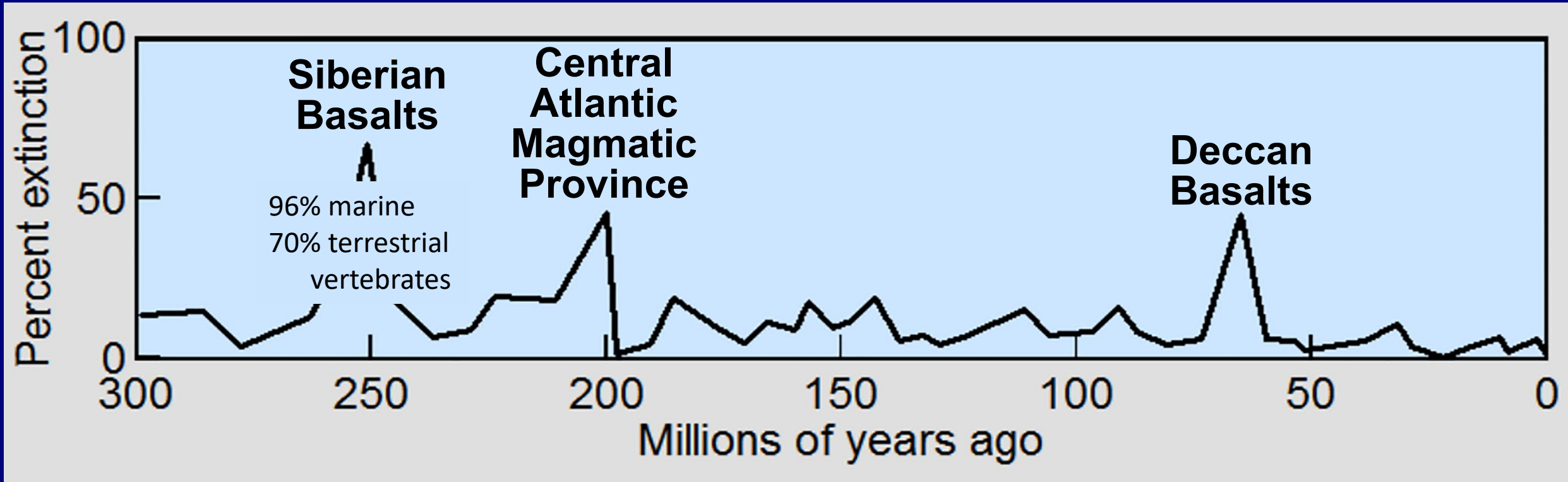
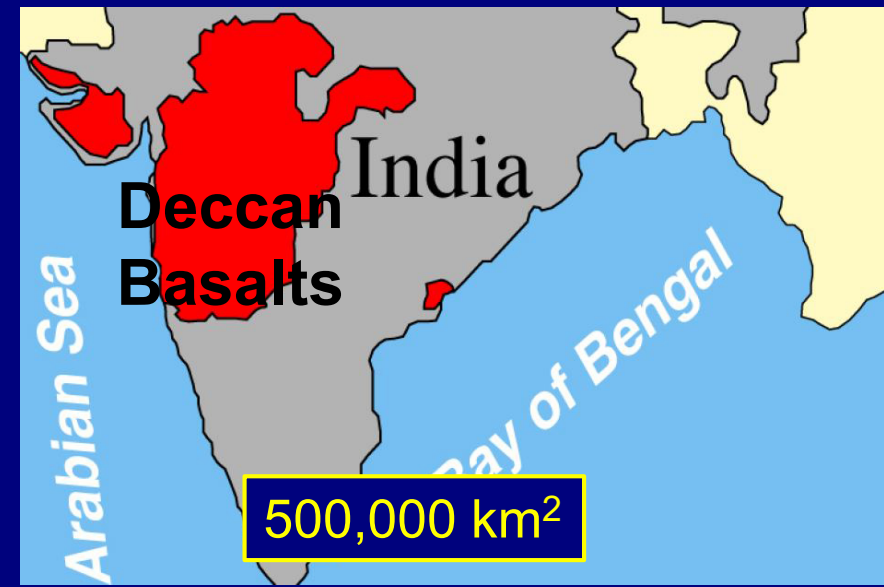
## Eldgjá 935 (Iceland)

800 km<sup>2</sup> in 3-8 years

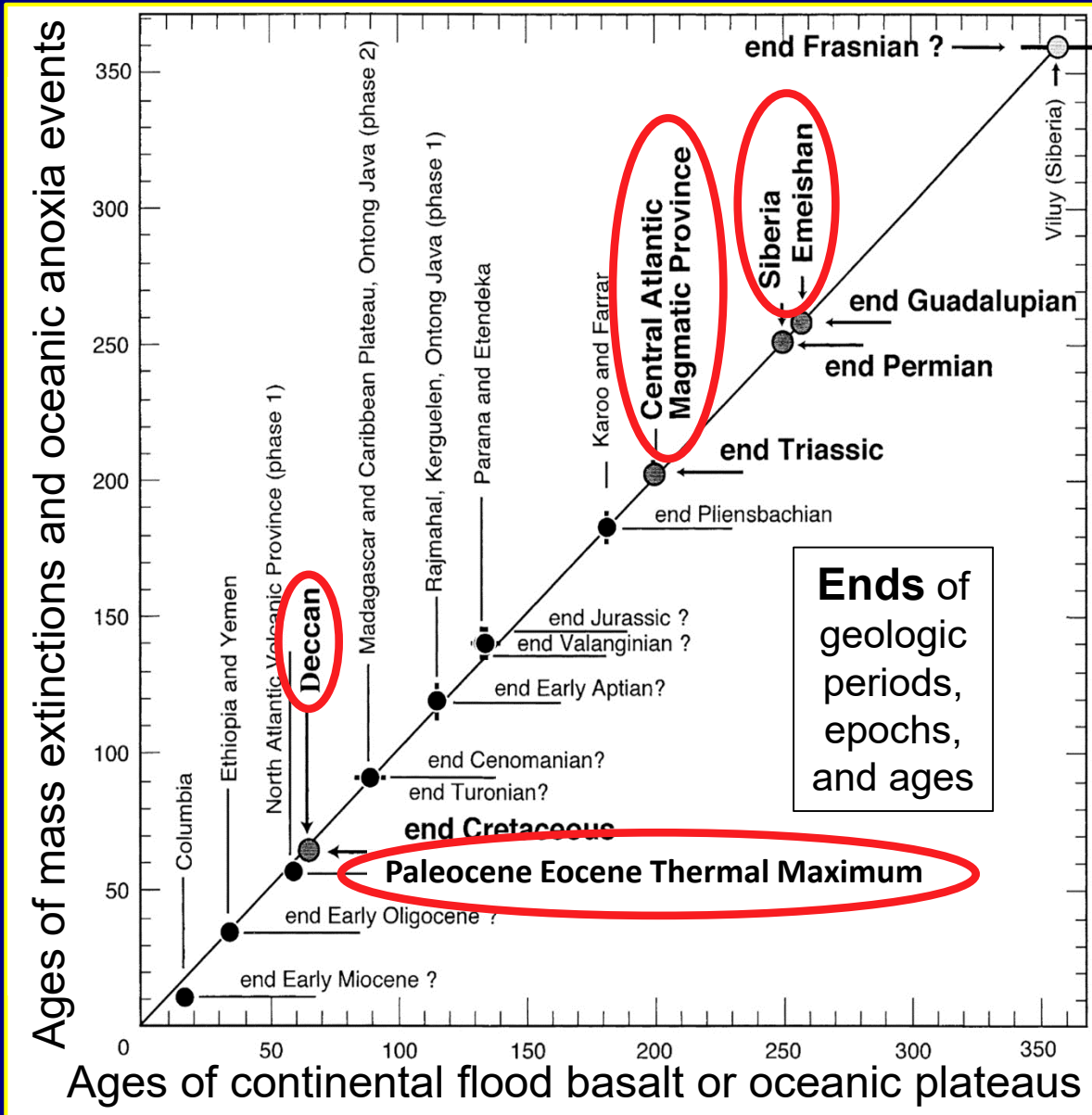


Led to the onset of the Medieval Warm Period





# Extinctions Versus Flood Basalts

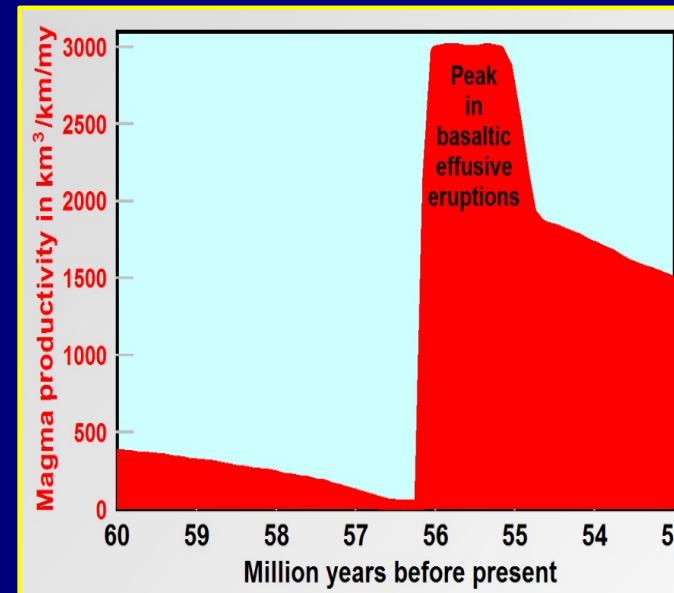


Courillot and Renne 2003

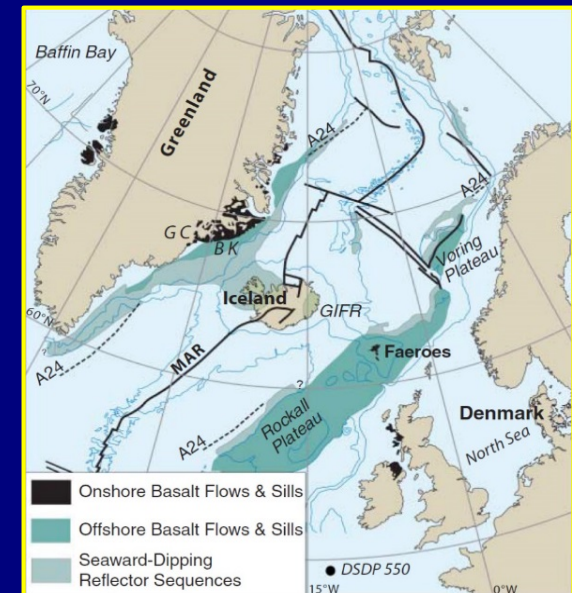
# Paleocene Eocene Thermal Maximum

Extrusion of basaltic magma reached a peak 56 million years ago during the opening of the Greenland-Norwegian Sea

Sea surface temperatures rose 6°C

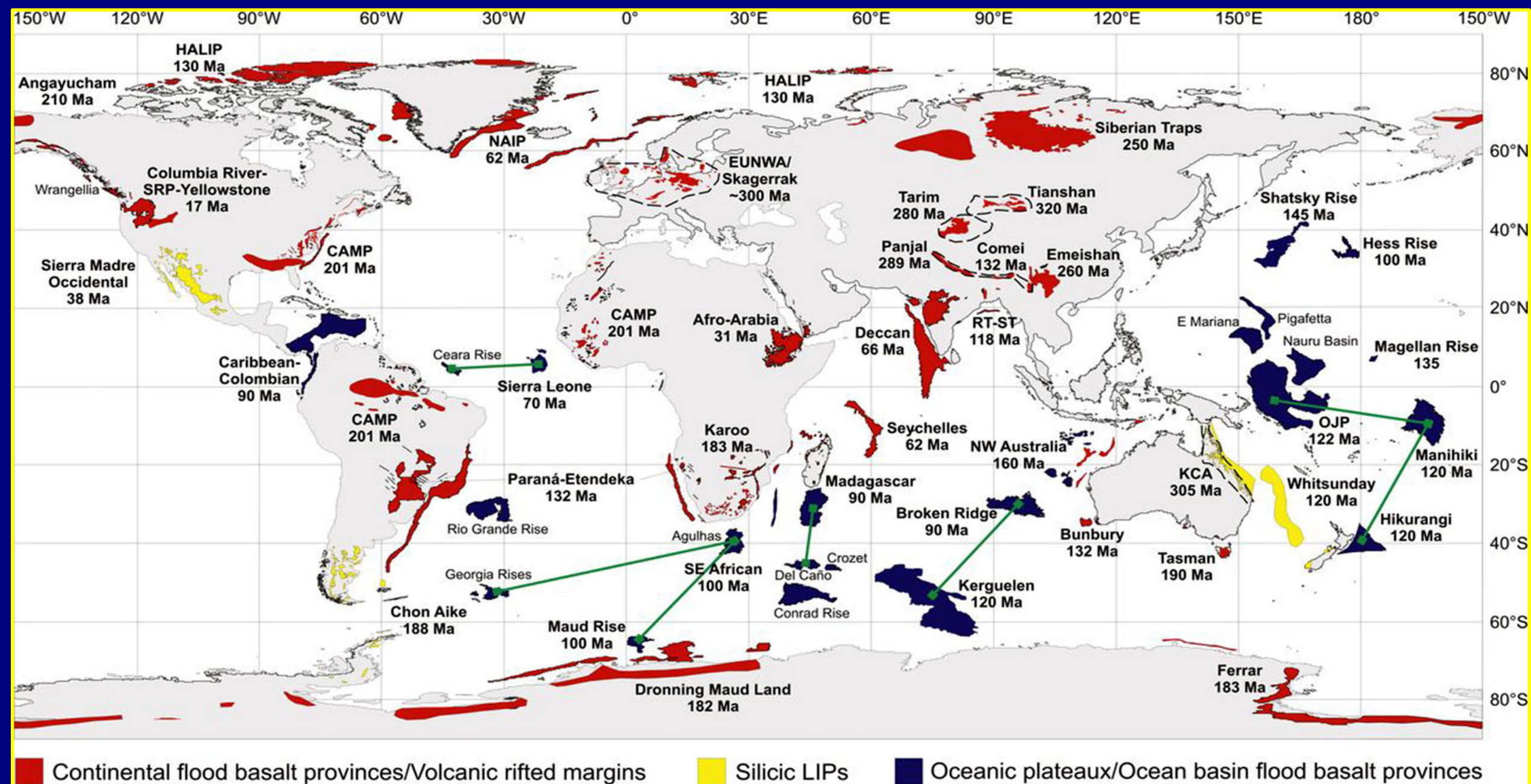


Storey et al. 2007



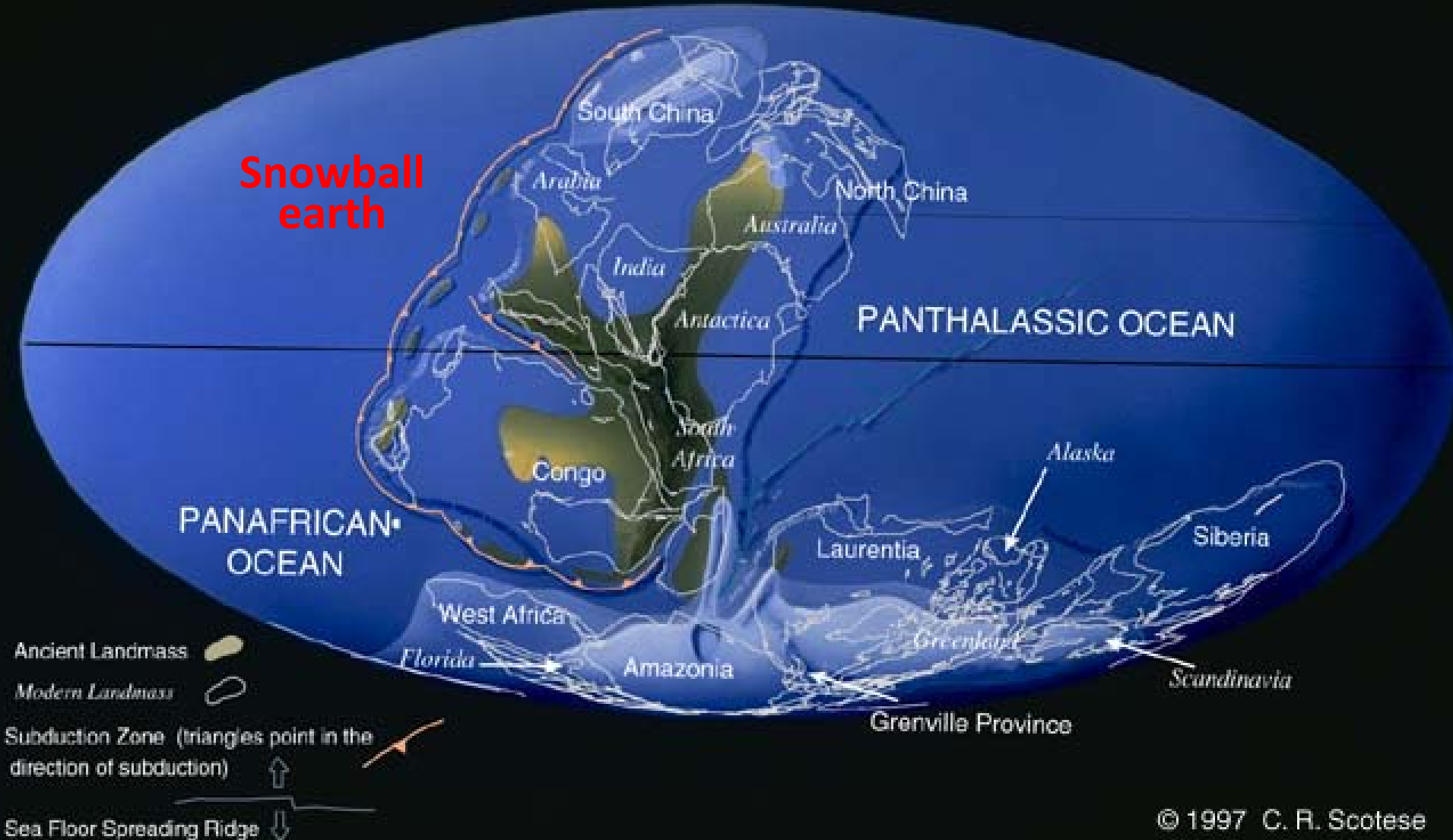


# More than 211 LIPs have been identified



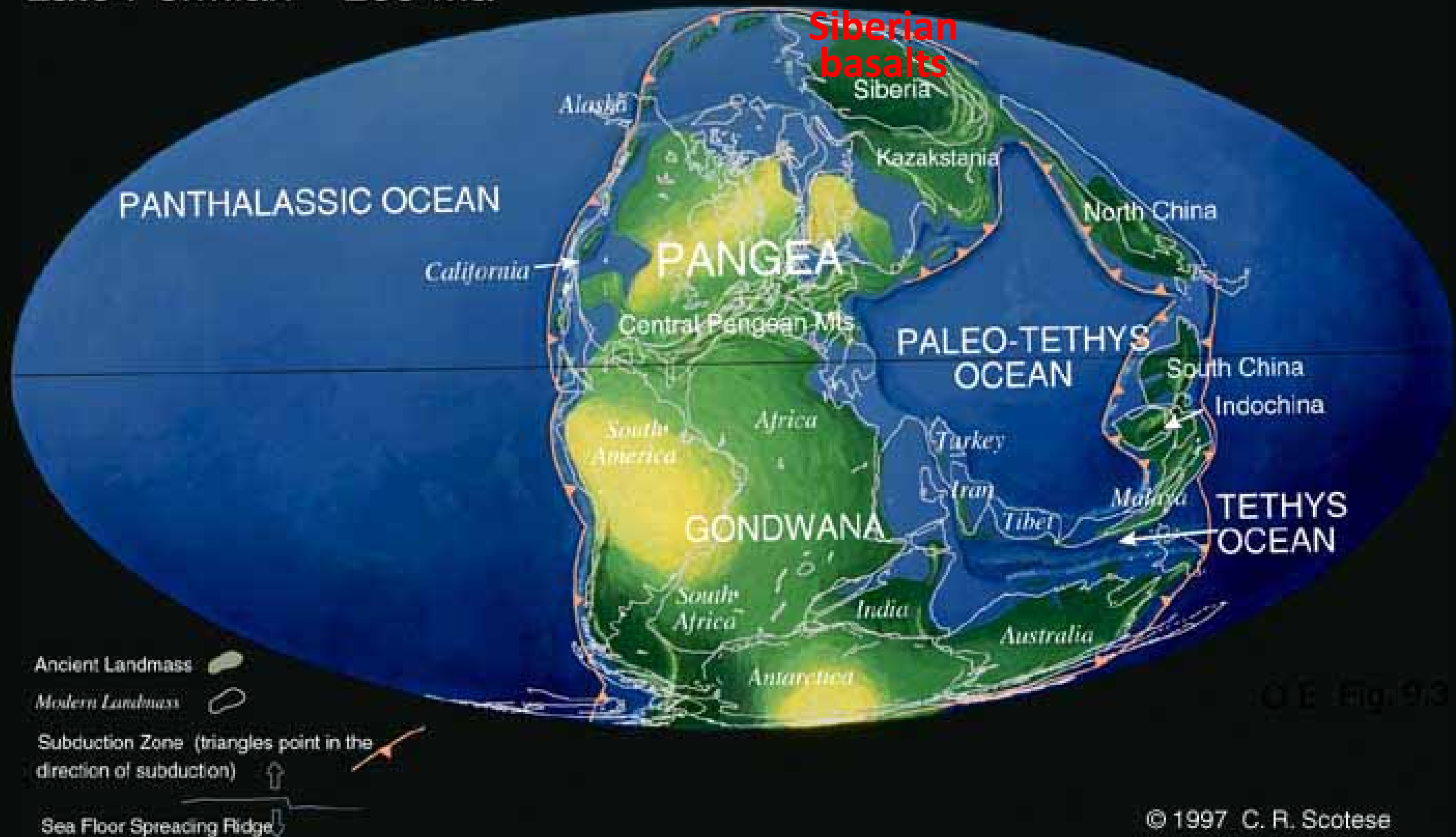
Late Proterozoic 650 Ma

Little sub-aerial rifting

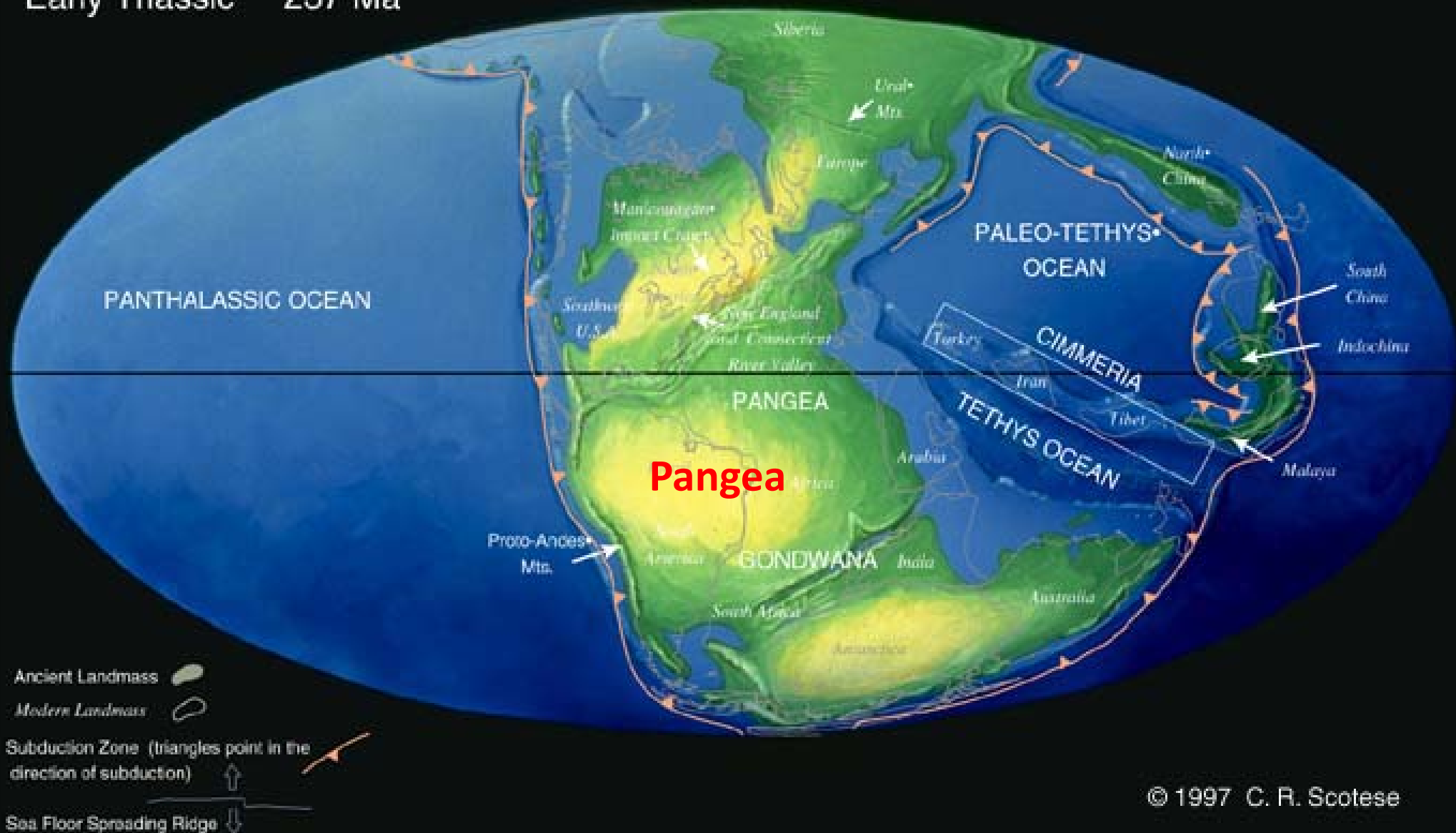




Late Permian 255 Ma

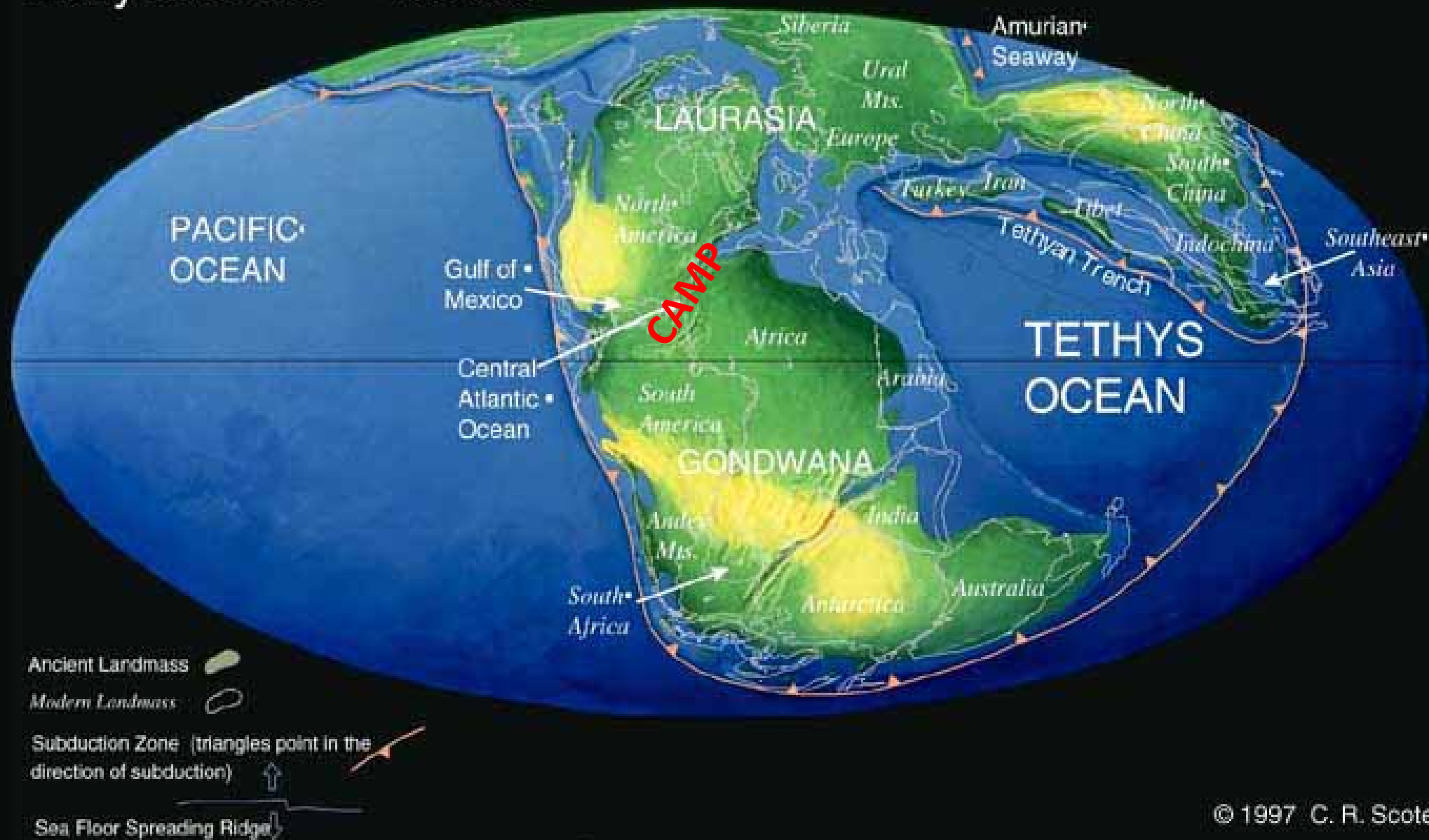


Early Triassic 237 Ma

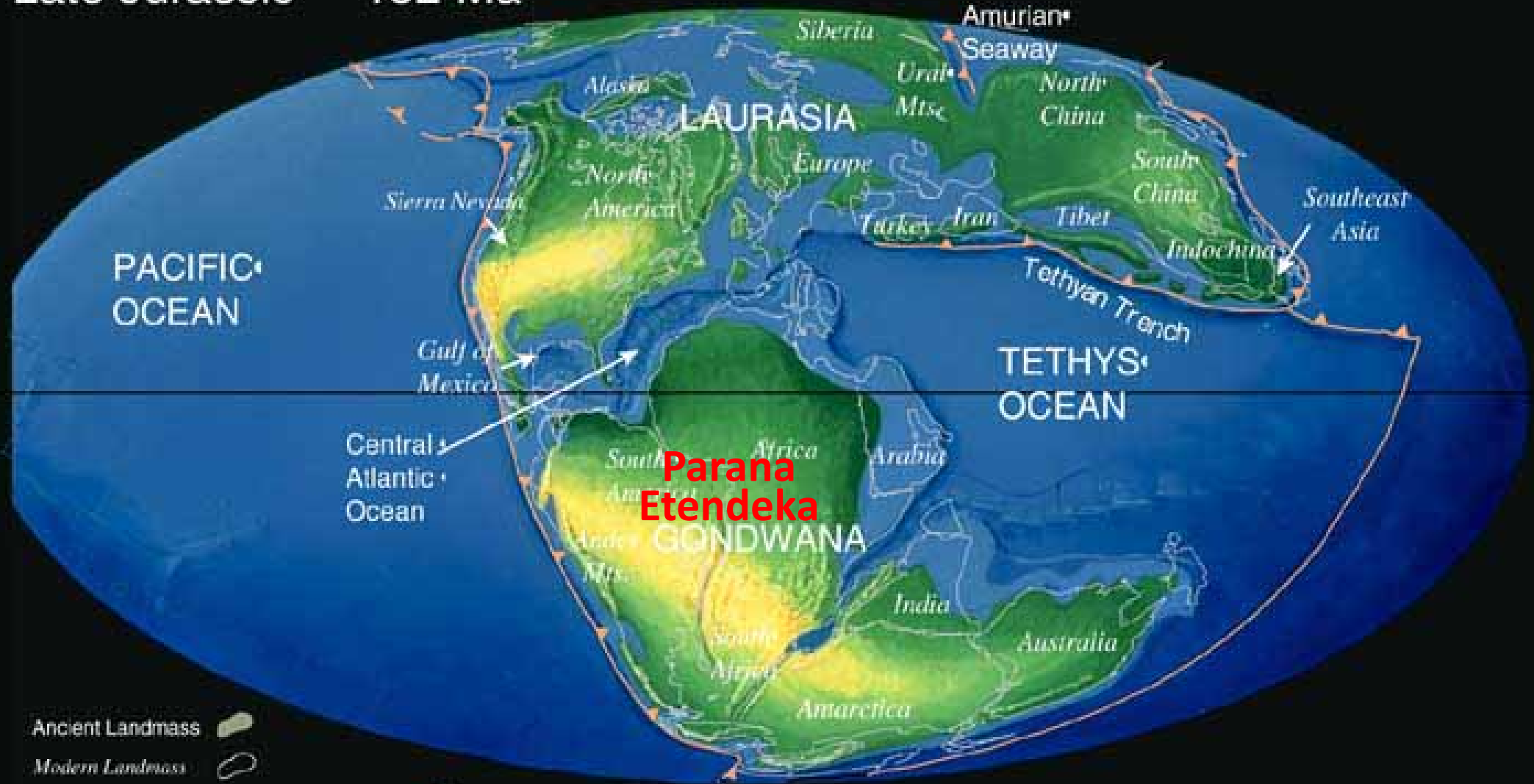




# Early Jurassic 195 Ma



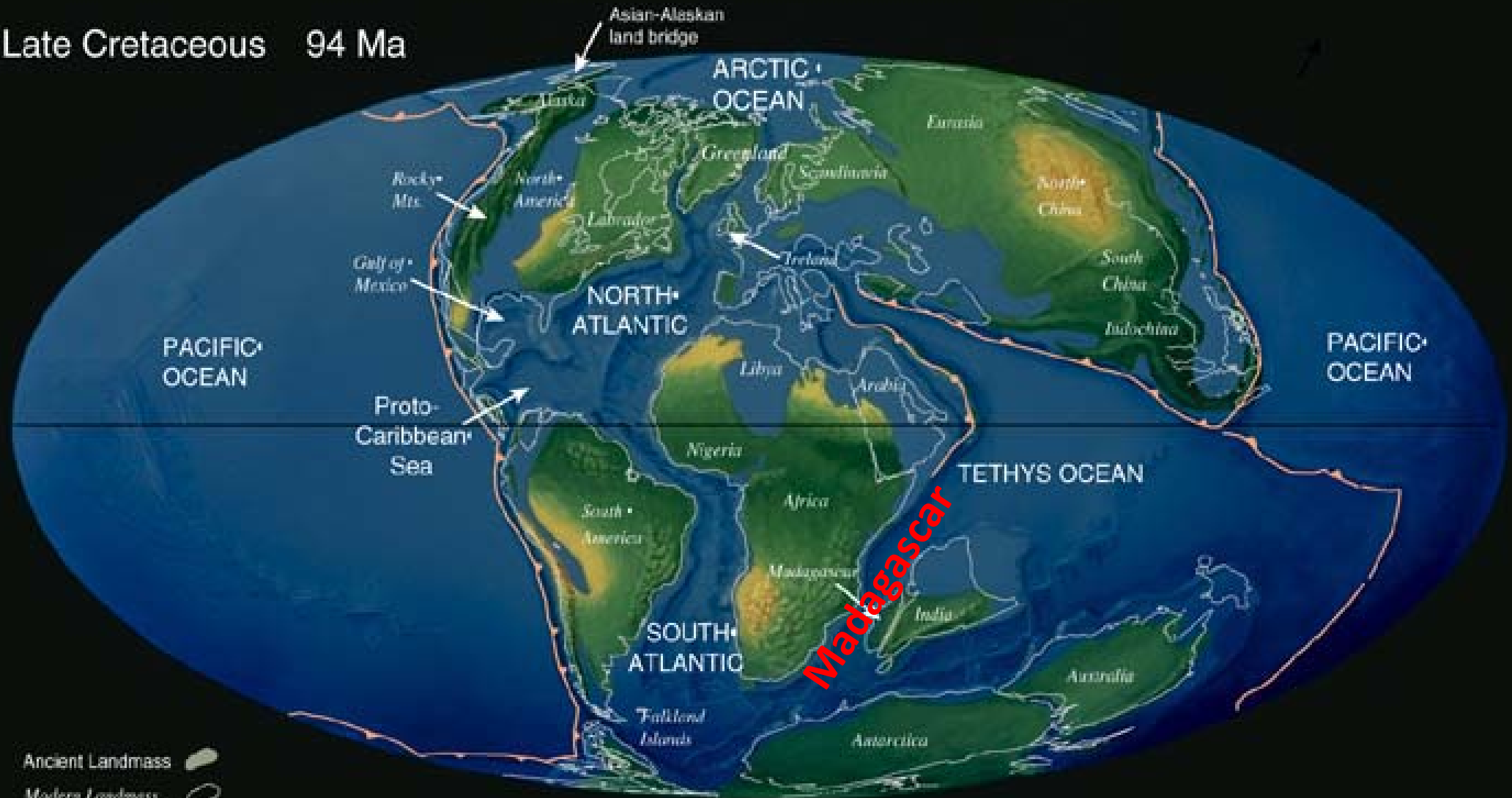
Late Jurassic 152 Ma



- Ancient Landmass
- Modern Landmass
- Subduction Zone (triangles point in the direction of subduction)
- Sea Floor Spreading Ridge



Late Cretaceous 94 Ma



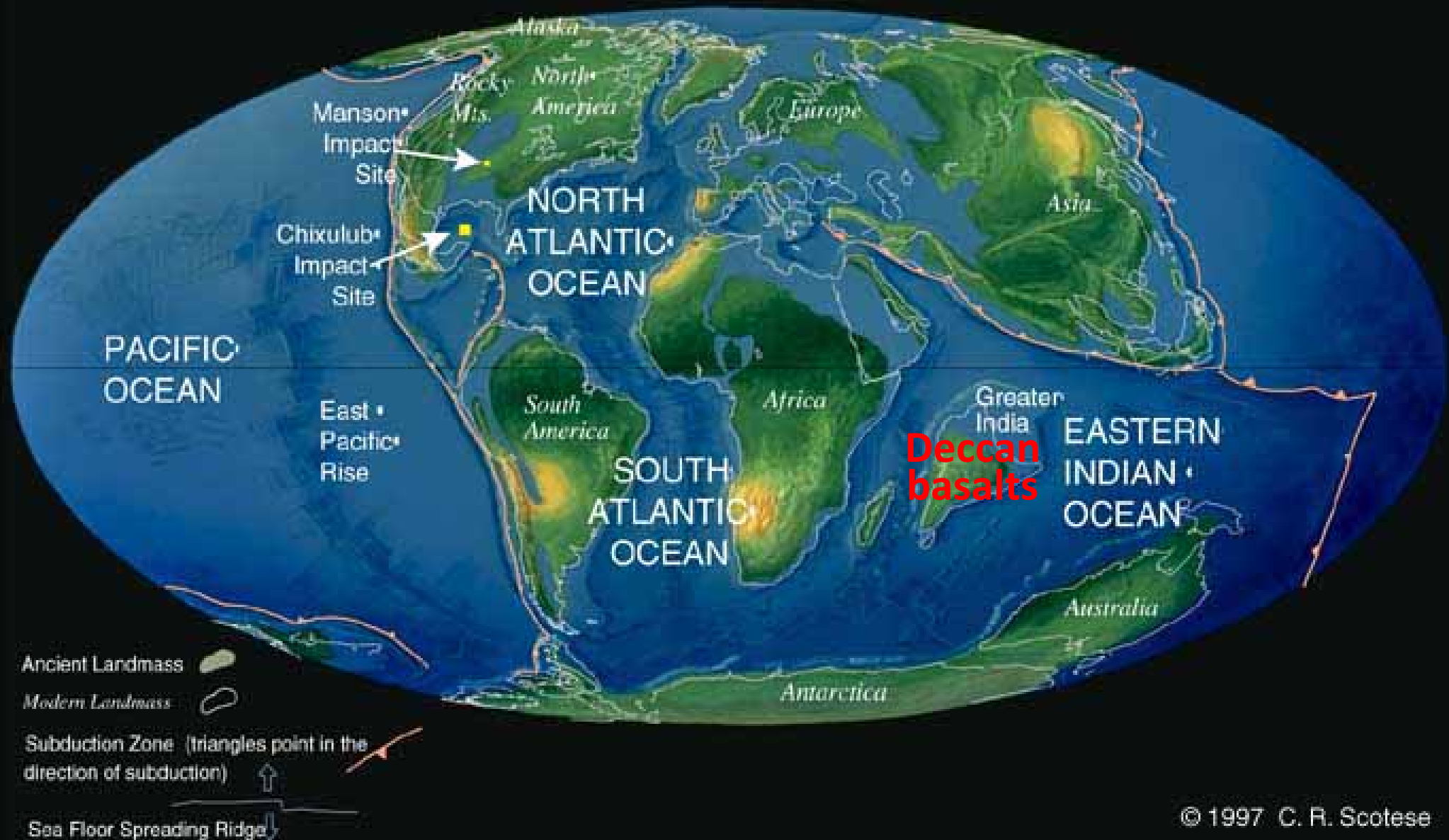
Ancient Landmass

Modern Landmass

Subduction Zone (triangles point in the direction of subduction)

Sea Floor Spreading Ridge

# Latest Cretaceous 69.4 Ma





# Middle Eocene 50.2 Ma



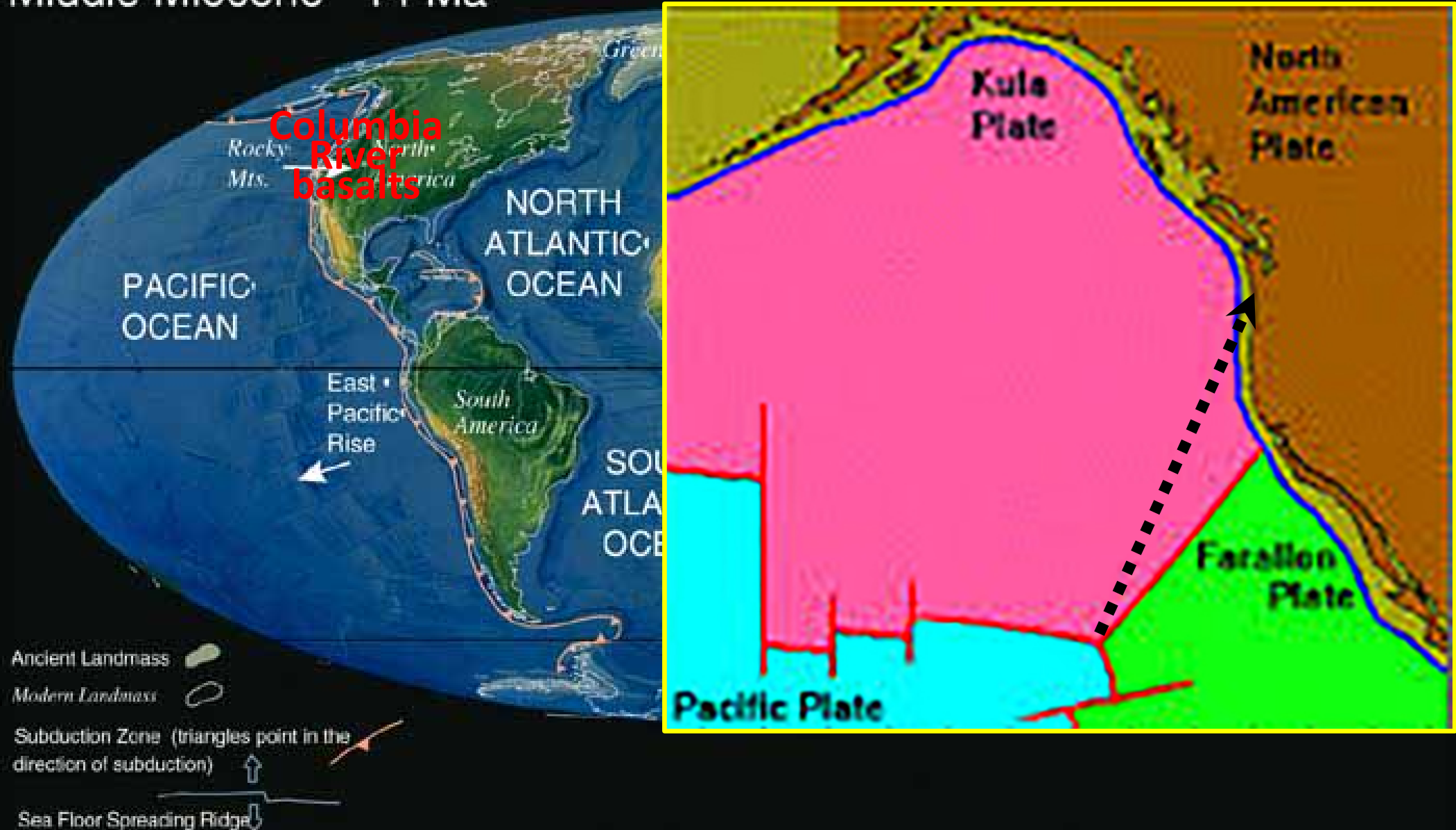
Ancient Landmass

Modern Landmass

Subduction Zone (triangles point in the direction of subduction)

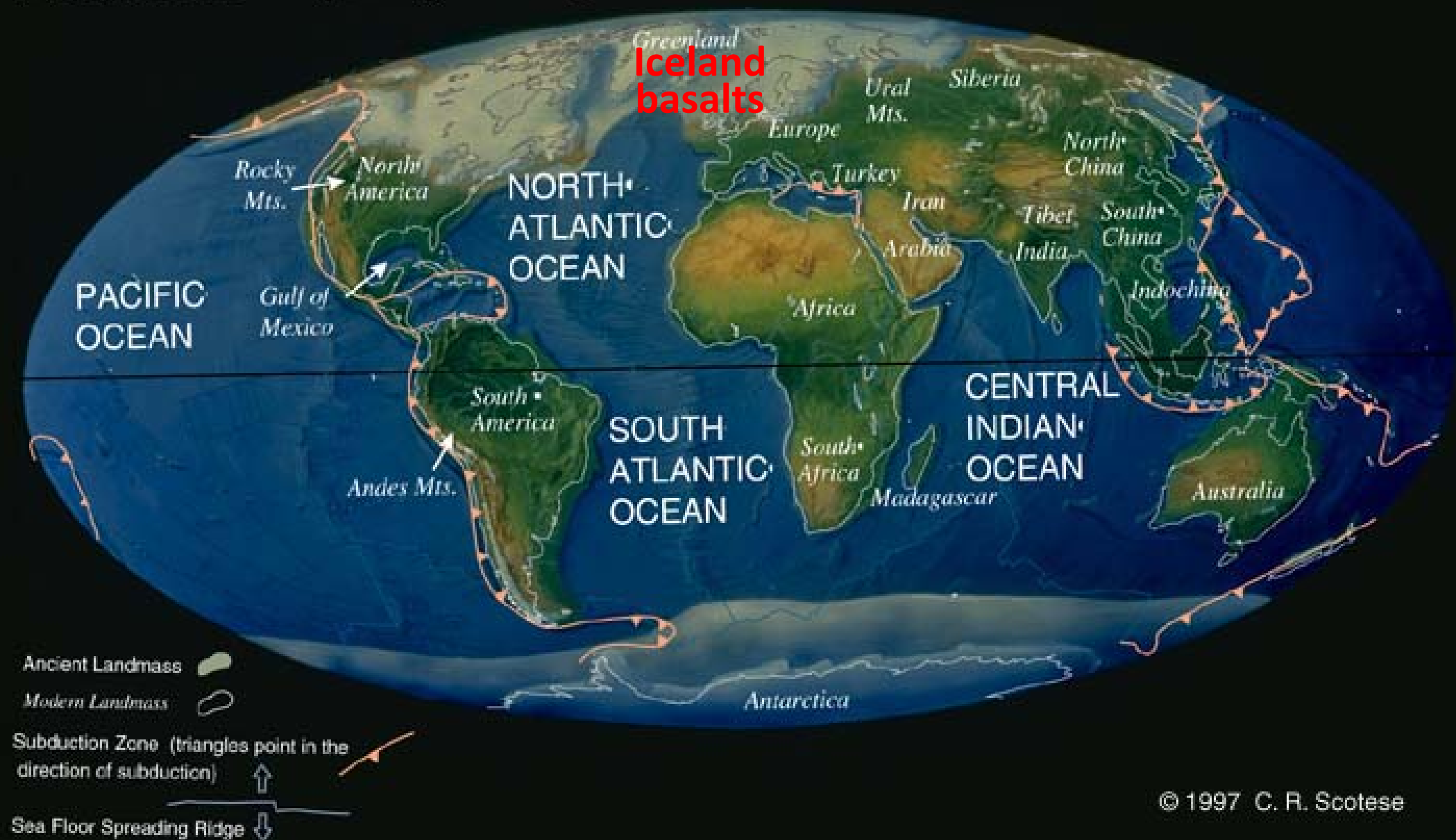
Sea Floor Spreading Ridge

Middle Miocene 14 Ma





# Pleistocene 18,000 years ago



# Rift-related, effusive, basaltic, volcanic eruptions warm Earth suddenly

Extrude basaltic lava for months to hundreds of thousands of years

The greater the duration, the greater the warming and extinctions

Range in size from Hawaii to Large Igneous Provinces (LIPs)

Cause major warming of air and, over millennia, of oceans

Cause major ocean acidity (sulfuric acid from  $\text{SO}_2$  and  $\text{H}_2\text{S}$ )

Cause major mass extinctions especially when lasting for long periods

Bárðarbunga largest since 1783—explains why 2016 hottest year

# Rapid Warming



**Effusive  
rift-related**

**Minimal aerosols  
Duration >months**

# Incremental Cooling

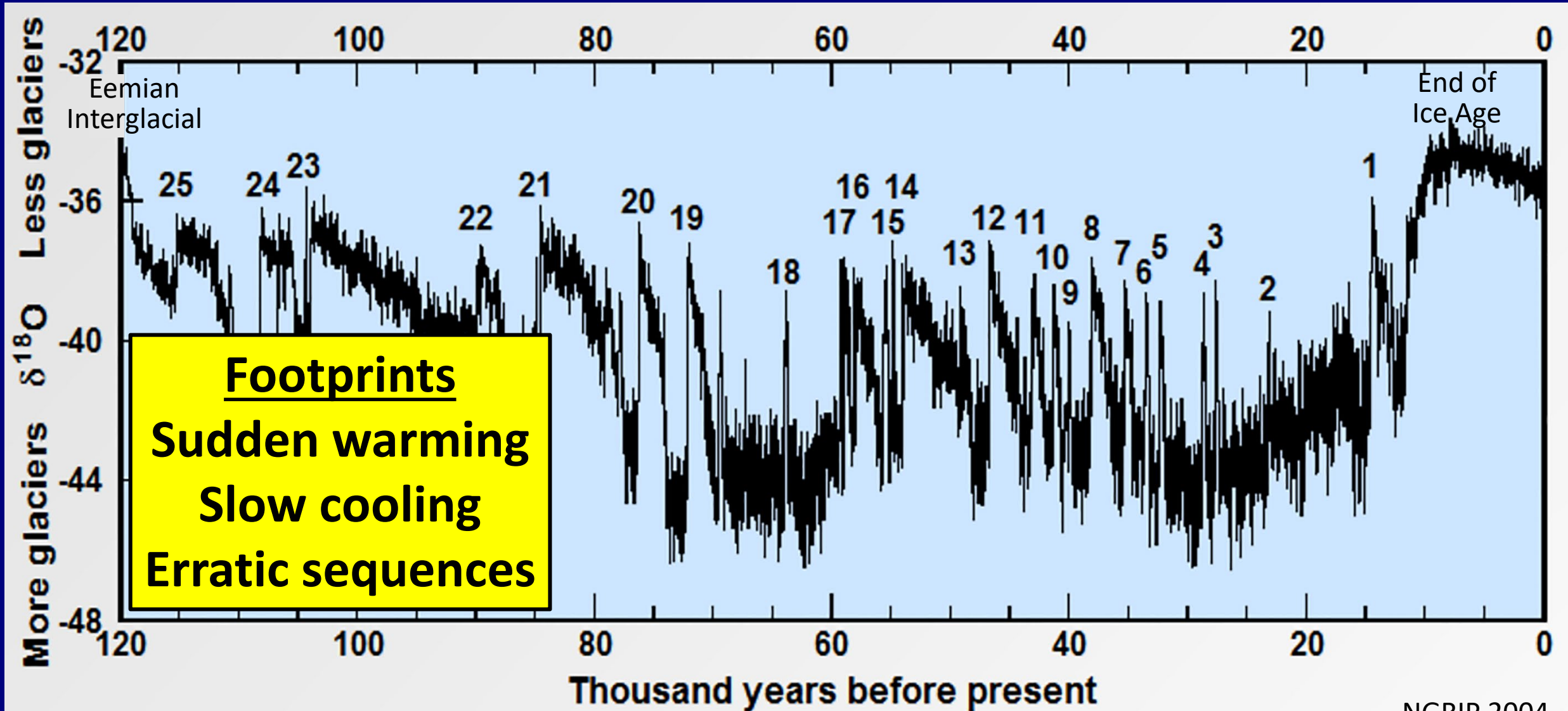


**Explosive  
subduction-related  
Extensive aerosols  
Frequency per century**

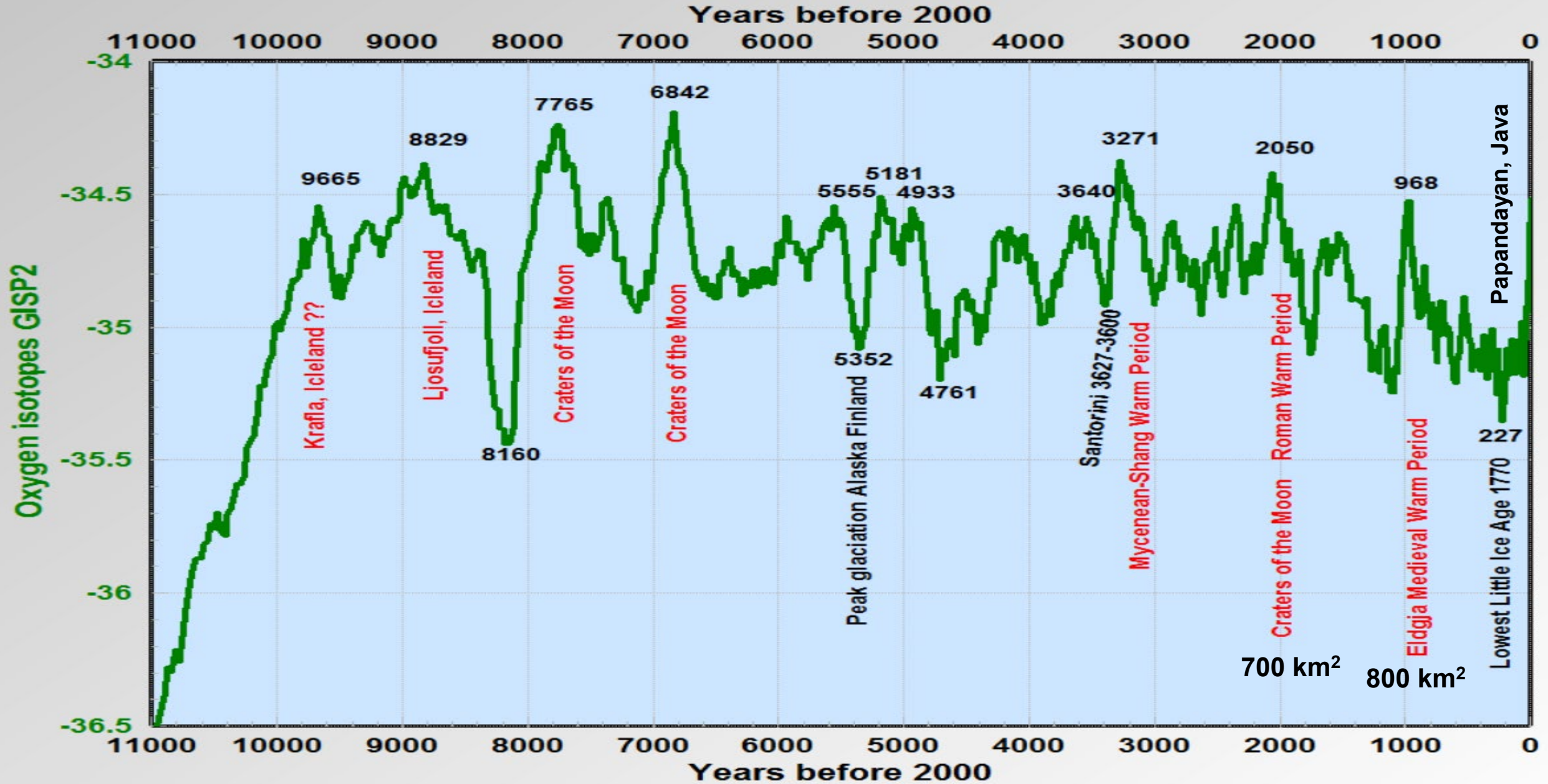


# Erratic sequences of rapid warming followed by slower cooling

## Dansgaard-Oeschger events observed in Greenland ice



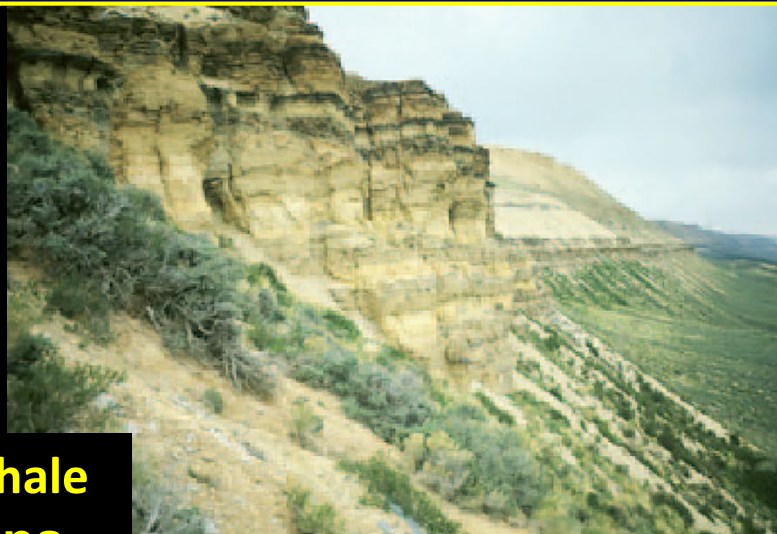
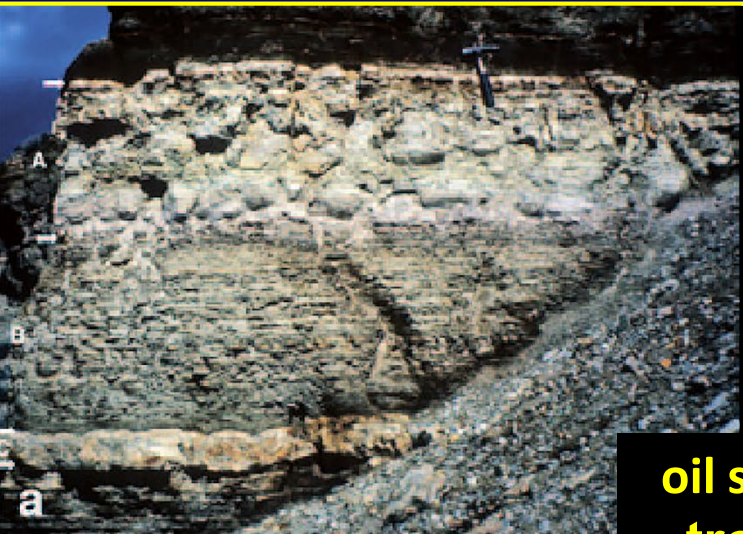
# Holocene temperatures and volcanism



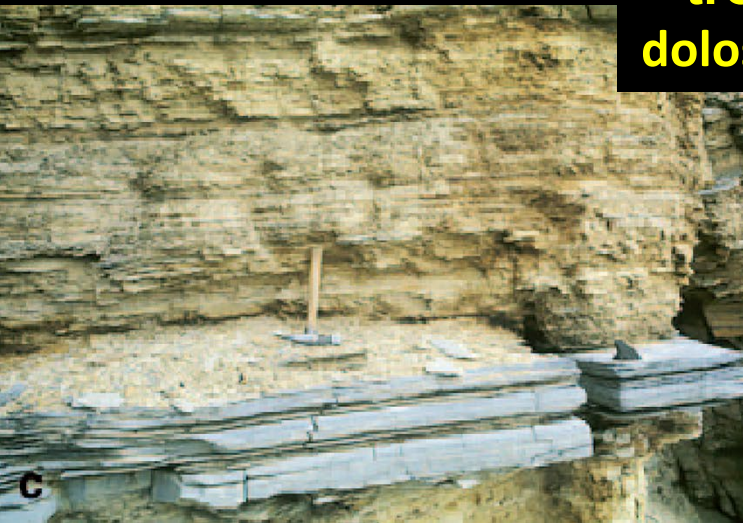


# 5000 Year Sequences in the Green River Formation, Southwestern Wyoming

**Around 50 Ma**



**oil shale  
trona  
dolostone**

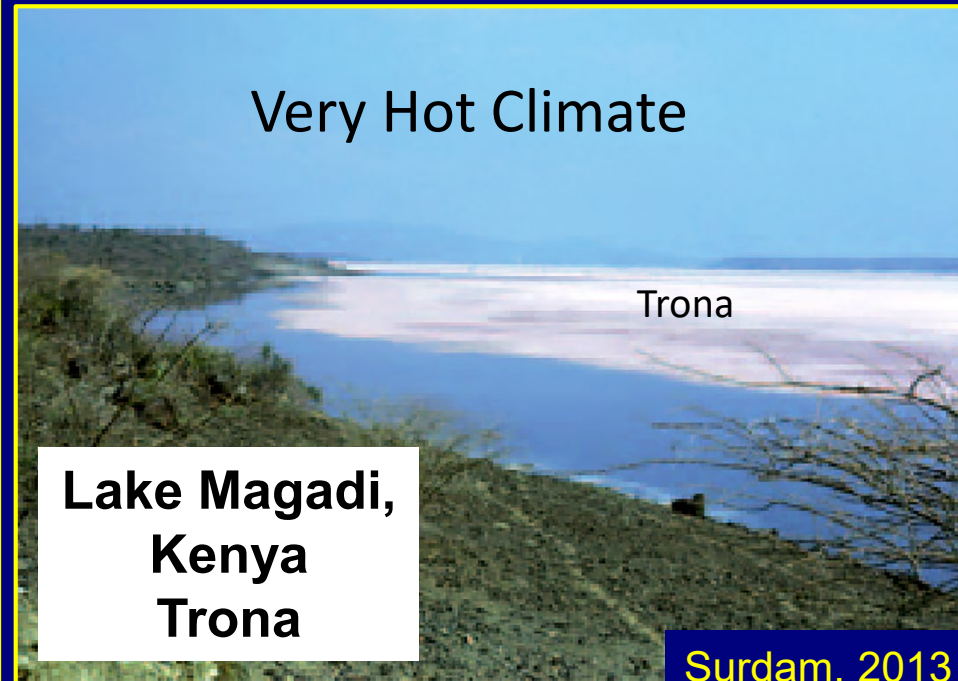


Temperate Climate



**Mud Lake  
Florida  
Oil shale**

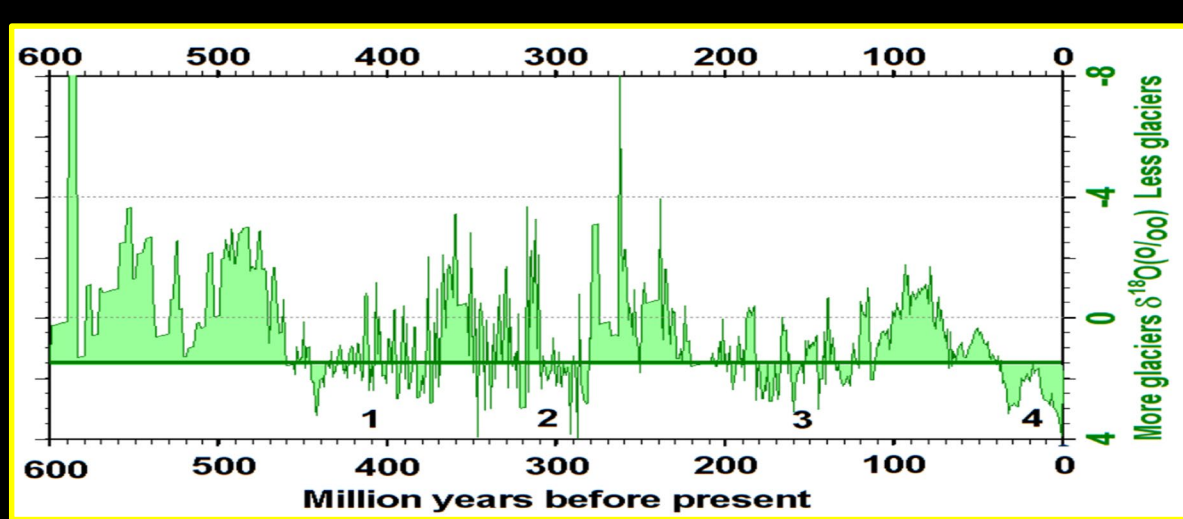
Very Hot Climate



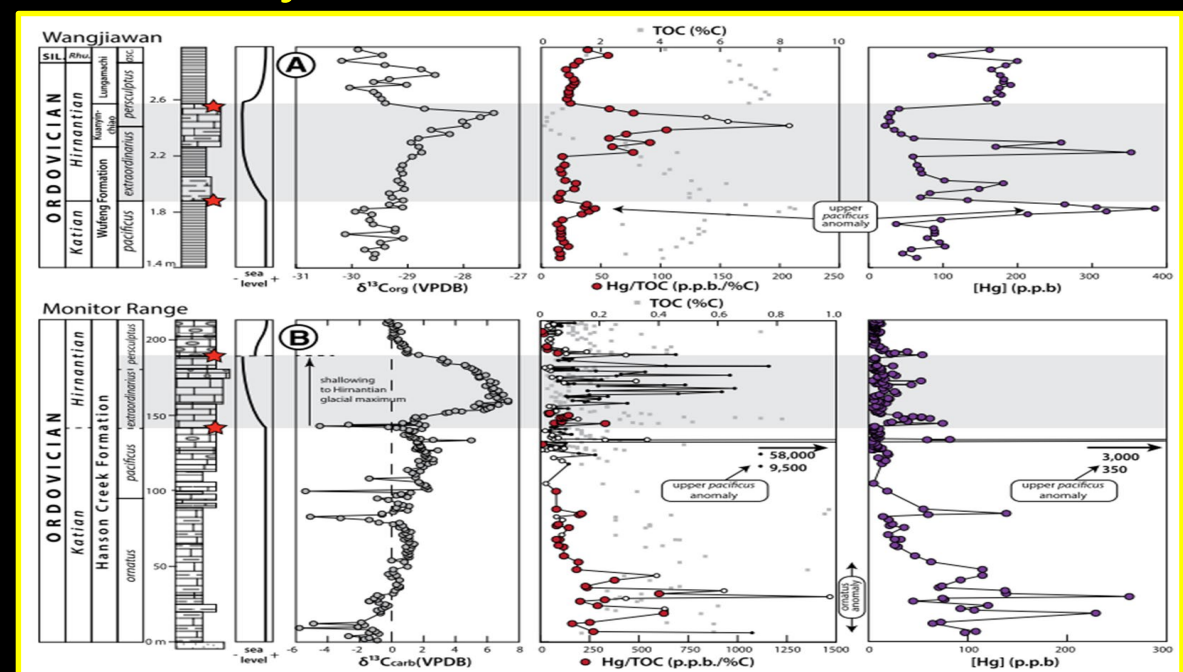
**Lake Magadi,  
Kenya  
Trona**

Trona



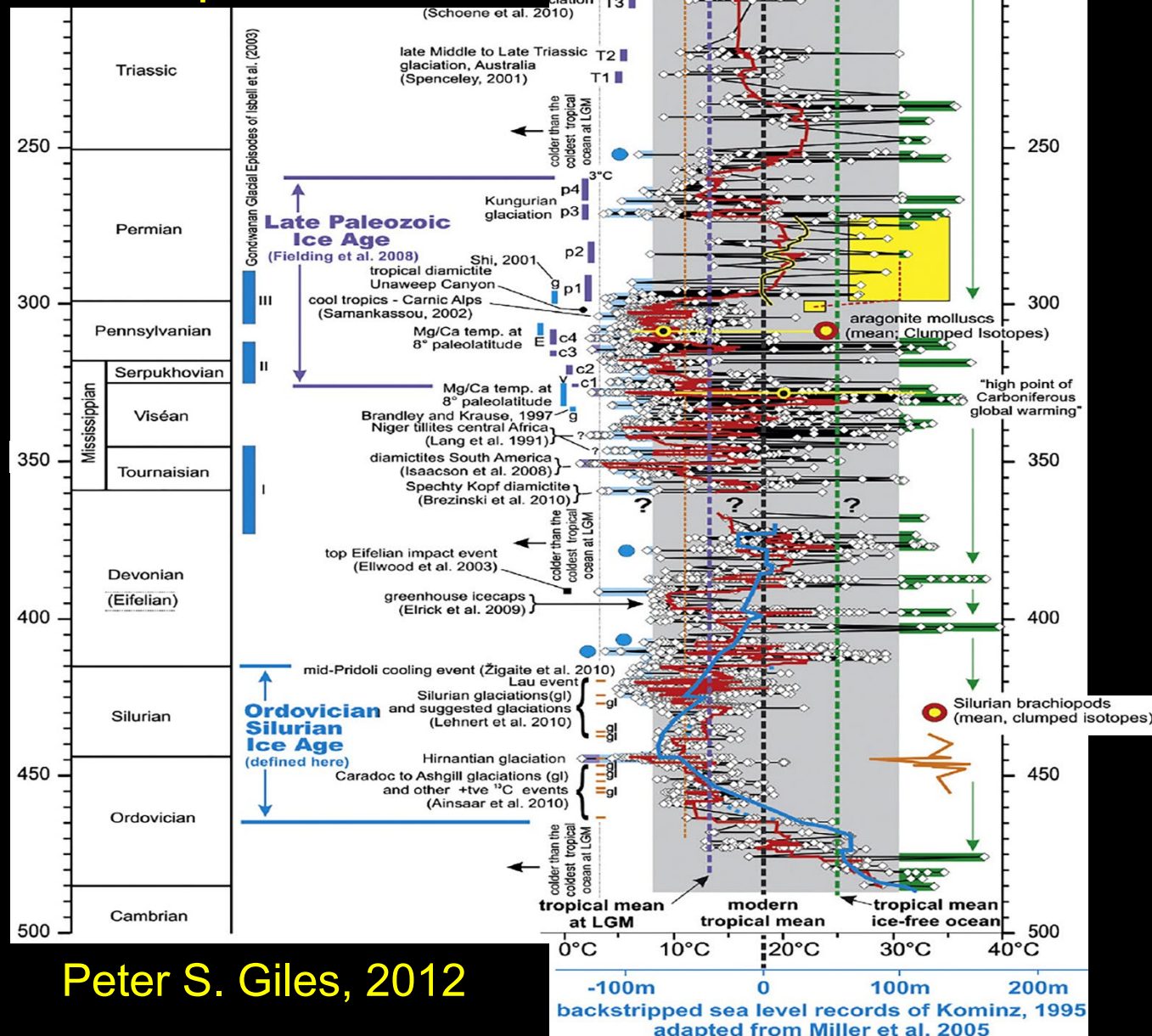


## Ordovician mercury (Hg) enrichment by LIP basaltic volcanism



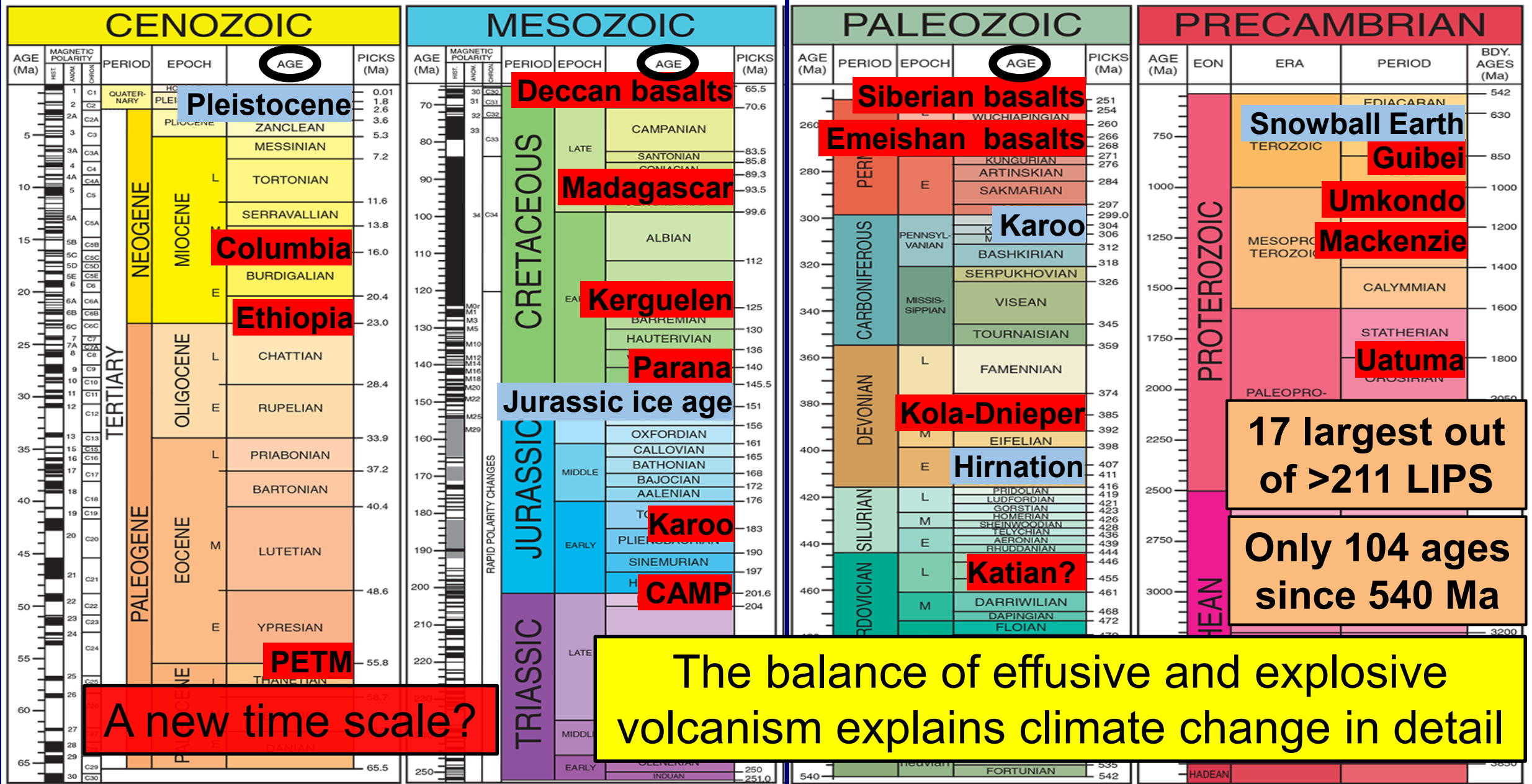
David S. Jones et al., 2017

## Paleozoic brachiopod habitat temperatures



Peter S. Giles, 2012

# Large Igneous Provinces punctuate the geologic time scale

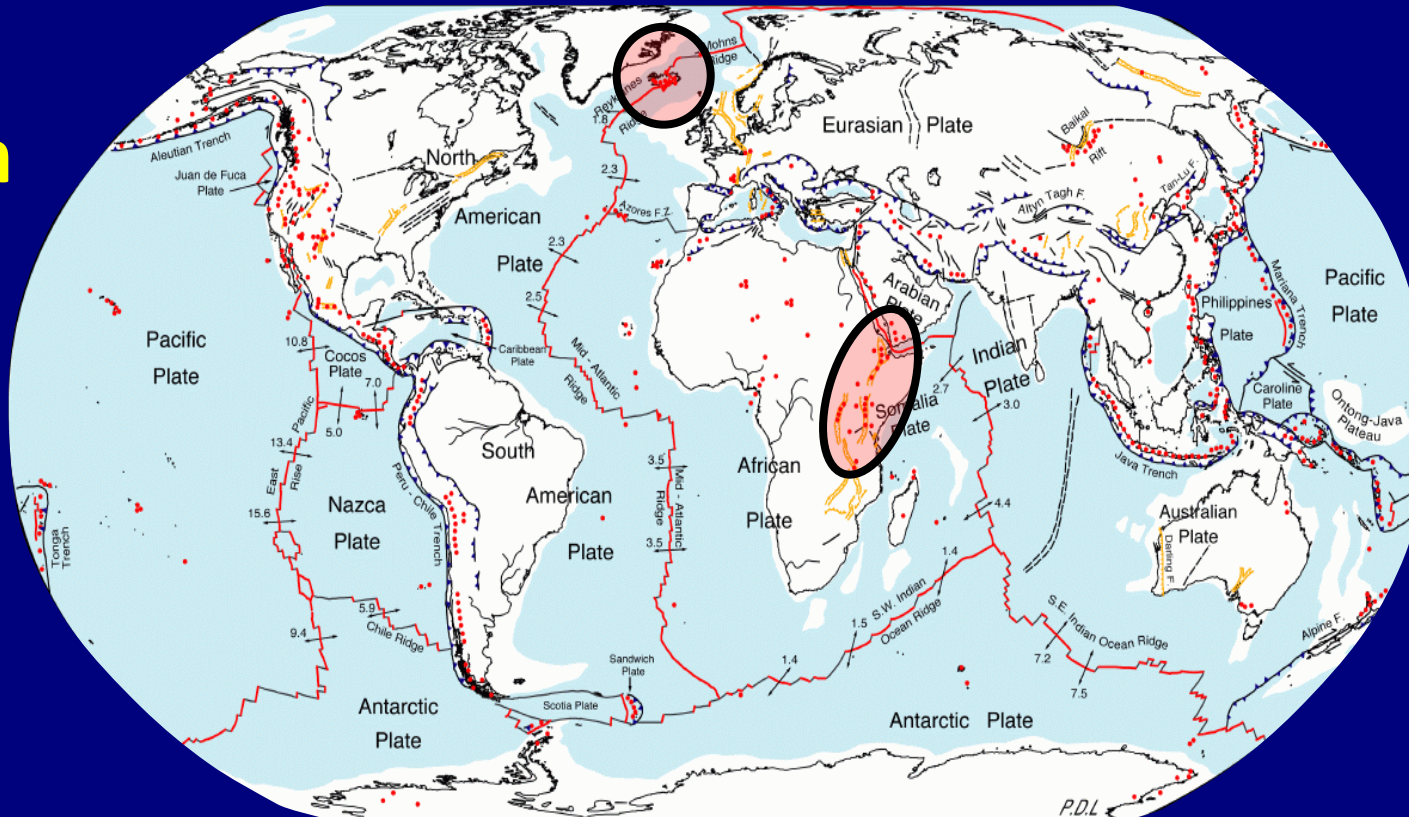




# Volcanoes Rule

WhyClimateChanges.com

We are not in  
an ice age  
now thanks  
to Iceland  
and the East  
African Rift



peward@Wyoming.com

