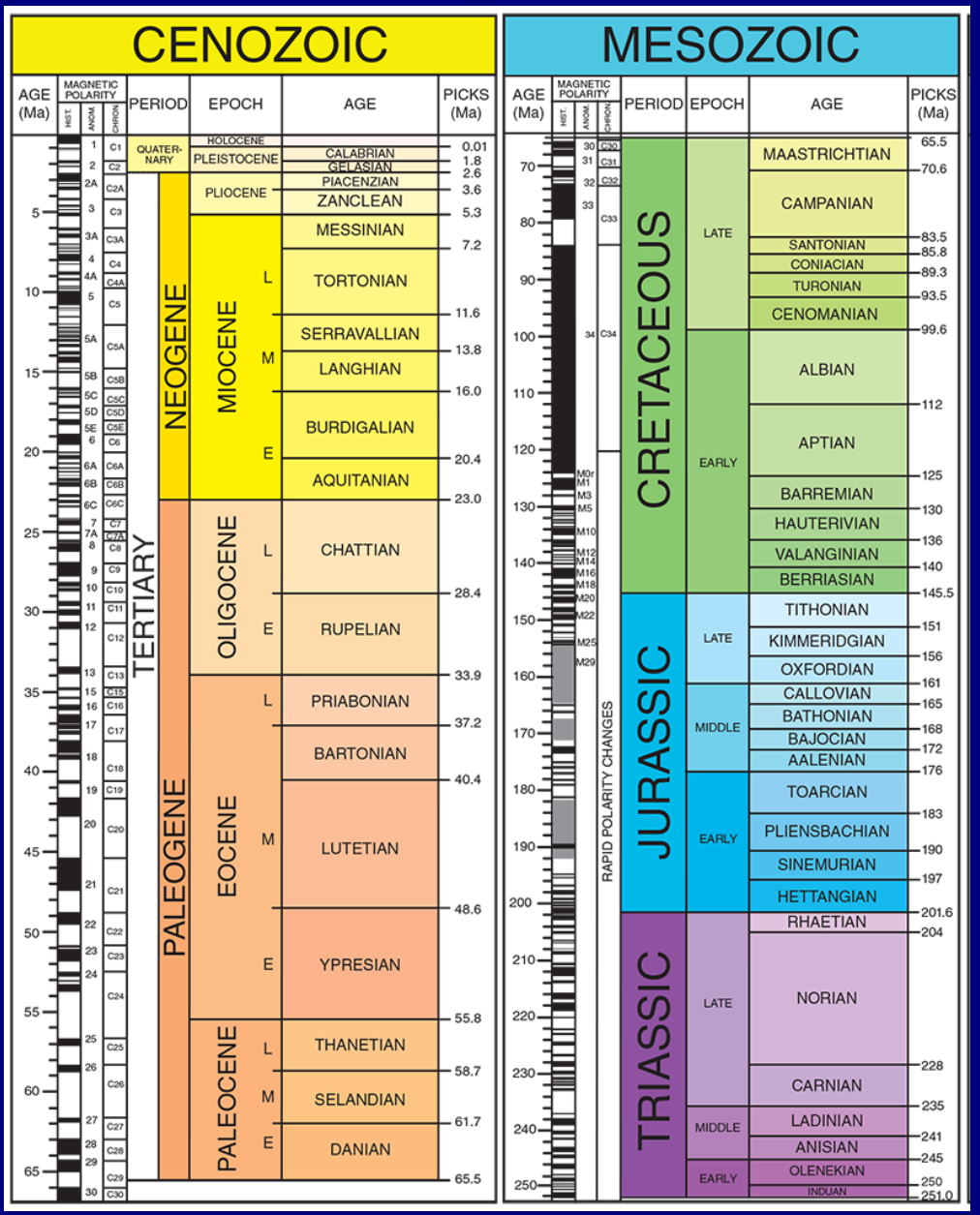
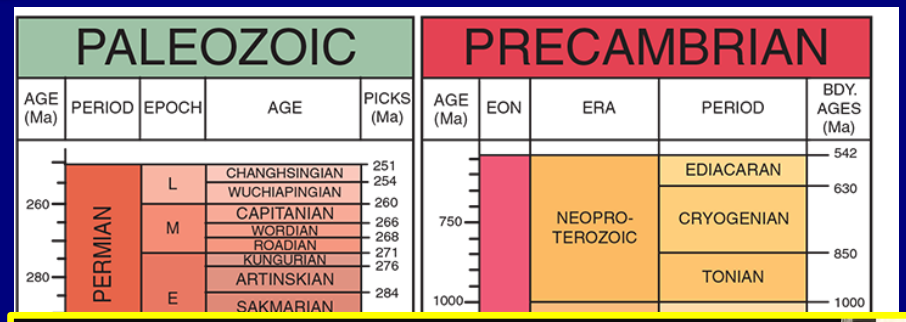
What punctuates the geologic time scale?



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

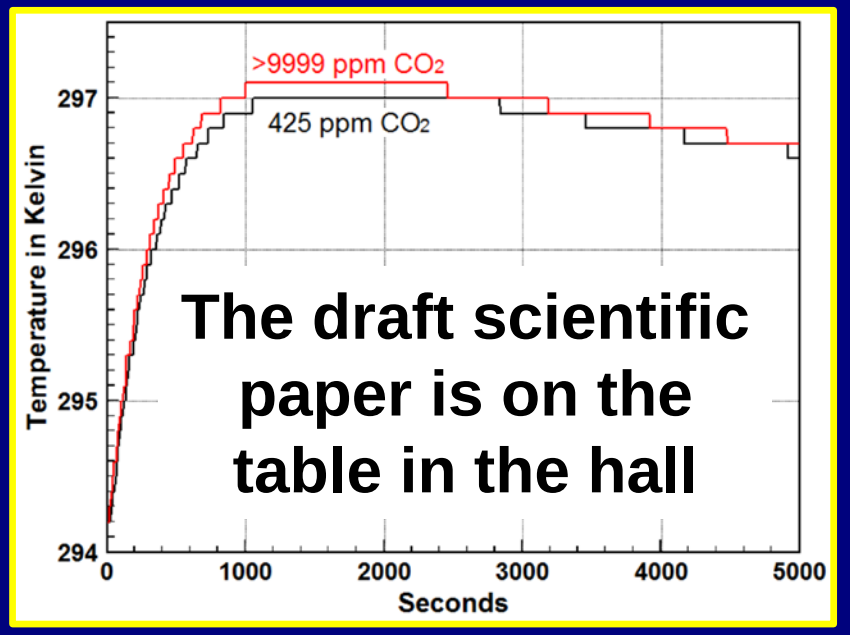

CO_2
CO_2
JOSH'16
DID YOU KNOW THAT CO2 WARMING THEORY HAS NEVER ACTUALLY BEEN FLIGHT TESTED?

JustProveCO2.com

"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

A simple negative demonstration



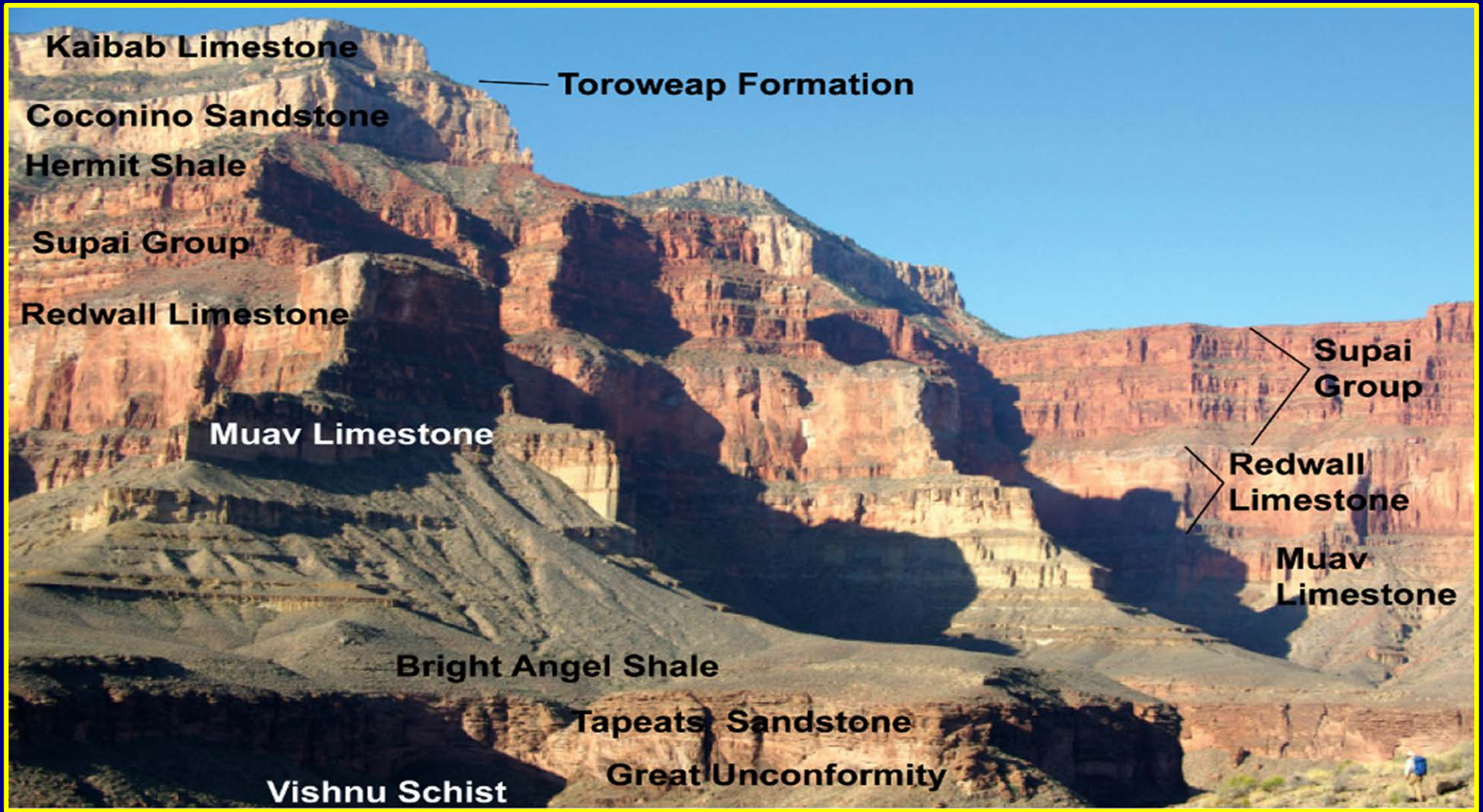
CO_2 simply does not absorb enough heat to warm Earth

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

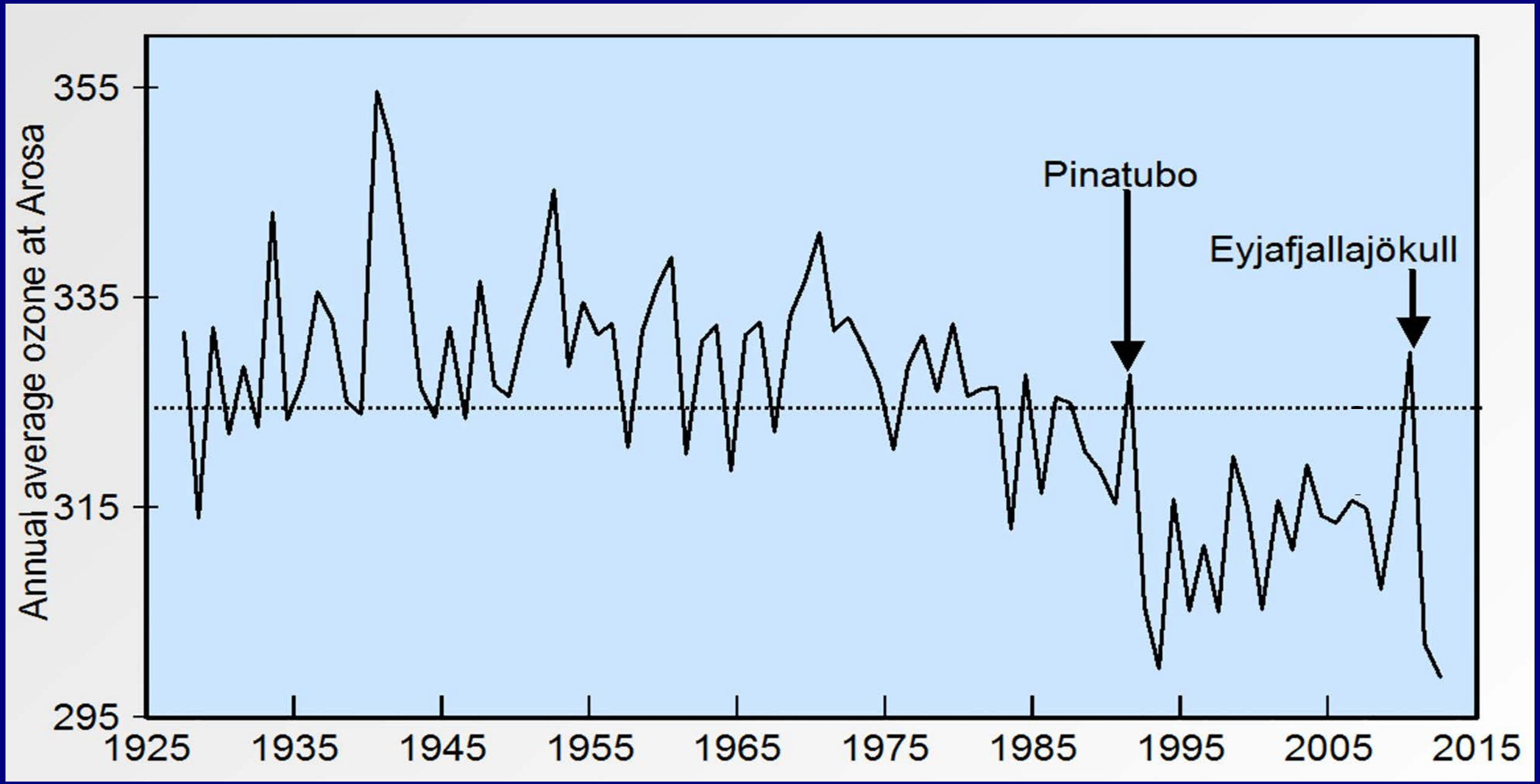
Atmospheric concentration of CO_2 may simply be a proxy for ocean temperature

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

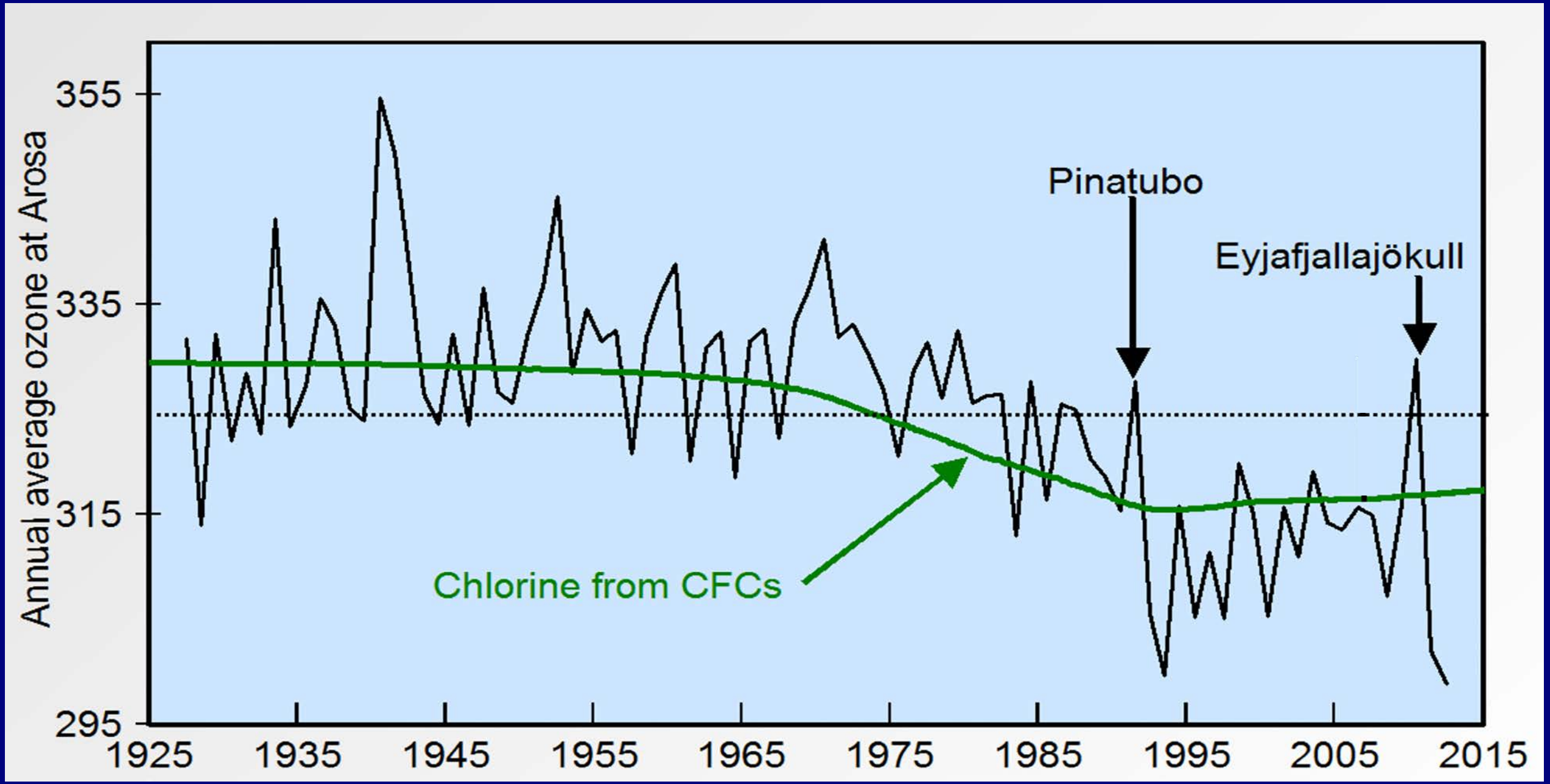
CO_2 cannot explain most periods of warming throughout the geologic record

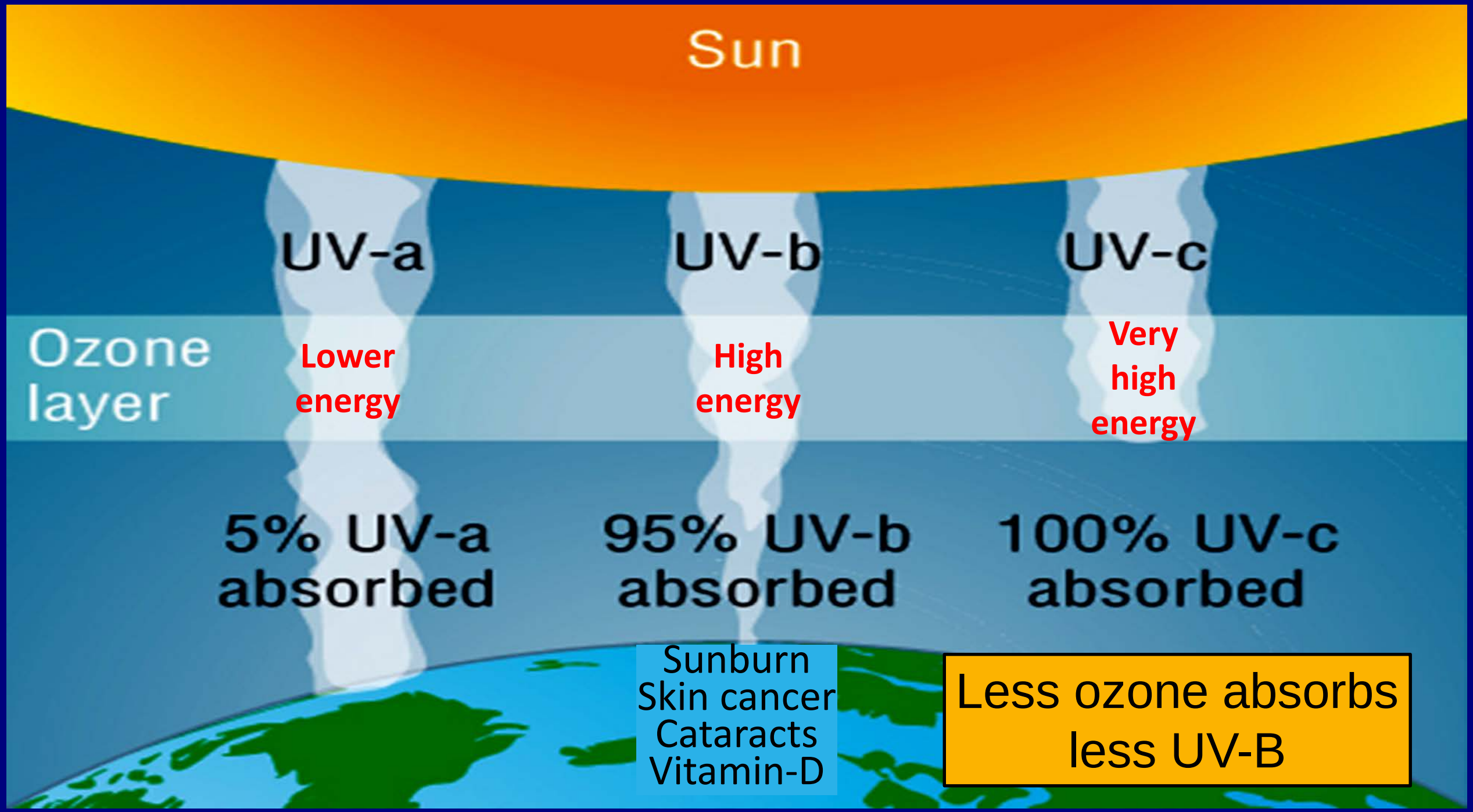

Kaibab Limestone
Toroweap Formation
Coconino Sandstone
Hermit Shale
Supai Group
Redwall Limestone
Muav Limestone
Supai Group
Redwall Limestone
Muav Limestone
Bright Angel Shale
Tapeats Sandstone
Great Unconformity
Vishnu Schist

Volcanic eruptions deplete the ozone layer

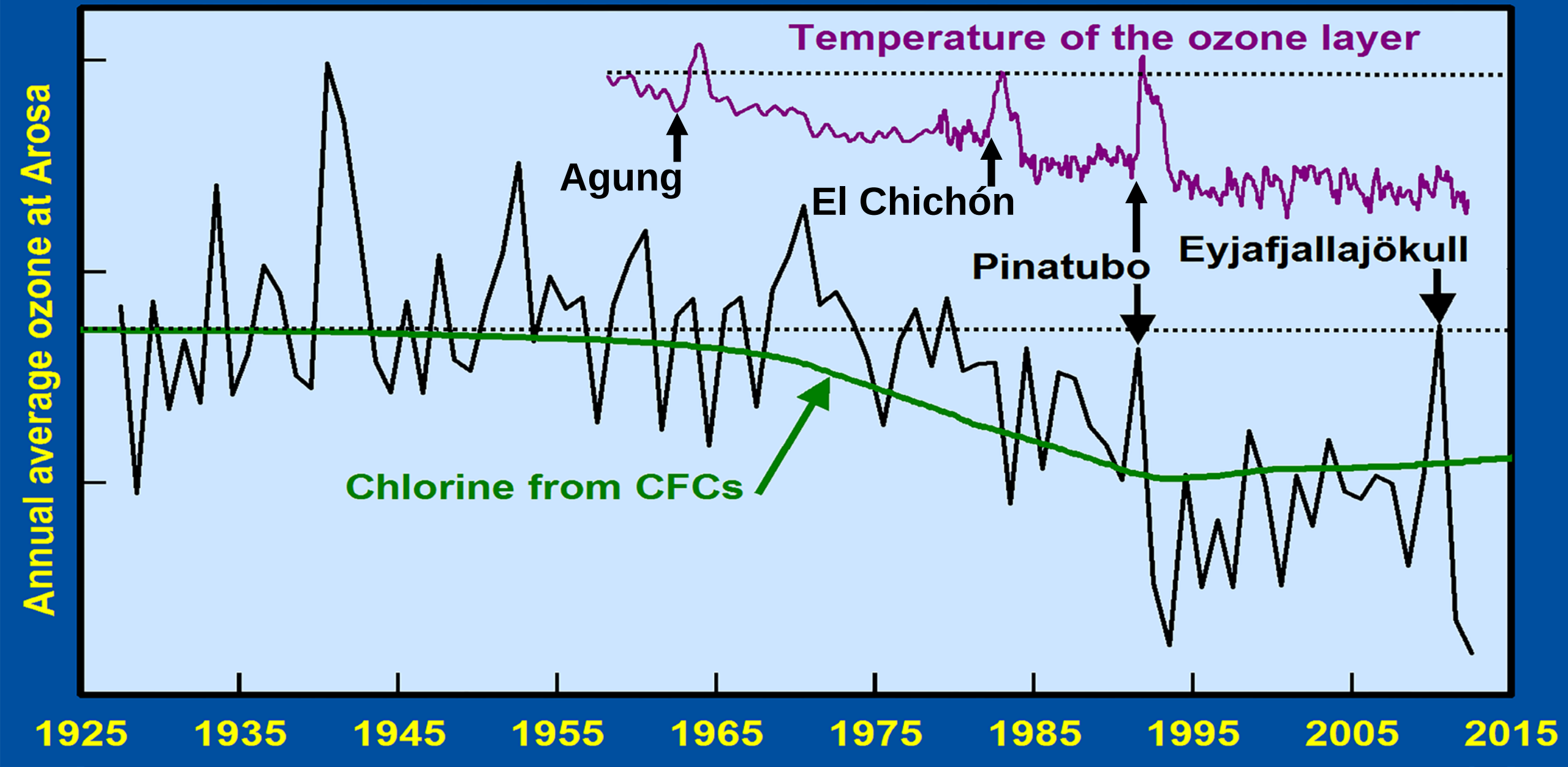


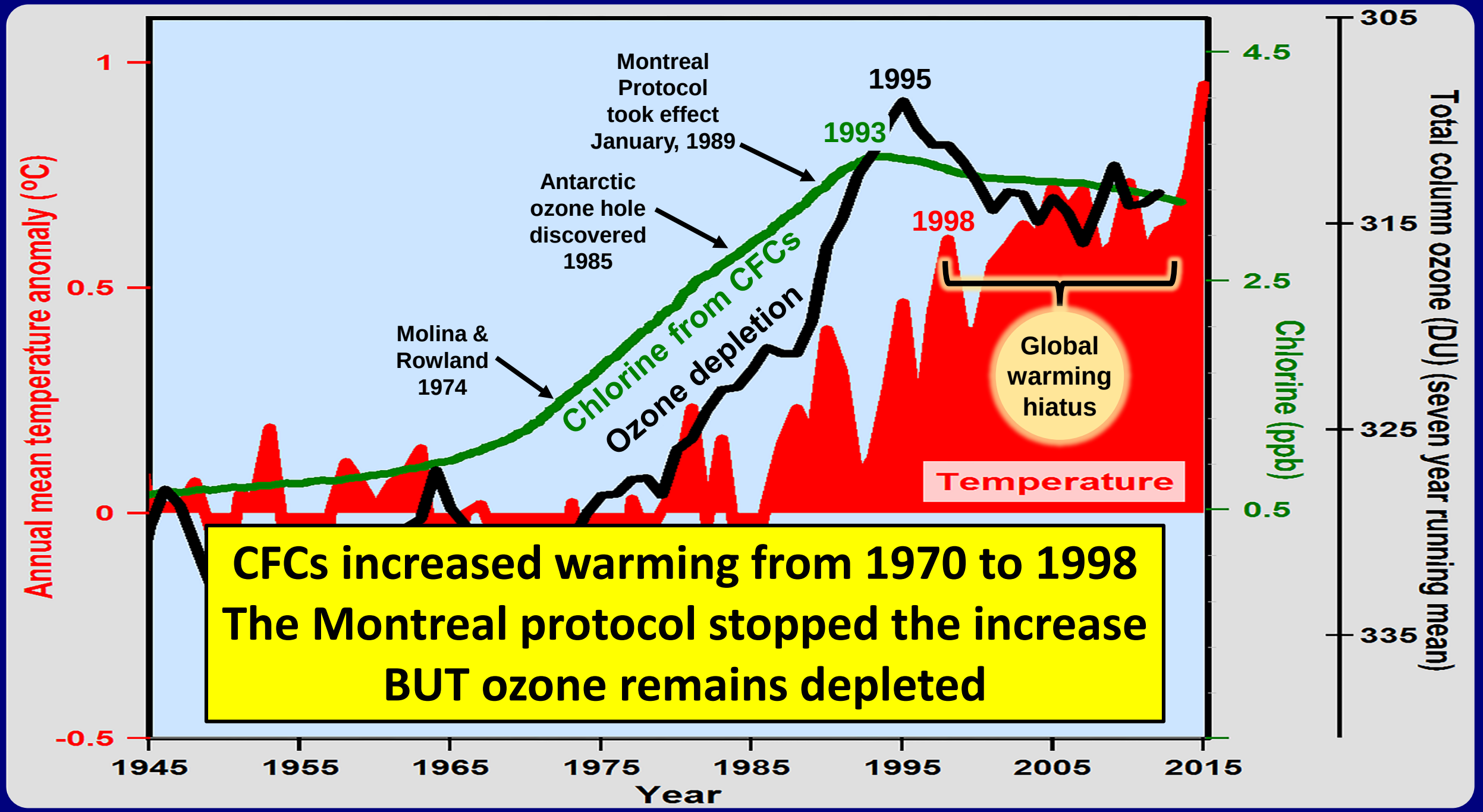
Chlorofluorocarbons (CFCs) also deplete the ozone layer



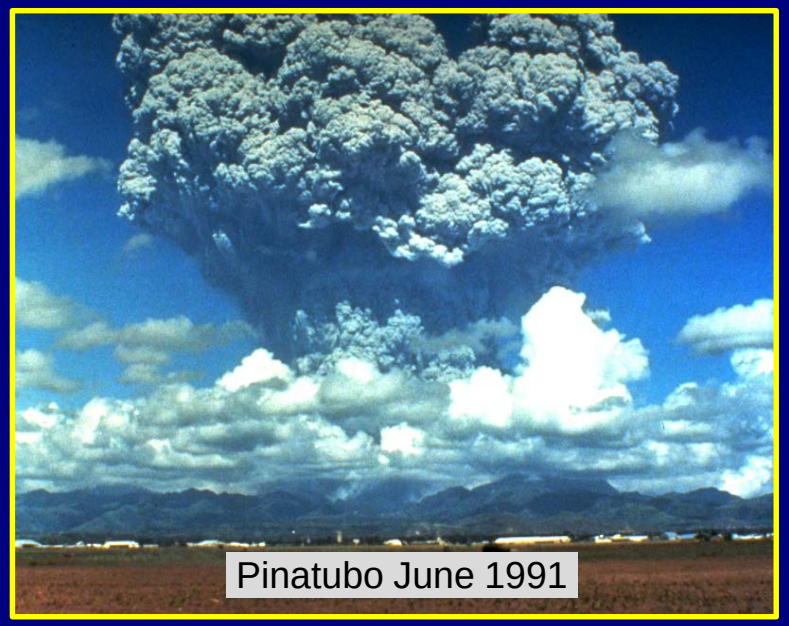

Sun
UV-a
UV-b
UV-c
Ozone layer
Lower energy
High energy
Very high energy
5% UV-a absorbed
95% UV-b absorbed
100% UV-c absorbed
Sunburn
Skin cancer
Cataracts
Vitamin-D
Less ozone absorbs less UV-B

Less ozone causes ozone layer to cool and Earth to warm




Annual mean temperature anomaly (°C)
1
0.5
0
-0.5
1945
1955
1965
1975
1985
1995
2005
2015
Year
4.5
2.5
0.5
Chlorine (ppb)
305
315
325
335
Total column ozone (DU) (seven year running mean)
Montreal Protocol took effect January, 1989
Antarctic ozone hole discovered 1985
Molina & Rowland 1974
1995
1993
1998
Chlorine from CFCs
Ozone depletion
Global warming hiatus
Temperature
CFCs increased warming from 1970 to 1998
The Montreal protocol stopped the increase
BUT ozone remains depleted

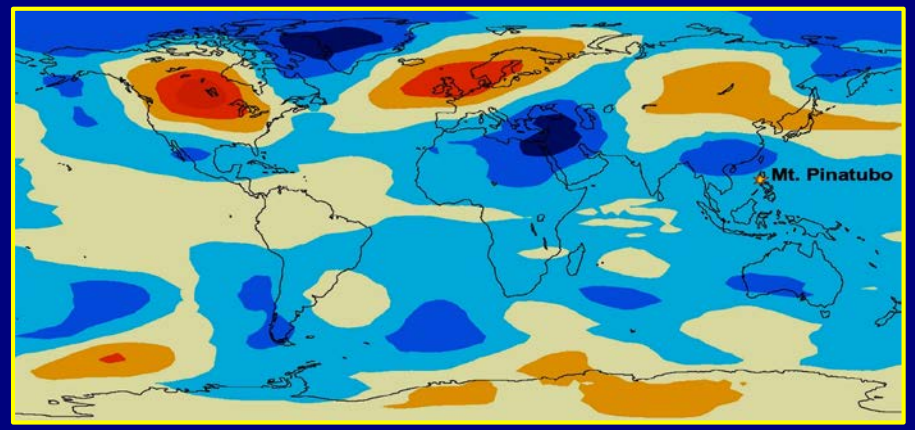
Explosive, aerosol forming, volcanic eruptions



USGS

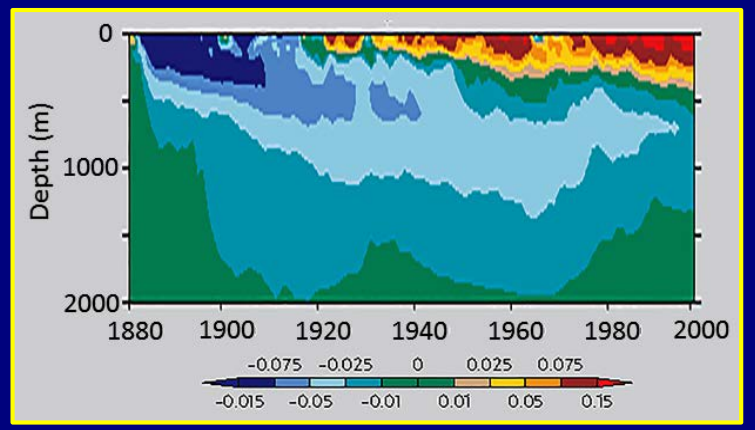
- Typical above subduction zones
- Erupt for days, may recur within 500 to 1000 years
- Deplete ozone causing short-term warming
- Form aerosols in the lower stratosphere that last for 2-4 years, scattering and reflecting solar energy, causing net global cooling of 0.5°C

Pinatubo warmed 3.5°C world
Dec 1991 to Feb 1992



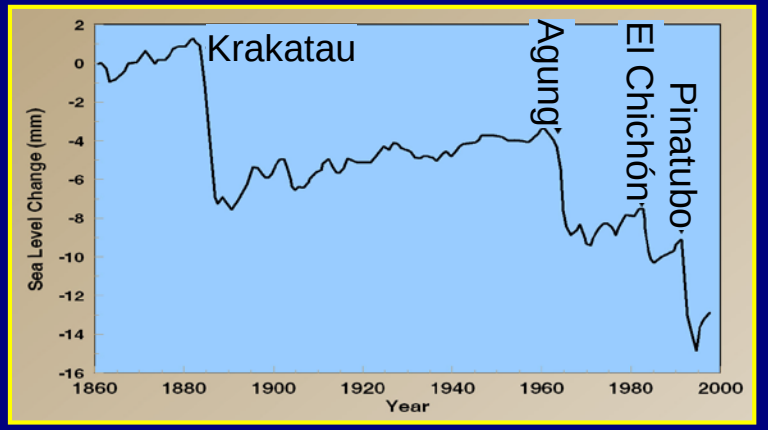
Robock, 2002

Krakatau (1883) cooled ocean
for more than 100 years



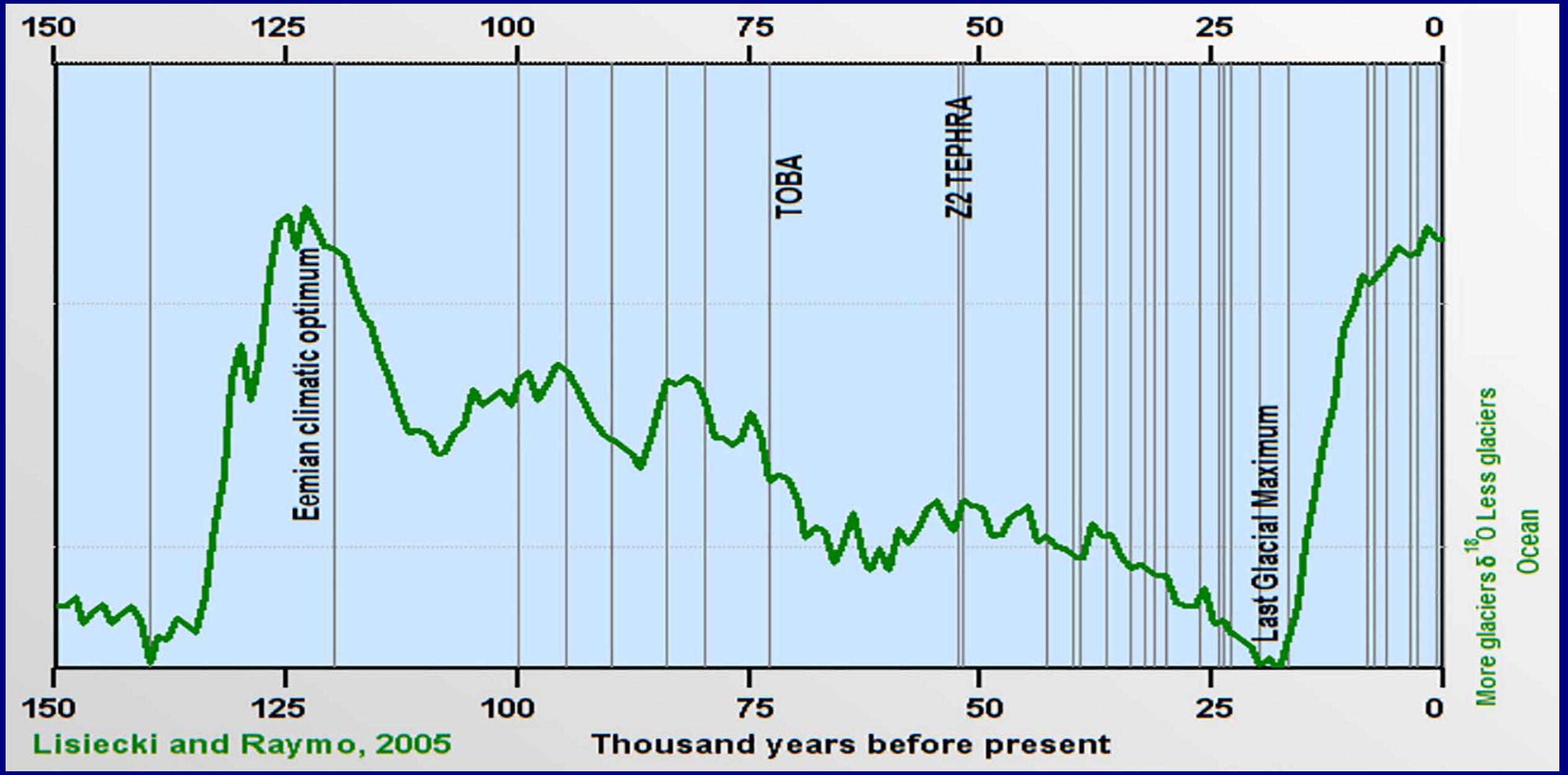
Gleckler et al., 2006

Multiple eruptions increment world
into an ice age

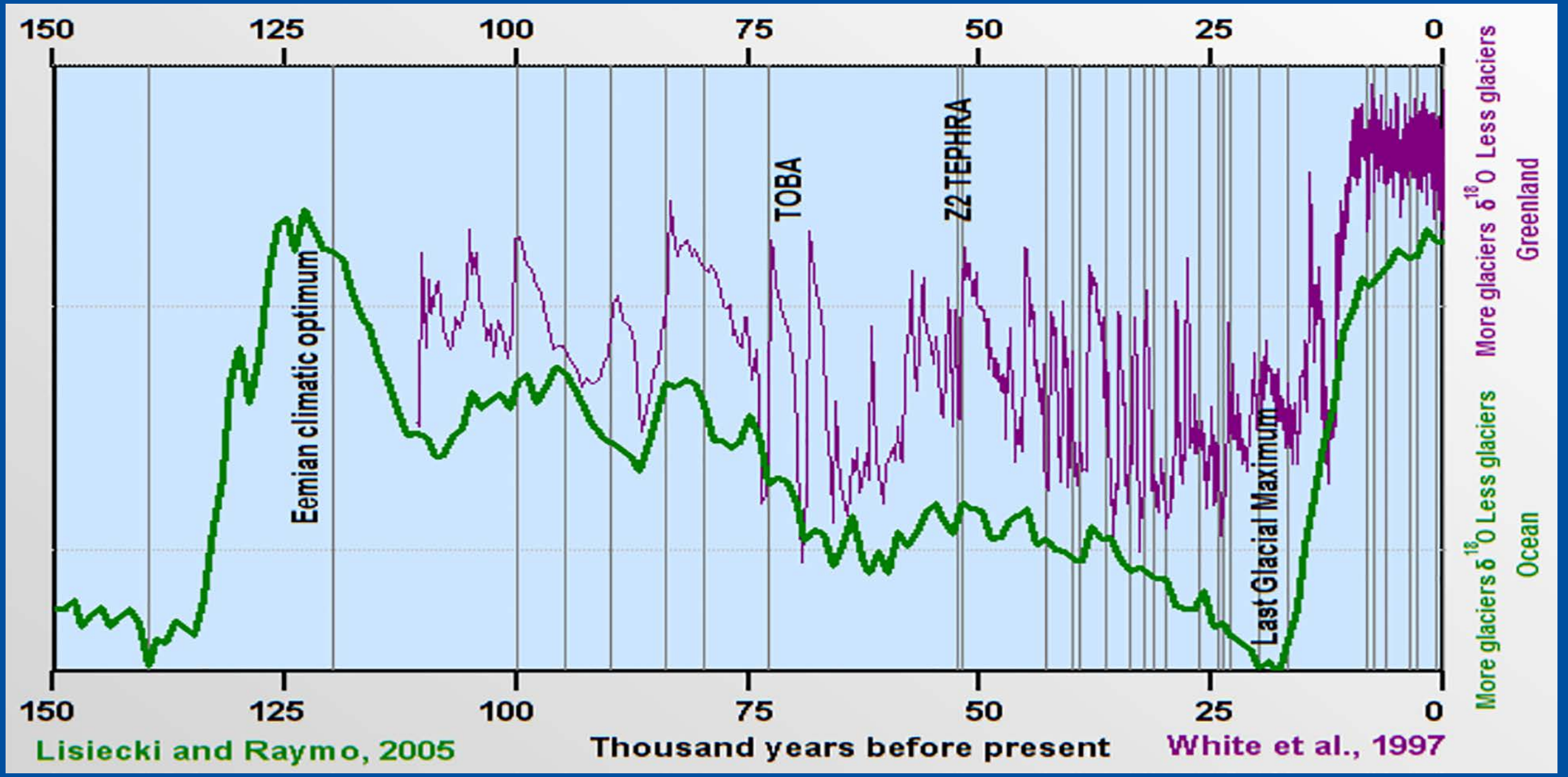


Gregory et al., 2006

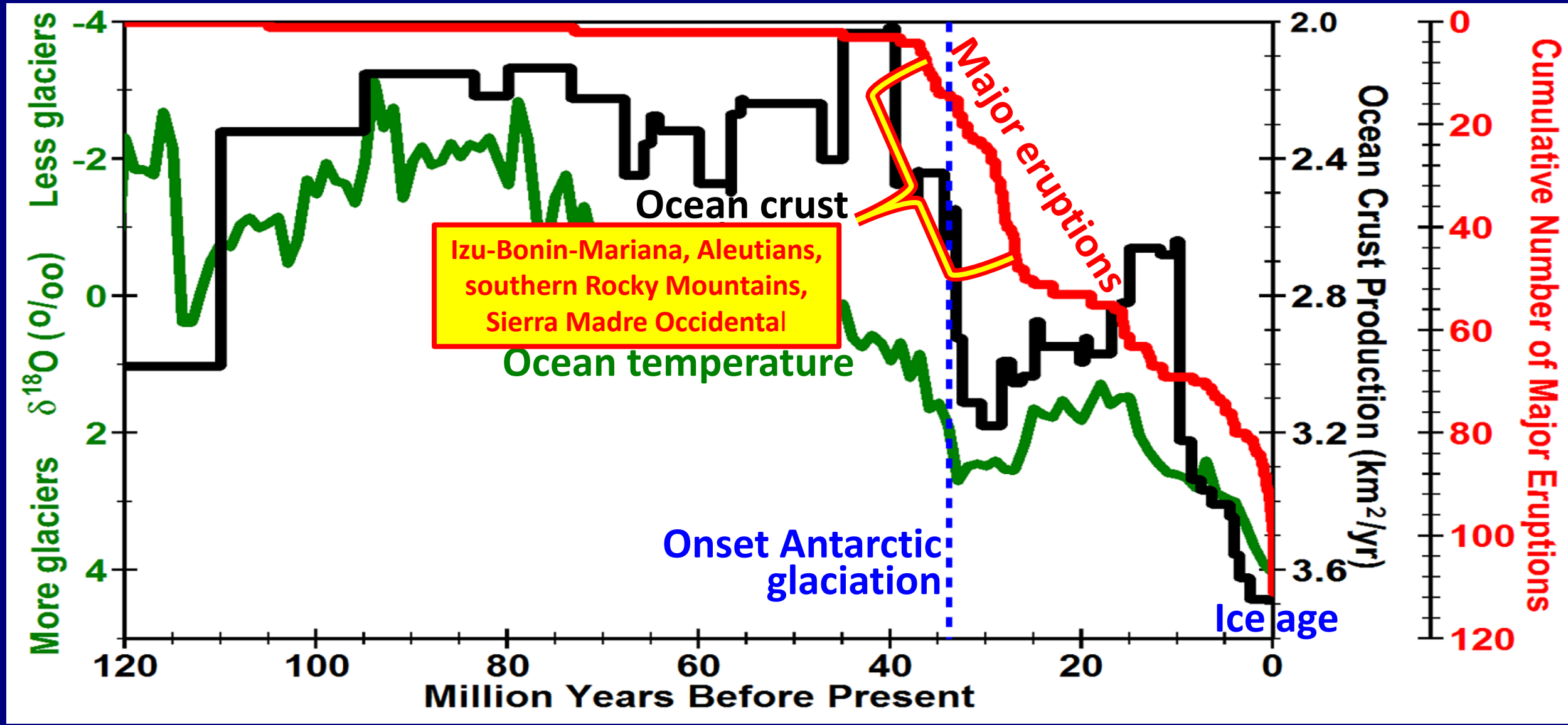
Stack of 57 globally distributed benthic δ O records



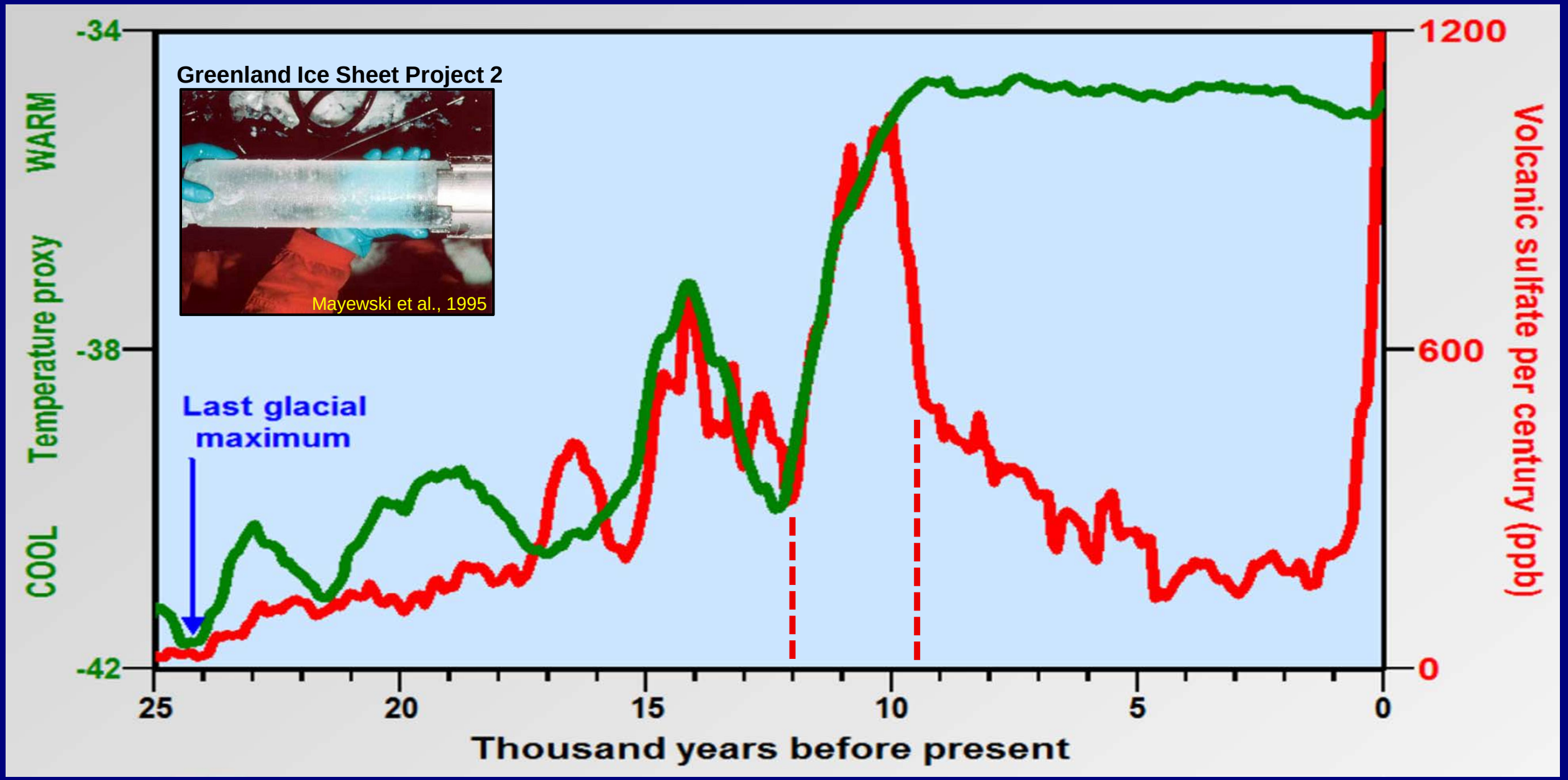
Greenland ice core $\delta^{18}O$ records



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

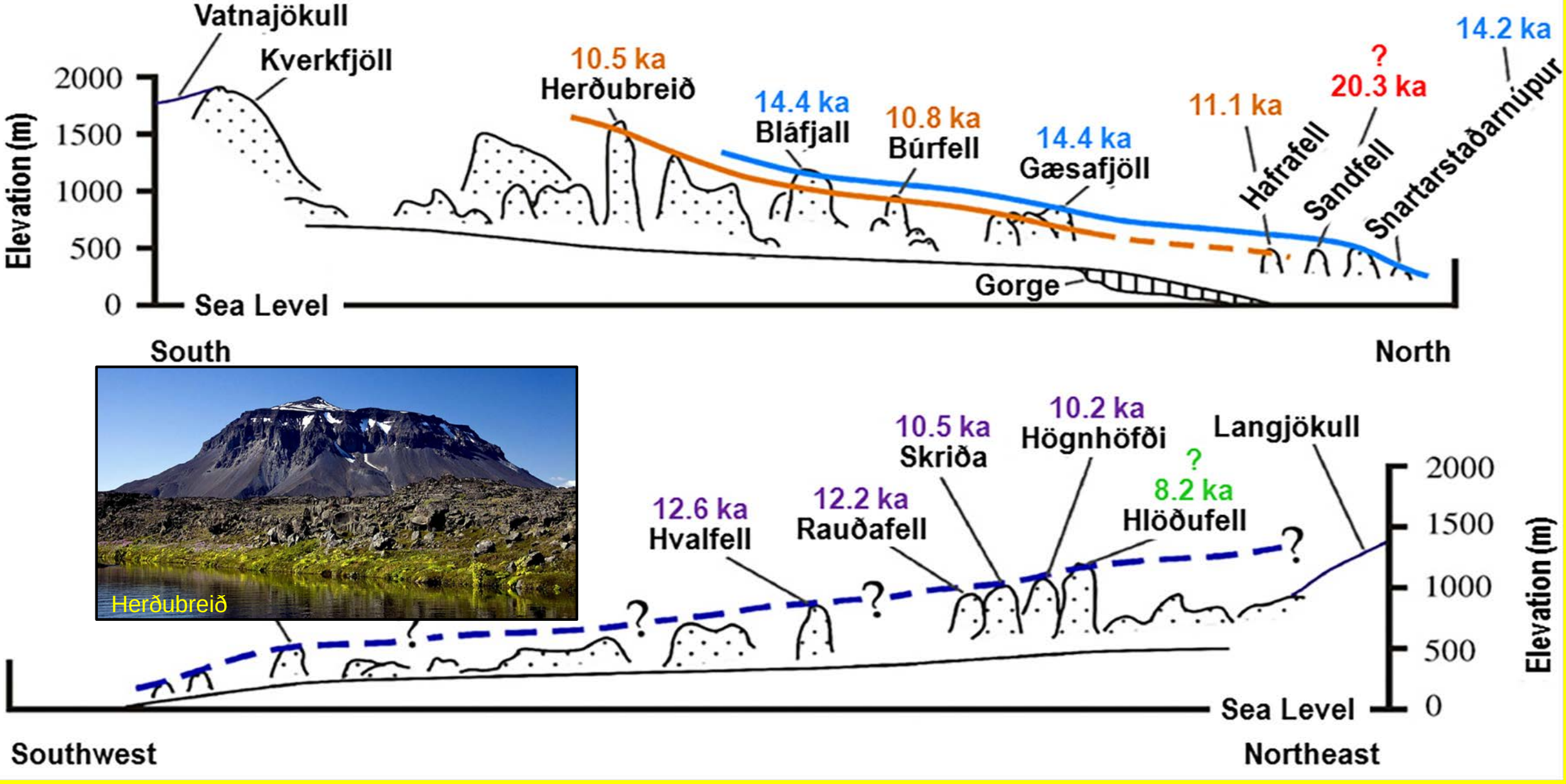


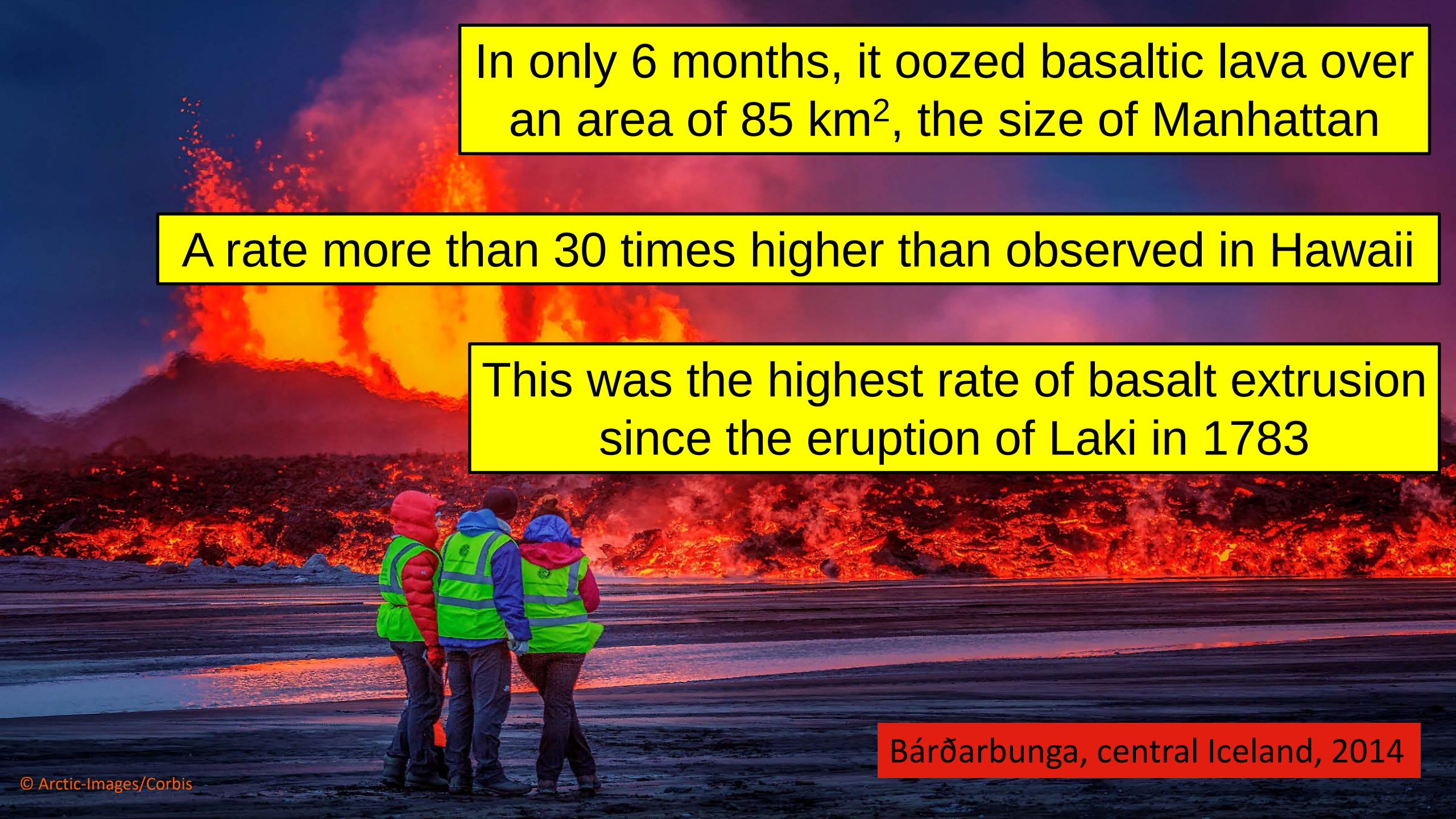
Basaltic volcanism warmed the world out of the last ice age



Zielinski et al., 1996

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

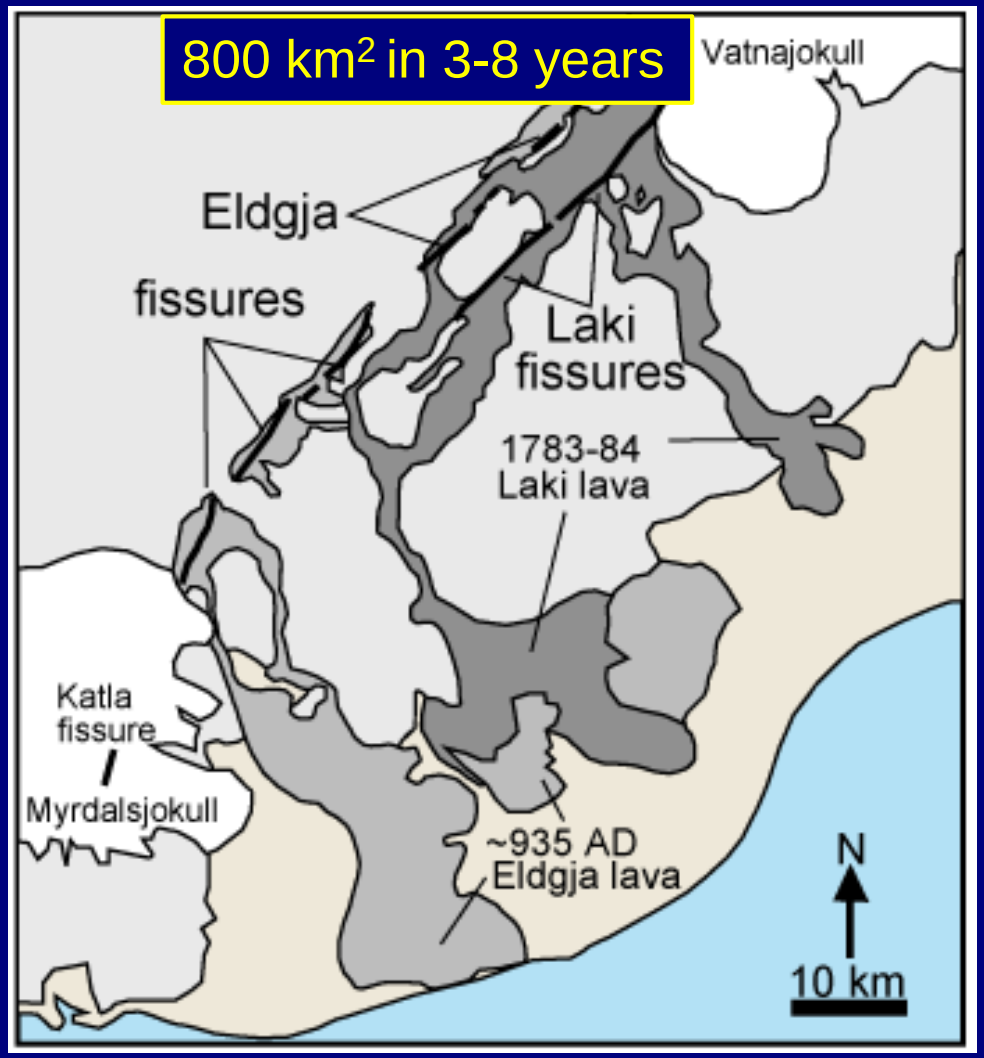



In only 6 months, it oozed basaltic lava over an area of 85 km^2, the size of Manhattan
A rate more than 30 times higher than observed in Hawaii
This was the highest rate of basalt extrusion since the eruption of Laki in 1783
Bárðarbunga, central Iceland, 2014
© Arctic-Images/Corbis

Laki 1783 (Iceland)

Temperatures in Europe raised 3.3°C, tens of thousands killed primarily by the effects of SO_2, sulfuric acid, and resulting famine

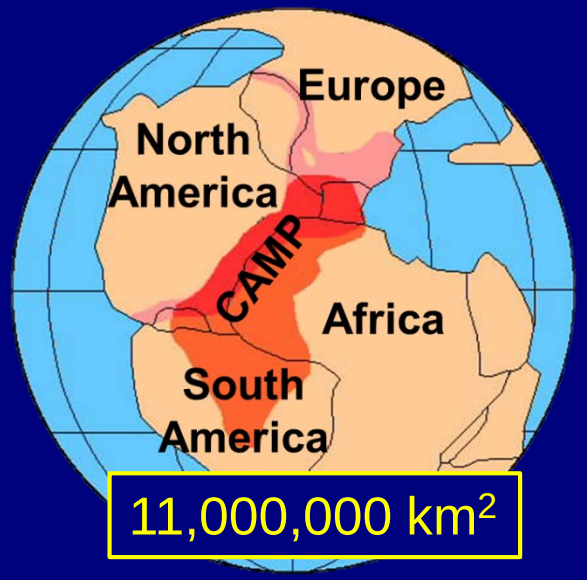
Eldgjá 935 (Iceland)

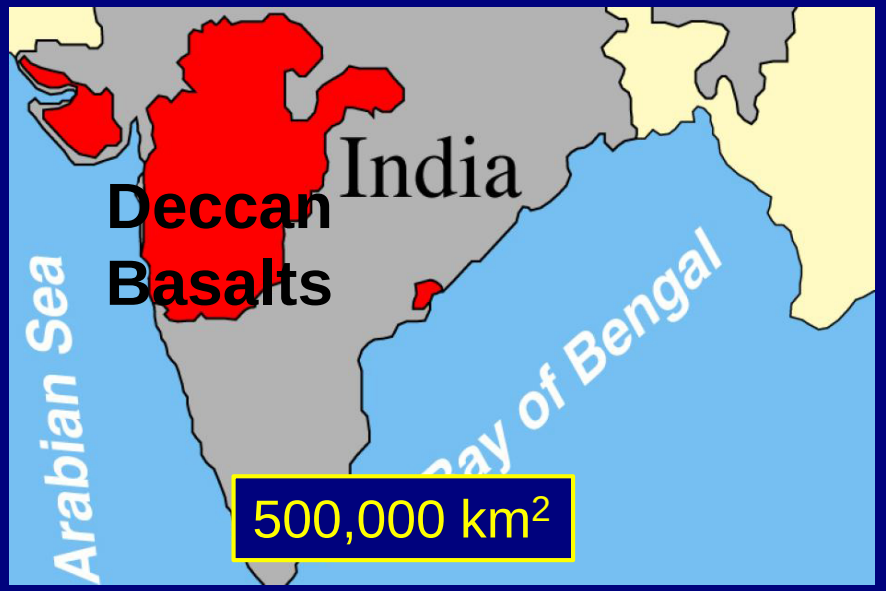


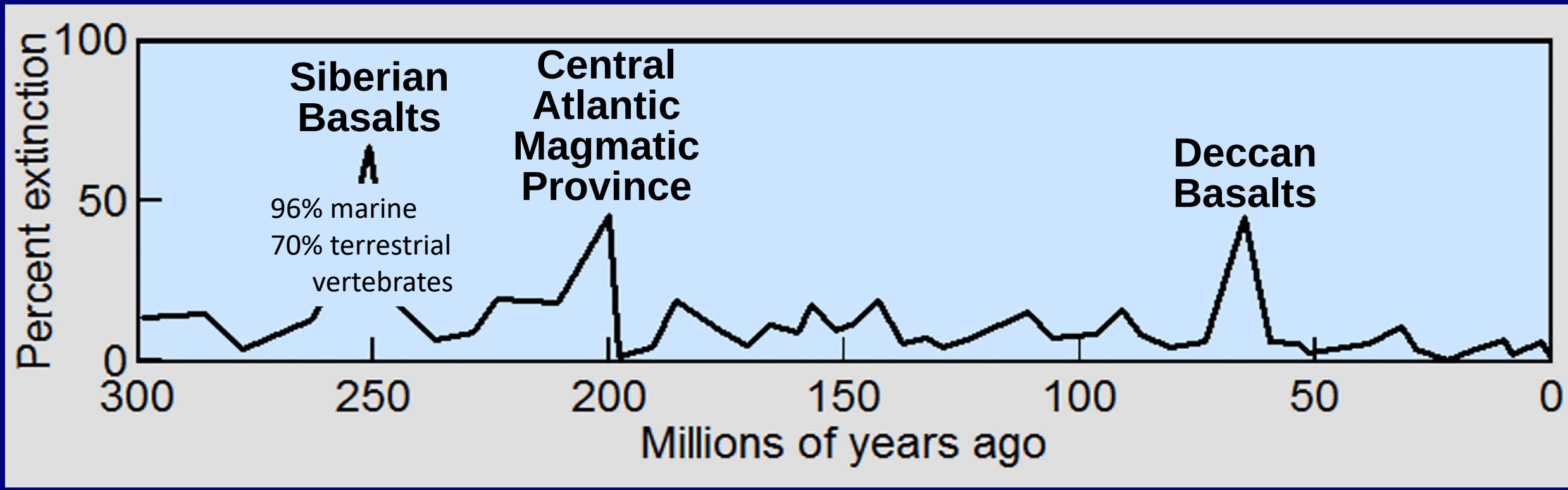
volcano.oregonstate.edu

Led to the onset of the Medieval Warm Period

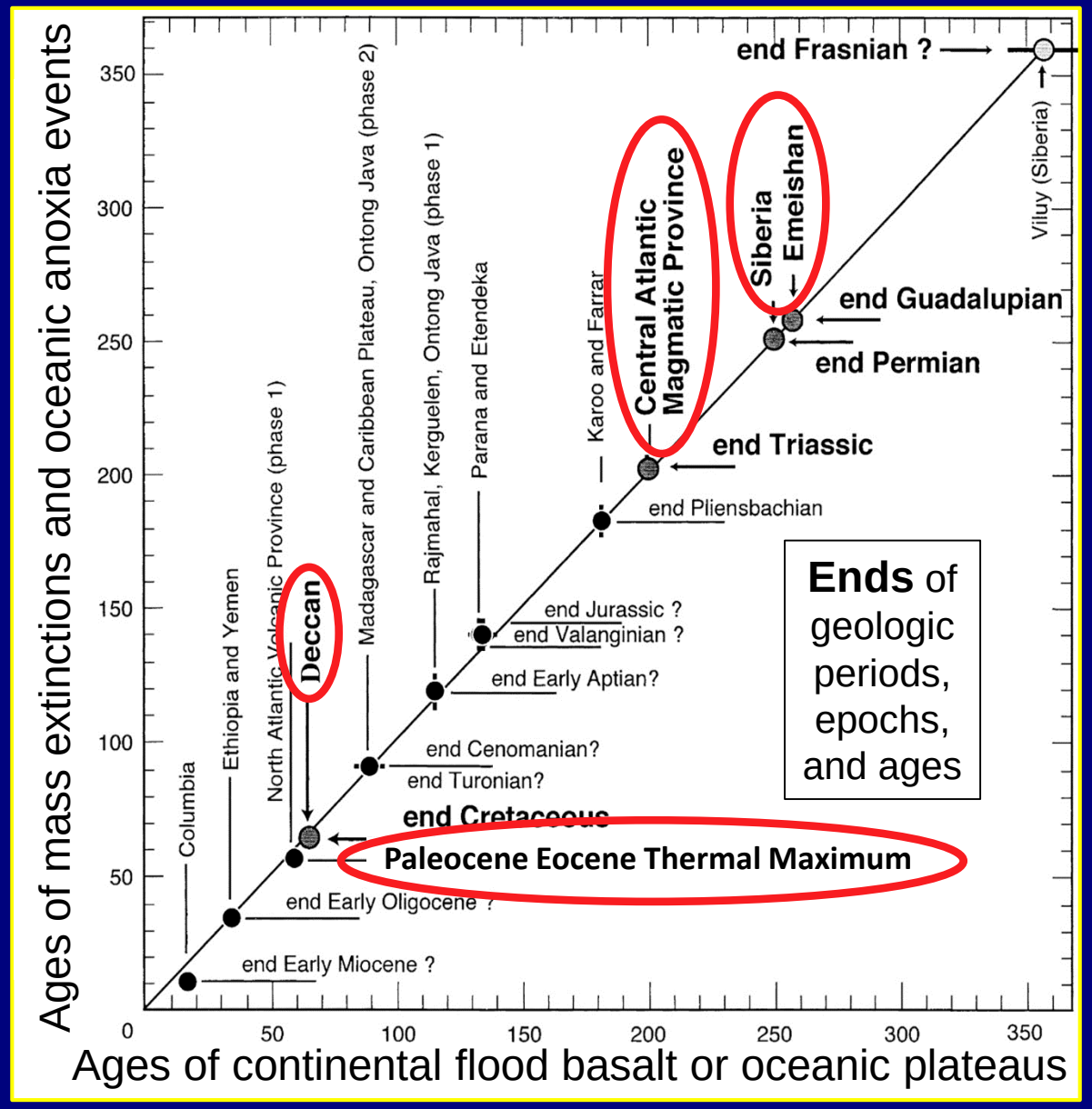

Arctic Ocean
Finland
Санкт-Петербург
Moscow
Волгоград
Caspian Sea
Sea of Okhotsk
Якутск
Lake Baikal
Siberian Basalts
7,000,000 km²


Europe
North America
CAMP
Africa
South America
11,000,000 km²


India
Deccan Basalts
Arabian Sea
Bay of Bengal
500,000 km²


Percent extinction
100
50
0
Siberian Basalts
96% marine
70% terrestrial vertebrates
Central Atlantic Magmatic Province
Deccan Basalts
300
250
200
150
100
50
0
Millions of years ago

Extinctions Versus Flood Basalts

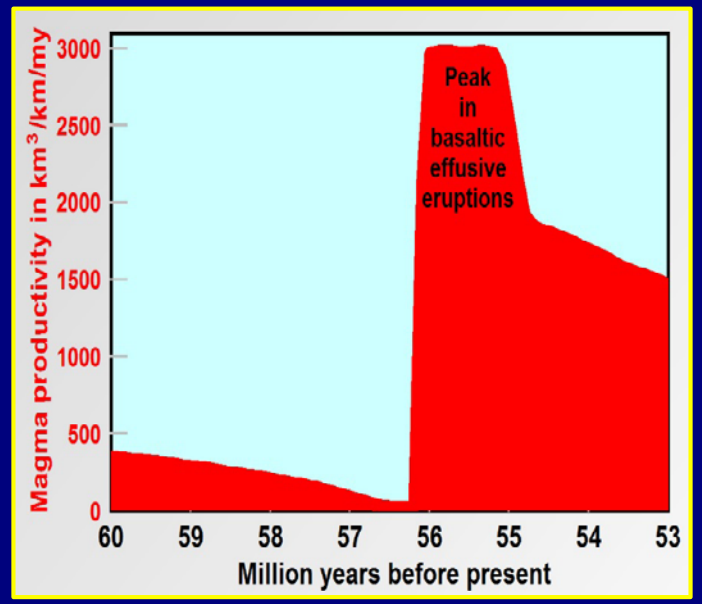


Courtillot and Renne 2003

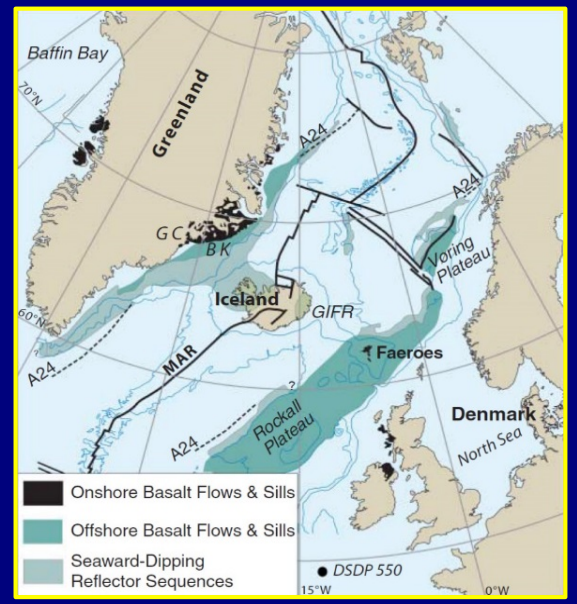
Paleocene Eocene Thermal Maximum

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

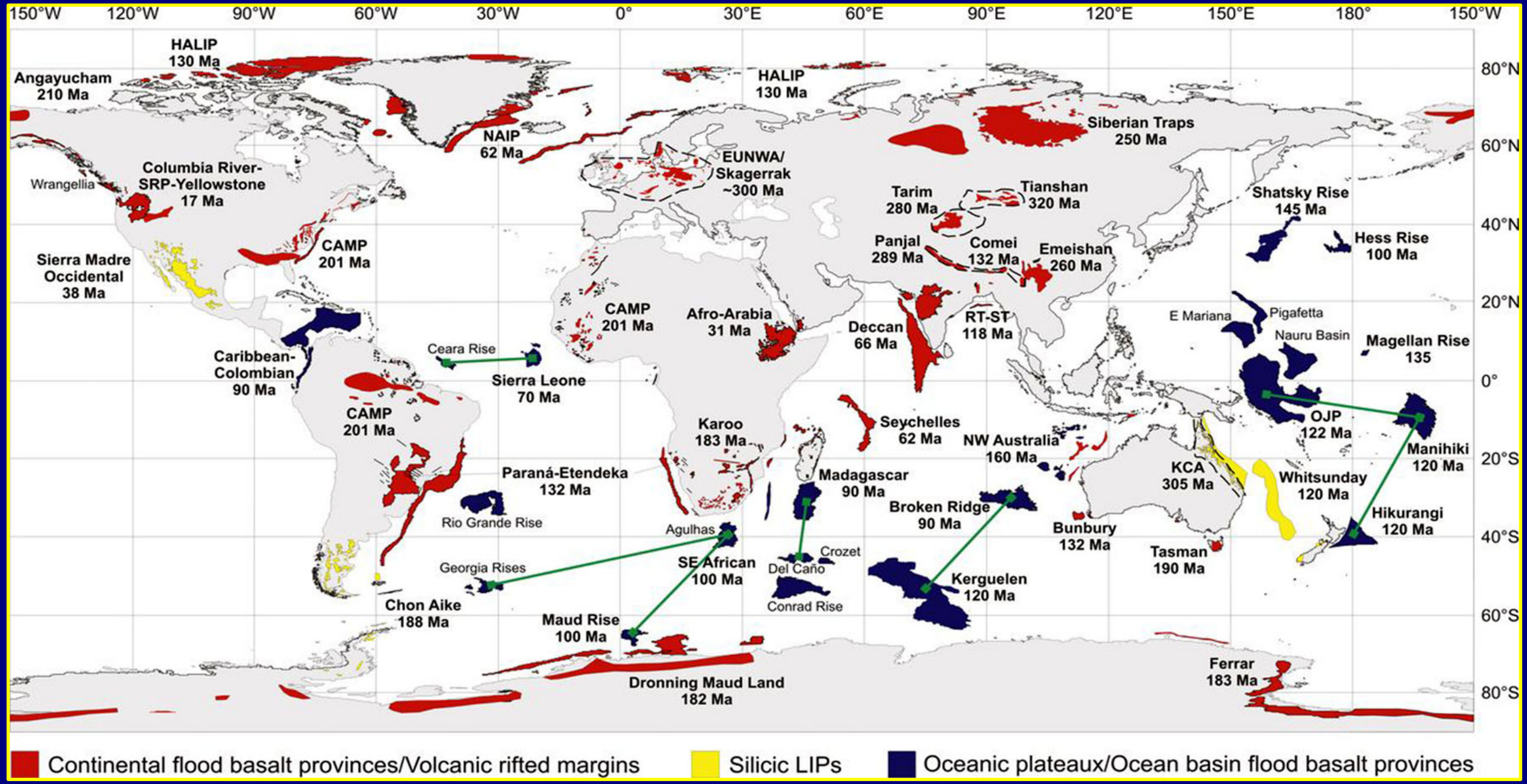
Sea surface temperatures rose 6°C

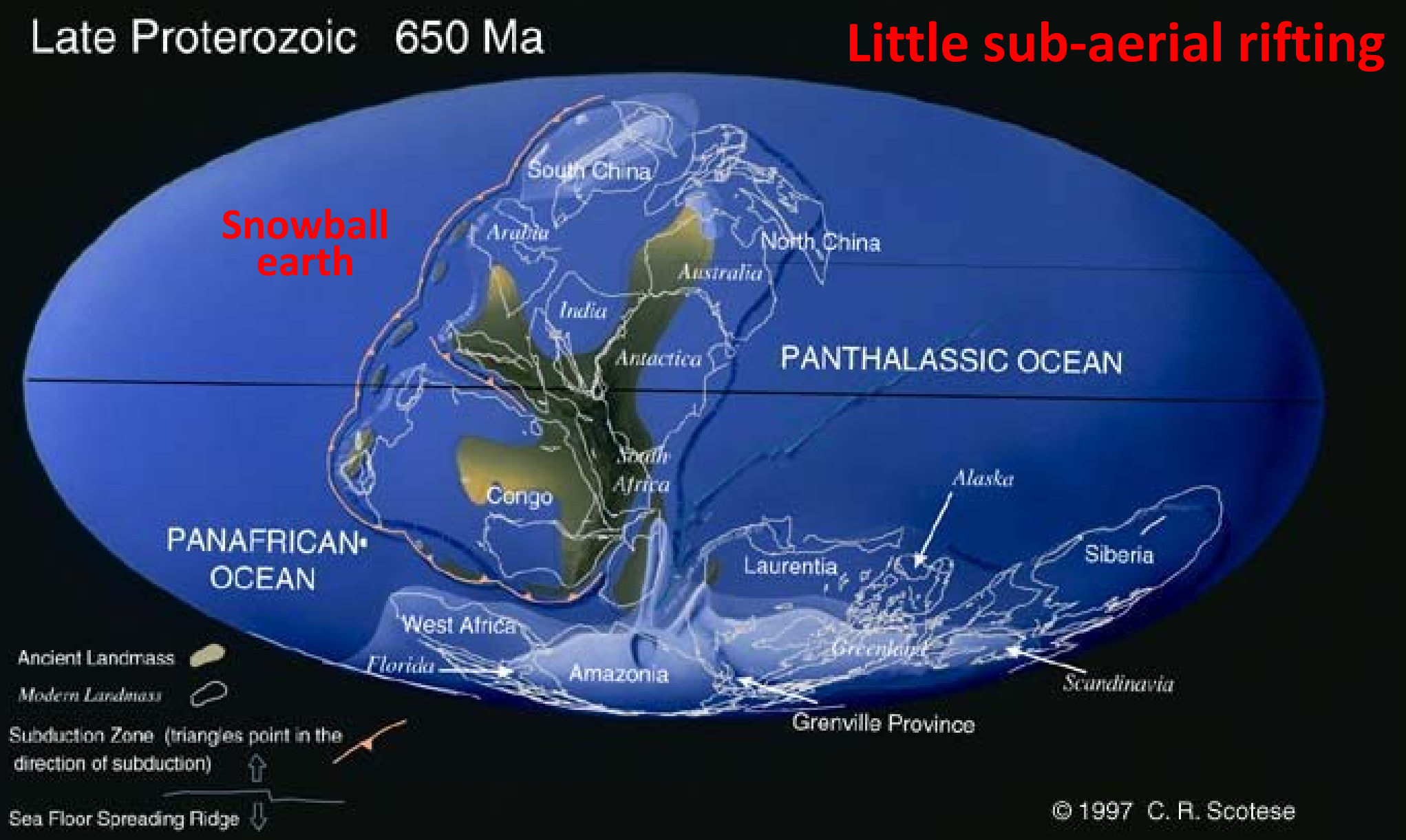


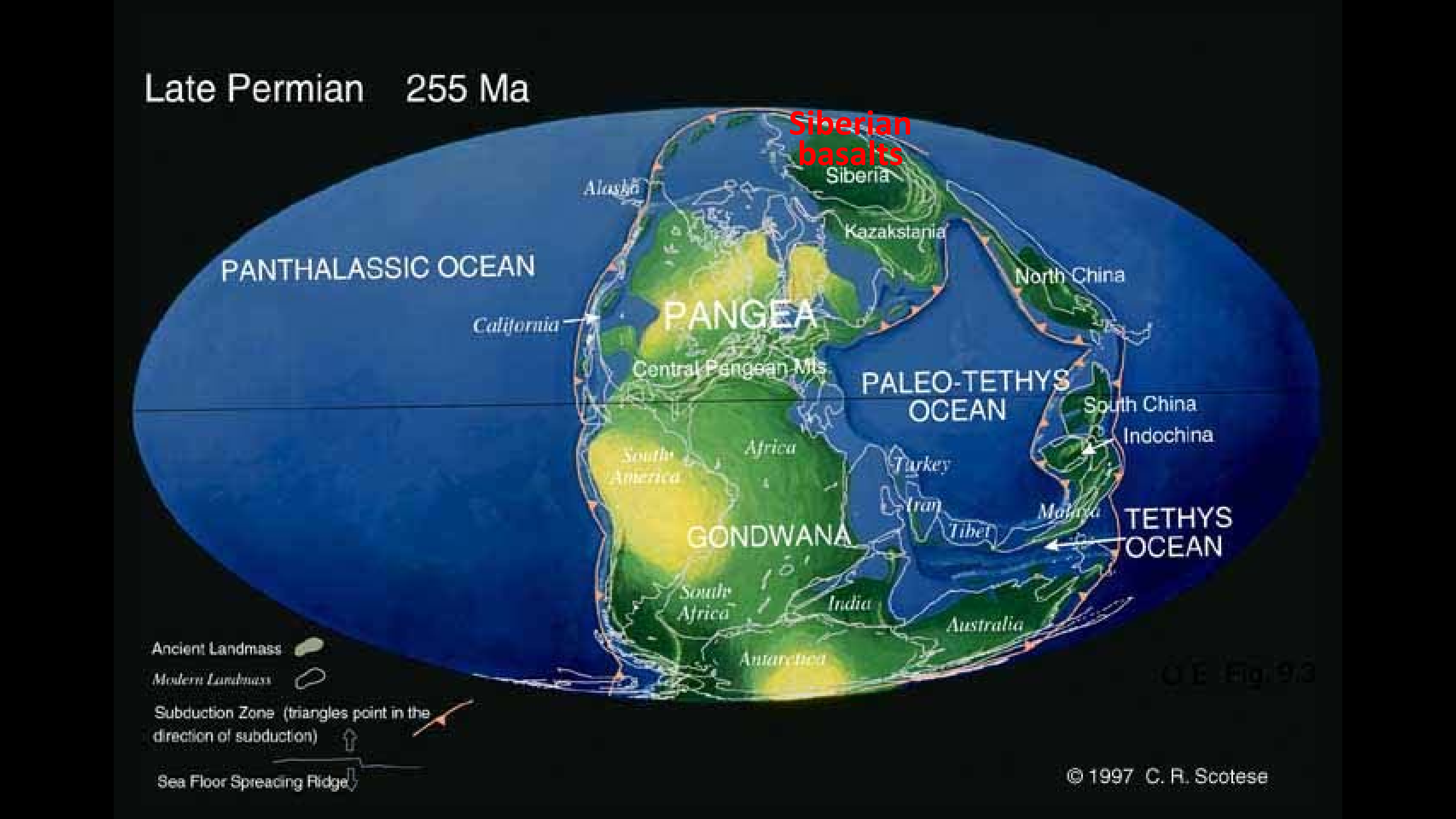
Storey et al. 2007

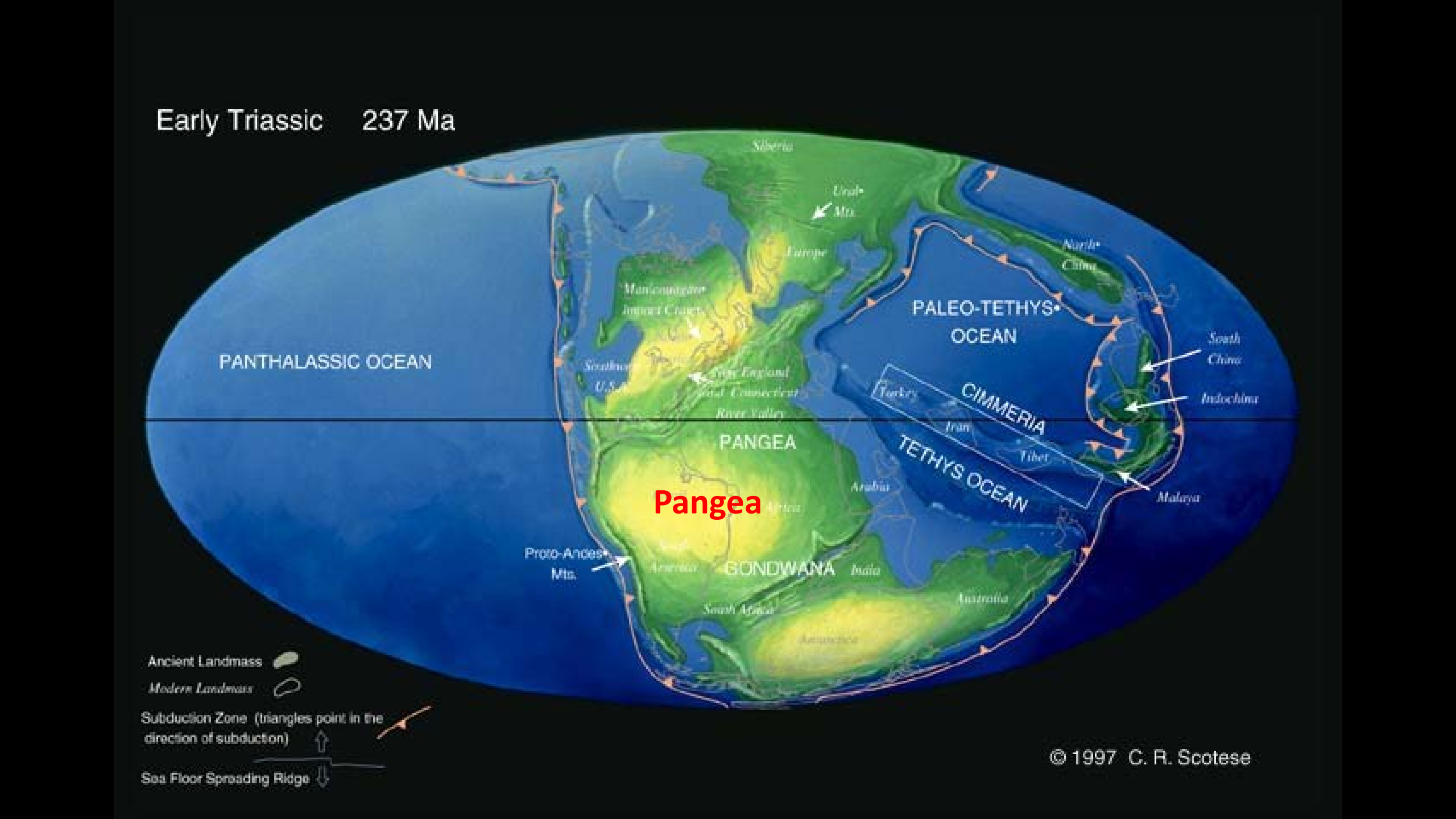


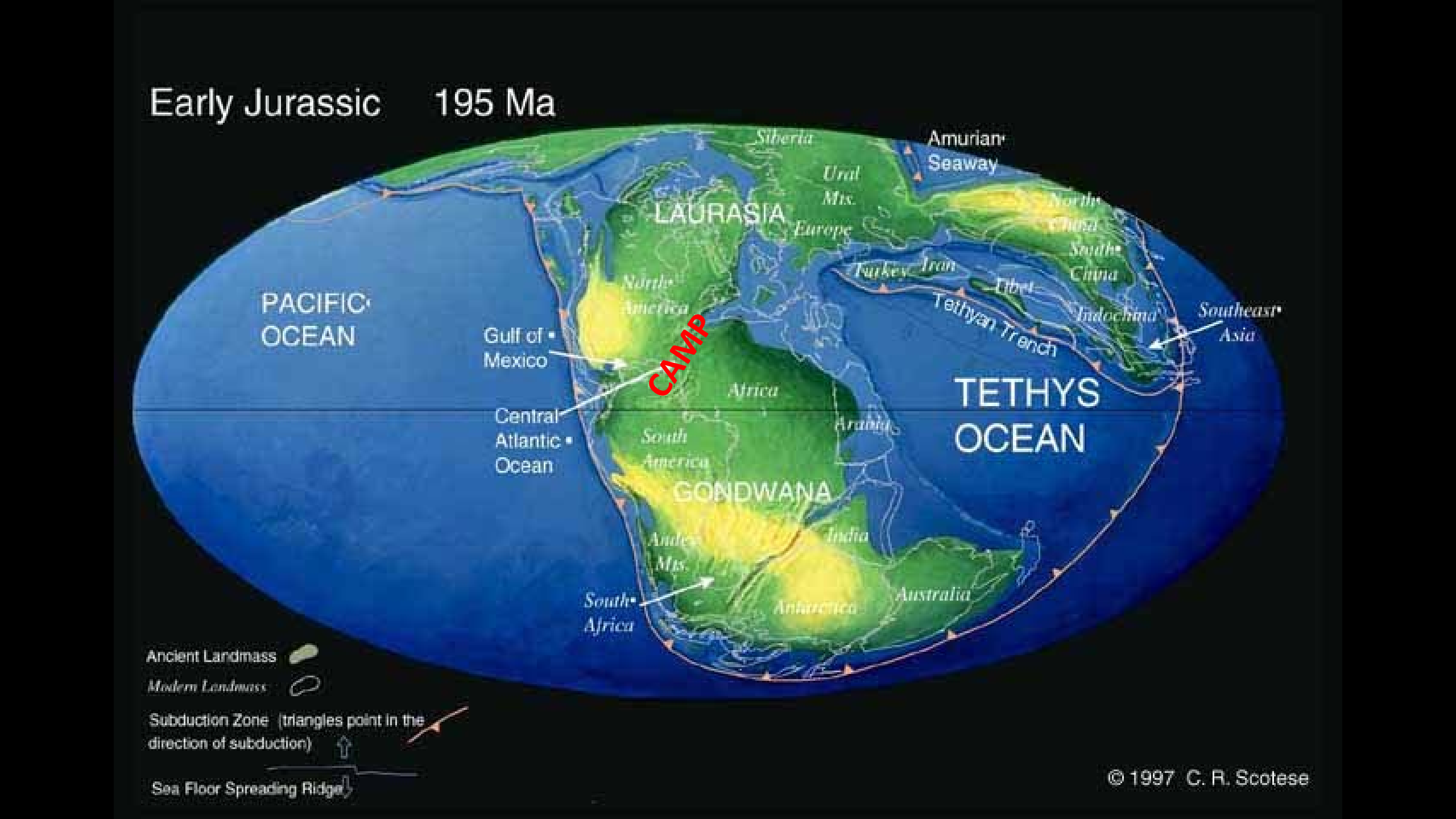
More than 211 LIPs have been identified

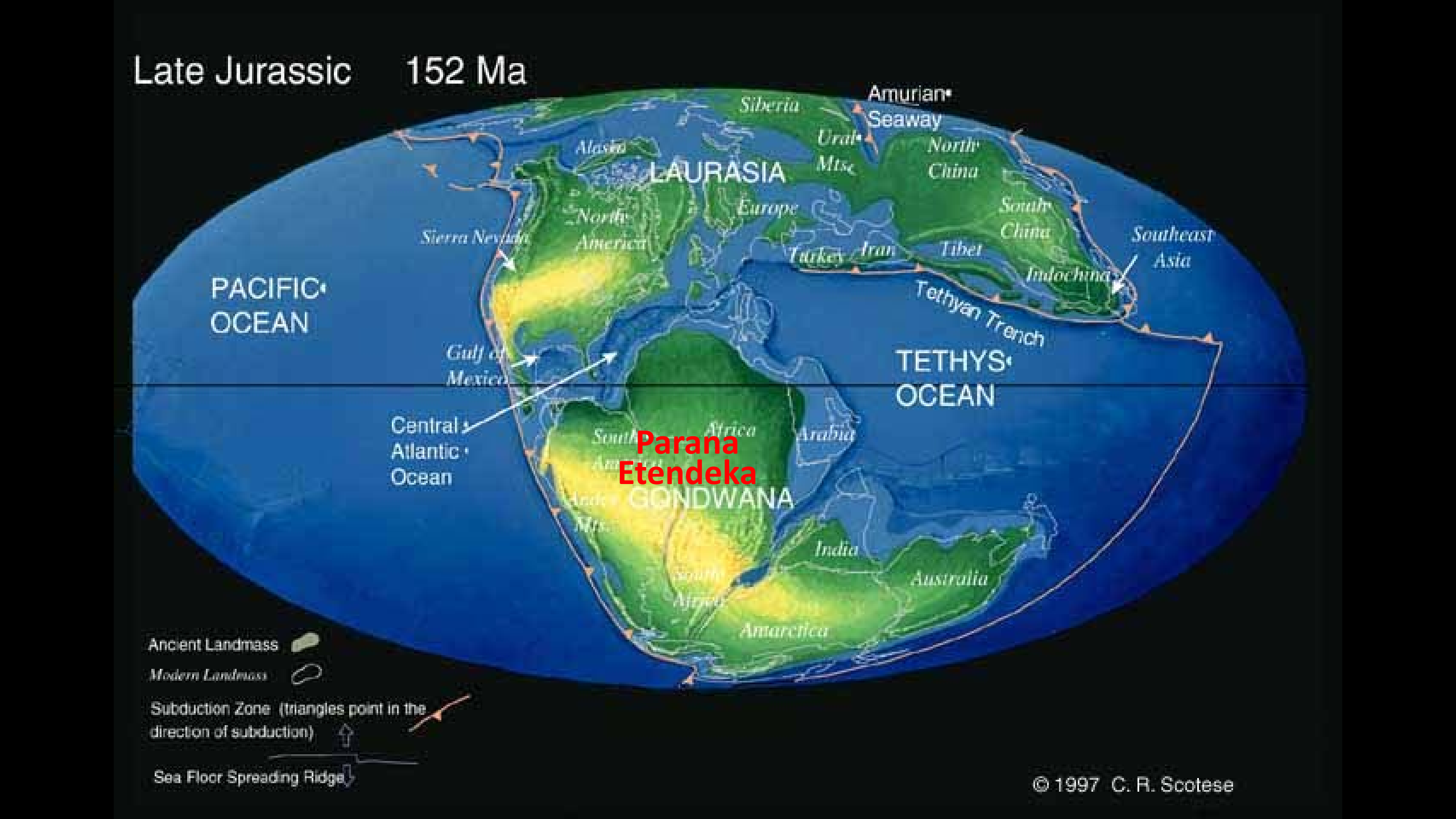


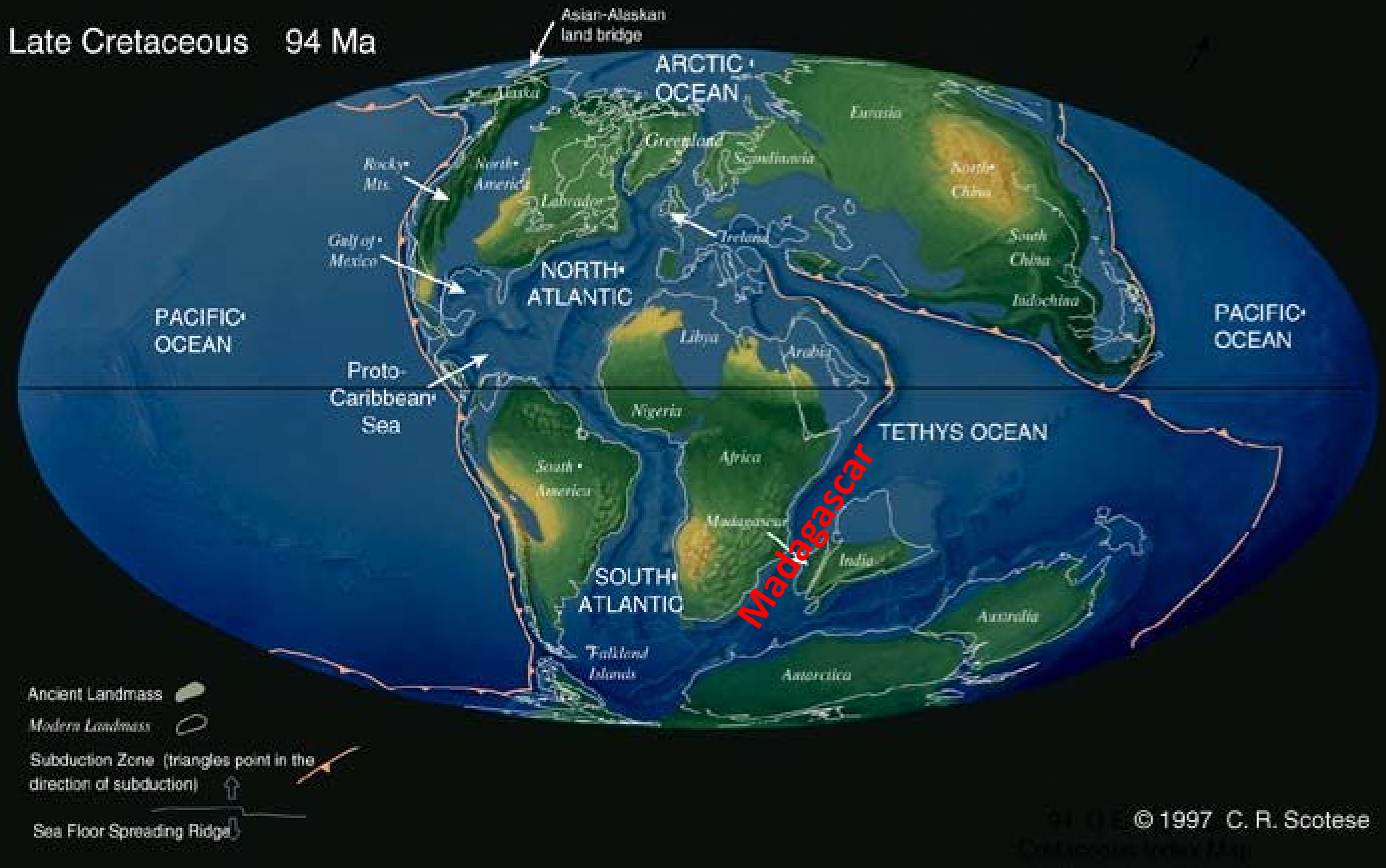

Late Proterozoic 650 Ma
Little sub-aerial rifting
Snowball earth
South China
Arabia
North China
Australia
India
Antarctica
PANTHALASSIC OCEAN
South Africa
Congo
Alaska
PANAFRICAN OCEAN
Laurentia
Siberia
West Africa
Florida
Amazonia
Greenland
Scandinavia
Grenville Province
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
© 1997 C. R. Scotese


Late Permian 255 Ma
Siberian basalts
Siberia
Alaska
Kazakstania
North China
PANTHALASSIC OCEAN
California
PANGEA
Central Pangean Mts
PALEO-TETHYS OCEAN
South China
Indochina
South America
Africa
Turkey
Iran
Malaya
Tibet
TETHYS OCEAN
GONDWANA
South Africa
India
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
© 1997 C. R. Scotese


Early Triassic 237 Ma
PANTHALASSIC OCEAN
PALEO-TETHYS OCEAN
CIMMERIA
TETHYS OCEAN
PANGEA
GONDWANA
Pangea
Siberia
Ural Mts.
Europe
North China
South China
Indochina
Malaya
Iran
Tibet
Arabia
India
Australia
Proto-Andes Mts.
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
© 1997 C. R. Scotese


Early Jurassic 195 Ma
Siberia
Amurian Seaway
Ural Mts.
LAURASIA
Europe
North China
South China
Turkey
Iran
Tibet
Indochina
Southeast Asia
PACIFIC OCEAN
North America
Gulf of Mexico
CAMP
Tethyan Trench
Africa
TETHYS OCEAN
Central Atlantic Ocean
Arabia
South America
GONDWANA
India
Andes Mts.
South Africa
Antarctica
Australia
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
© 1997 C. R. Scotese


Late Jurassic 152 Ma
Siberia
Amurian Seaway
Ural Mts
Alaska
LAURASIA
North China
South China
Southeast Asia
Indochina
Europe
North America
Sierra Nevada
Turkey
Iran
Tibet
PACIFIC OCEAN
Tethyan Trench
TETHYS OCEAN
Gulf of Mexico
Central Atlantic Ocean
Africa
Arabia
Parana
Etendeka
GONDWANA
India
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
© 1997 C. R. Scotese


Late Cretaceous 94 Ma
Asian-Alaskan land bridge
ARCTIC OCEAN
Alaska
Eurasia
Greenland
Scandinavia
North China
Rocky Mts.
North America
Labrador
Ireland
South China
Gulf of Mexico
NORTH ATLANTIC
Indochina
PACIFIC OCEAN
PACIFIC OCEAN
Libya
Arabia
Proto-Caribbean Sea
Nigeria
TETHYS OCEAN
Africa
South America
Madagascar
India
SOUTH ATLANTIC
Australia
Falkland Islands
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
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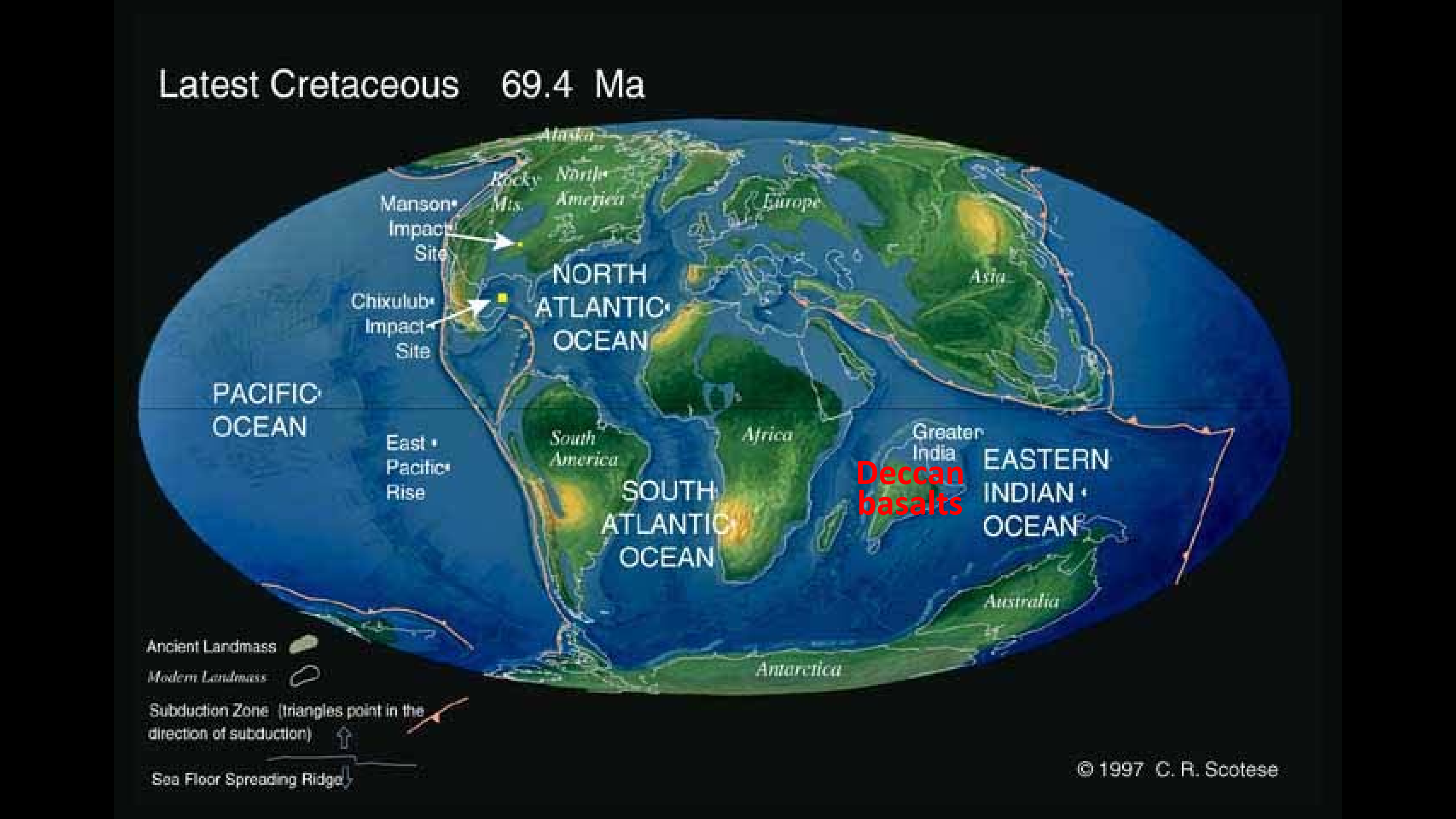
Latest Cretaceous 69.4 Ma
Alaska
Rocky Mts.
North America
Europe
Manson Impact Site
Chixulub Impact Site
NORTH ATLANTIC OCEAN
Asia
PACIFIC OCEAN
East Pacific Rise
South America
Africa
Greater India
Deccan basalts
EASTERN INDIAN OCEAN
SOUTH ATLANTIC OCEAN
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
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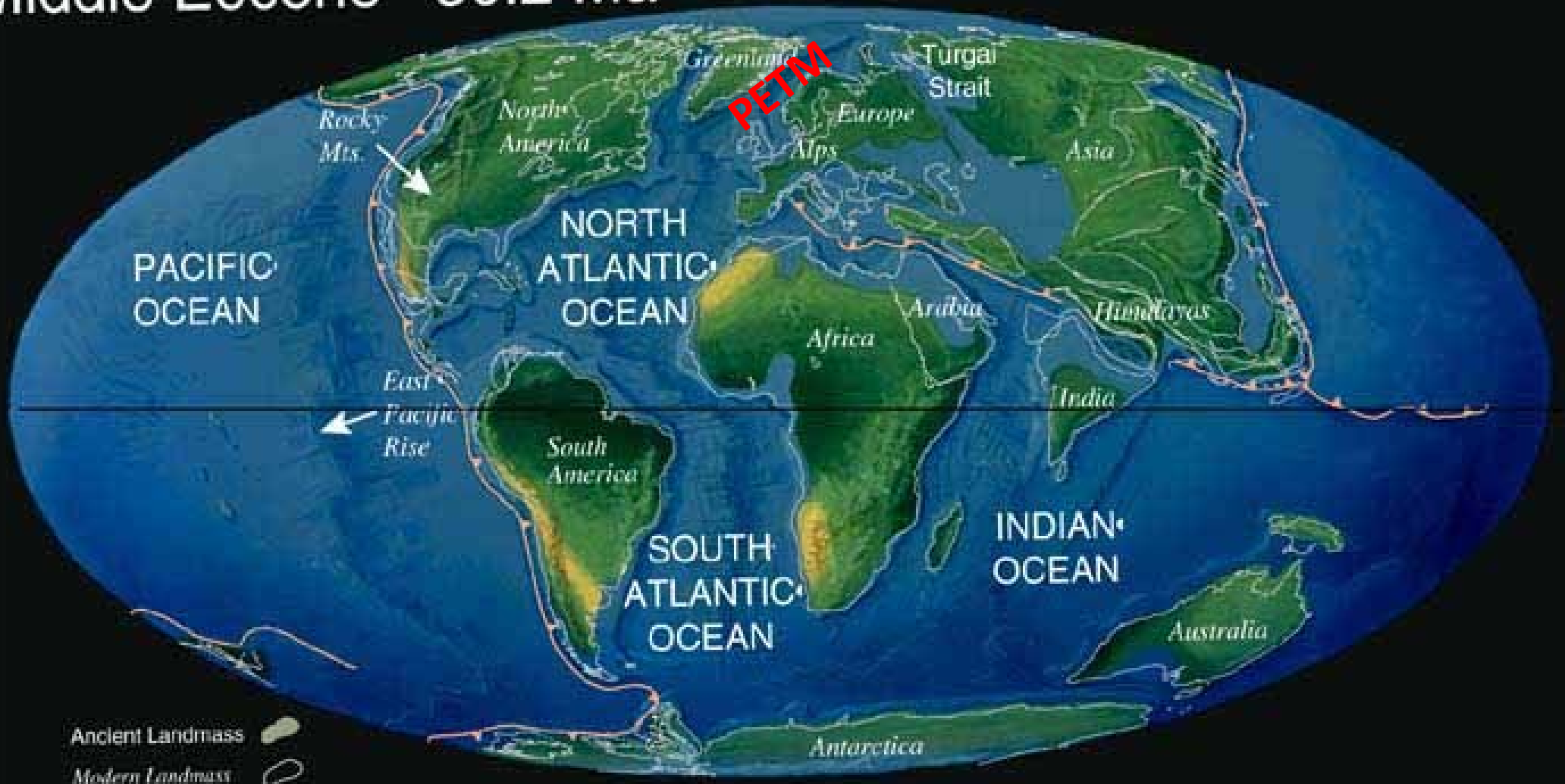
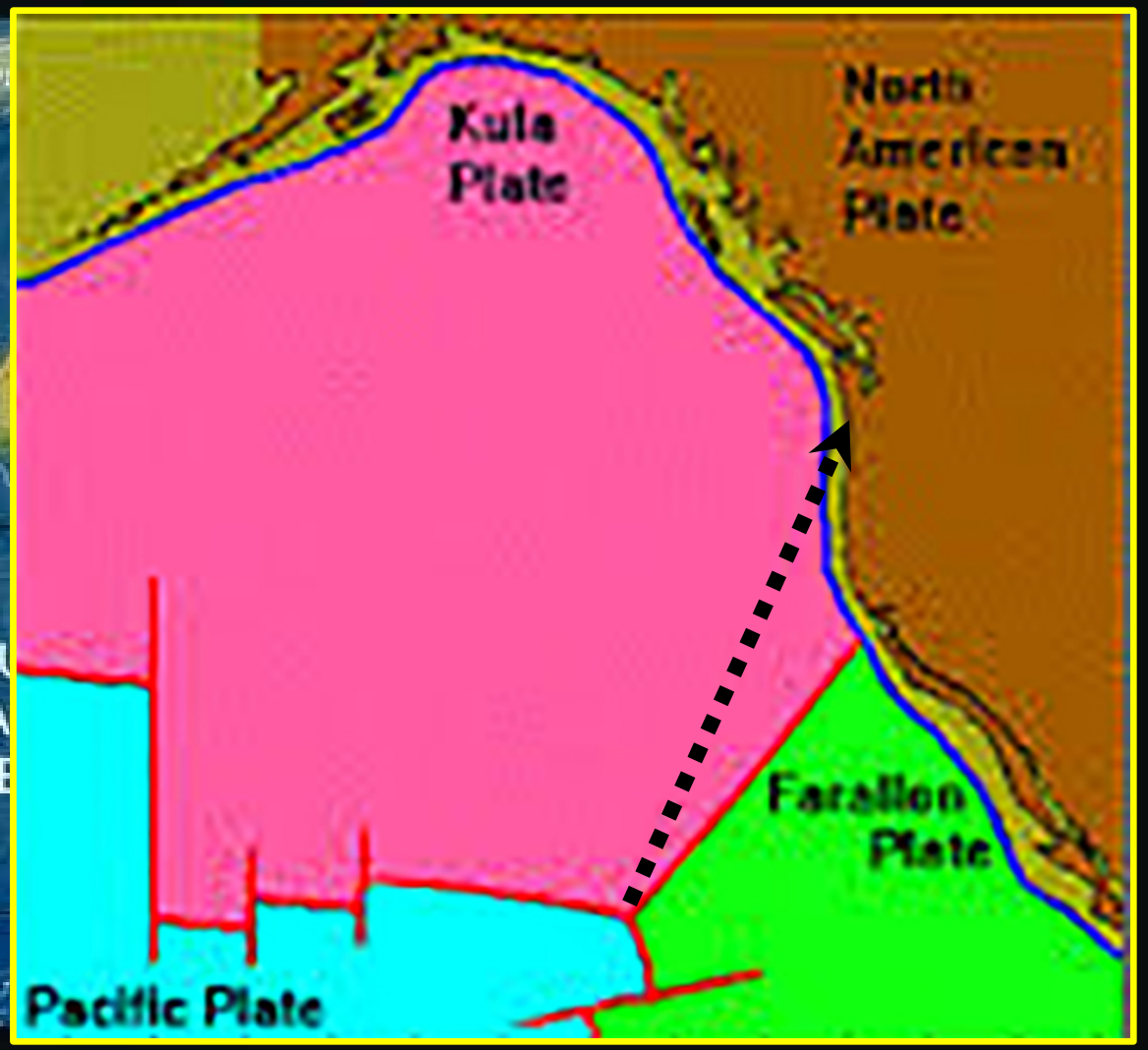
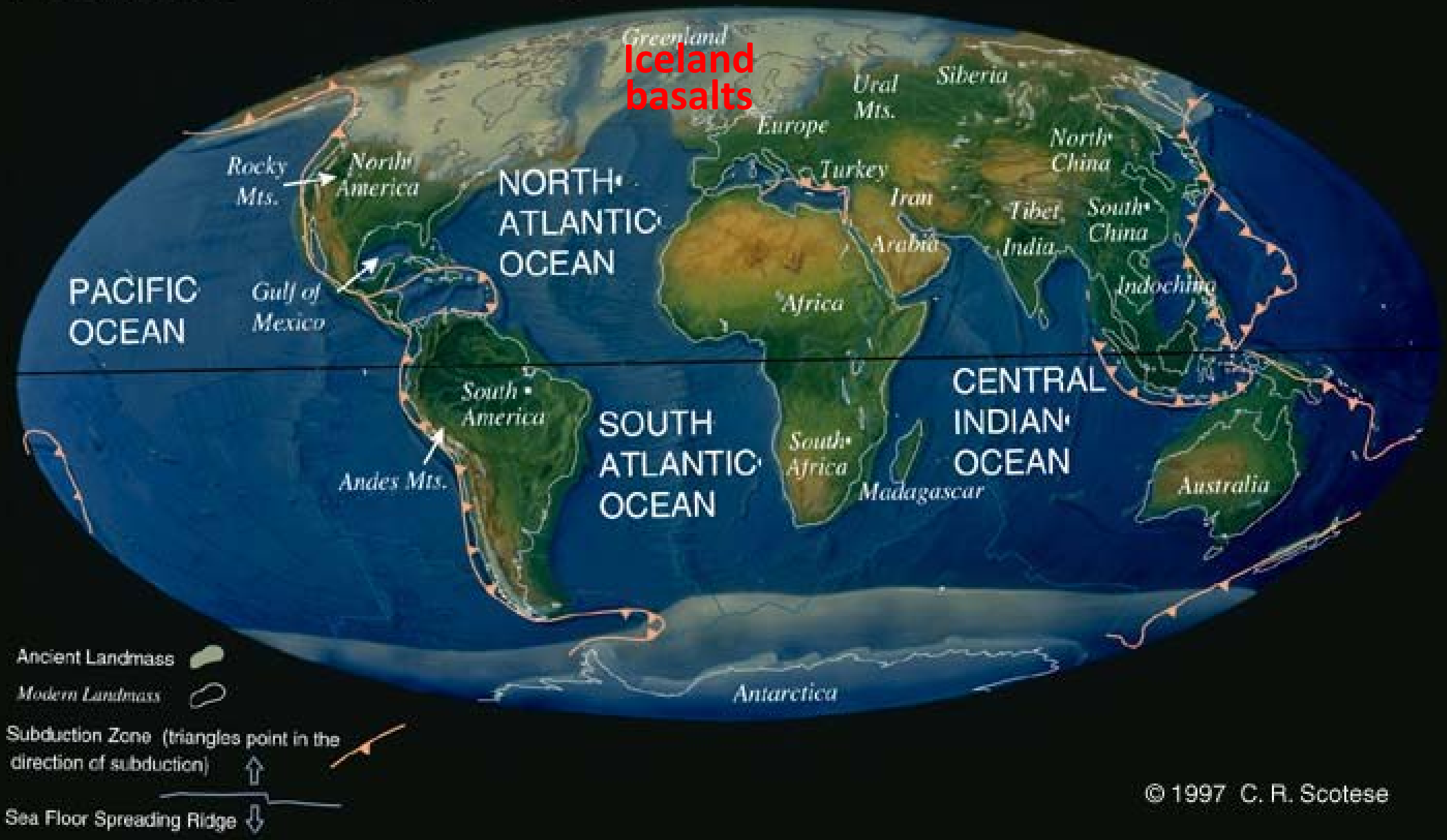
Middle Eocene 50.2 Ma



Middle Miocene 14 Ma




Pleistocene 18,000 years ago
Iceland basalts
Greenland
Ural Mts.
Siberia
Europe
North China
Rocky Mts.
North America
NORTH ATLANTIC OCEAN
Turkey
Iran
Tibet
South China
Arabia
India
PACIFIC OCEAN
Gulf of Mexico
Africa
Indochina
CENTRAL INDIAN OCEAN
South America
SOUTH ATLANTIC OCEAN
South Africa
Madagascar
Australia
Andes Mts.
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge
© 1997 C. R. Scotese

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 SO_2 and H_2S)

Cause major mass extinctions especially when lasting for long periods

Bárðarbunga largest since 1783—explains why 2016 hottest year

Rapid Warming

Incremental Cooling

Effusive

rift-related

Minimal aerosols

Duration >months

Explosive

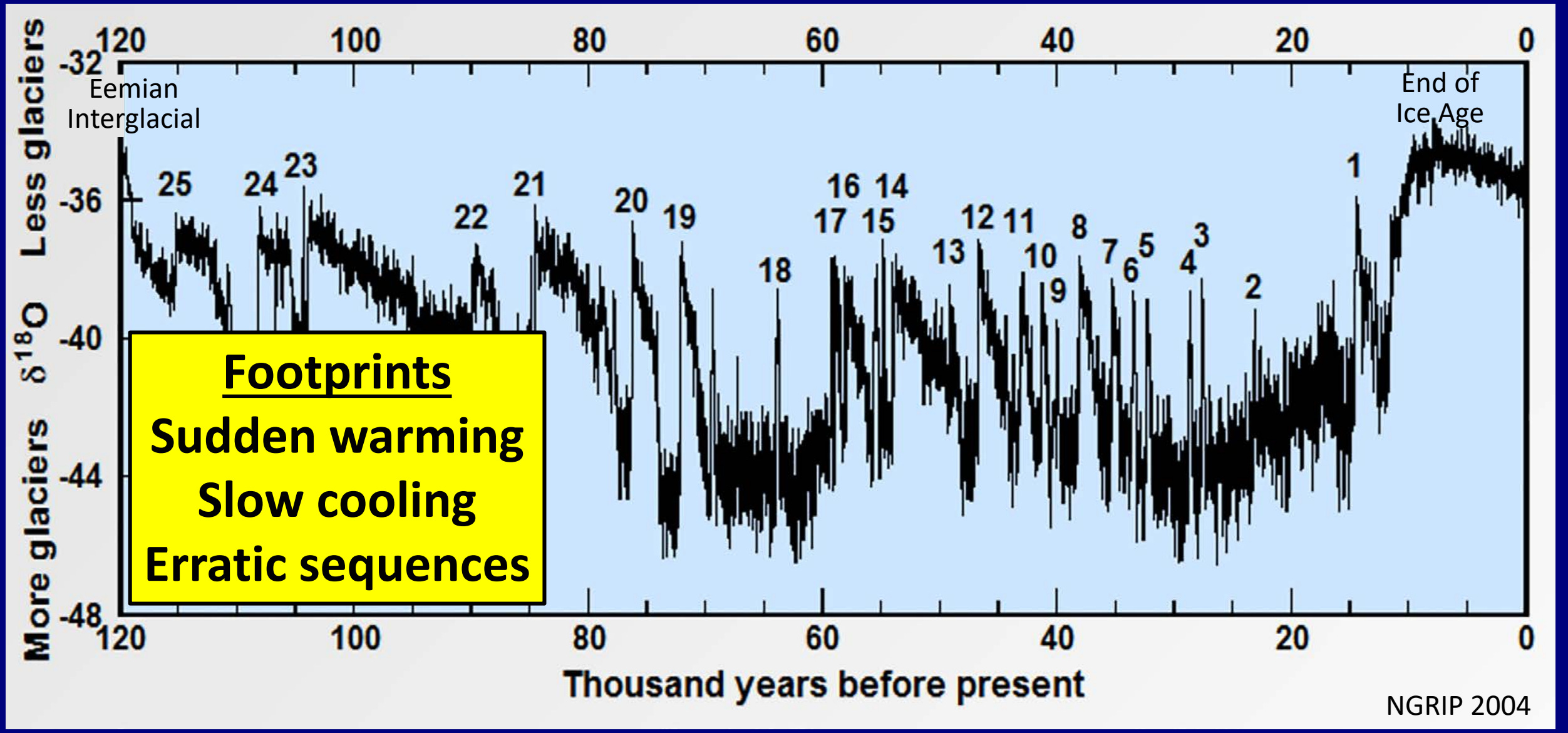
subduction-related

Extensive aerosols

Frequency per century

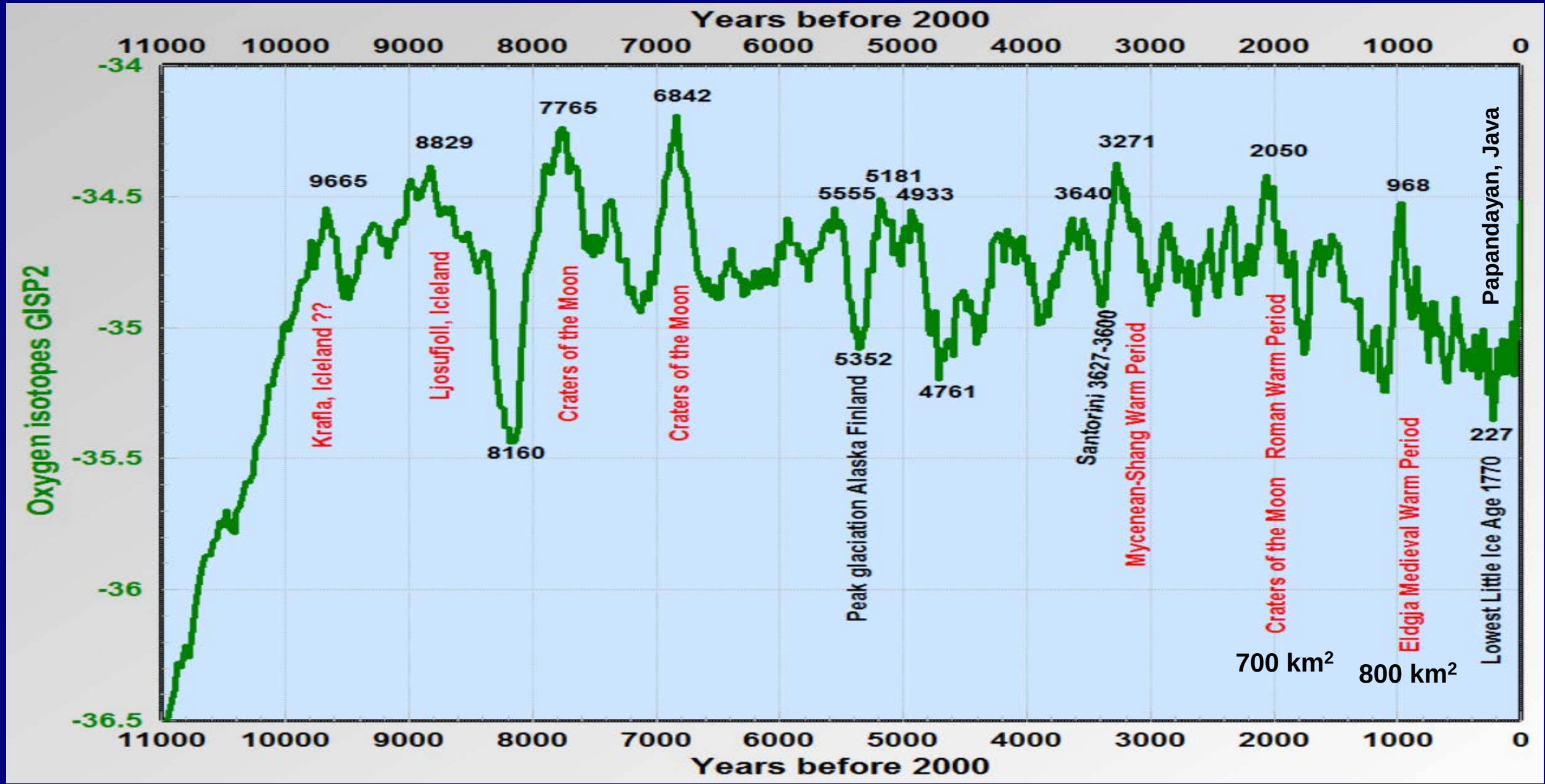
Erratic sequences of rapid warming followed by slower cooling

Dansgaard-Oeschger events observed in Greenland ice



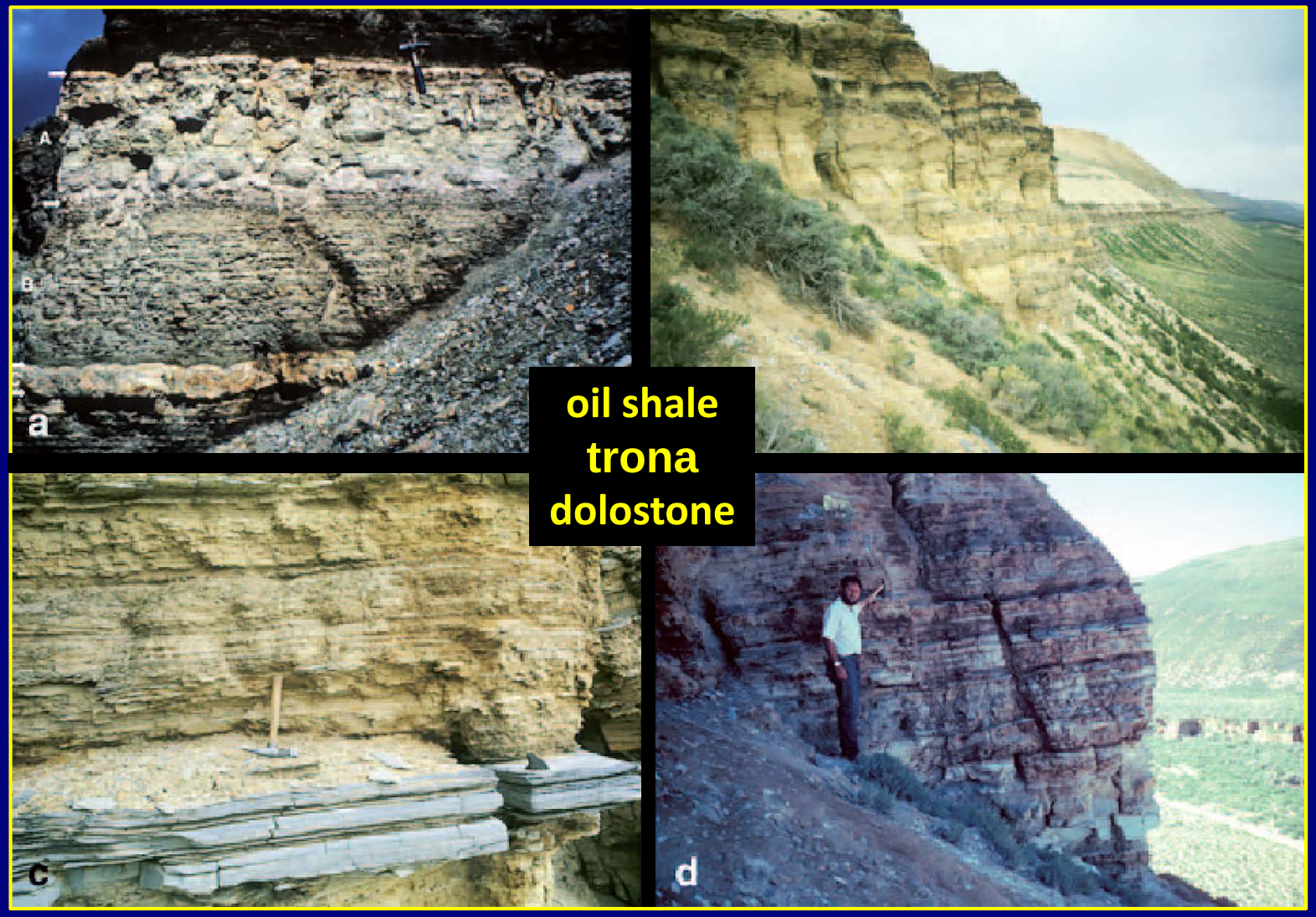
NGRIP 2004

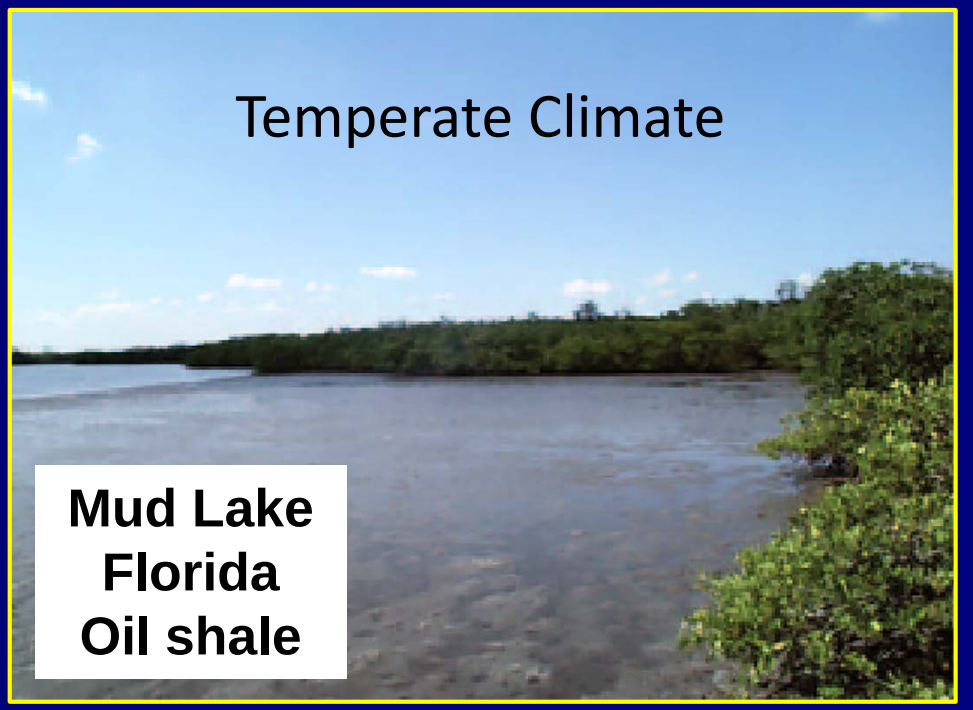
Holocene temperatures and volcanism

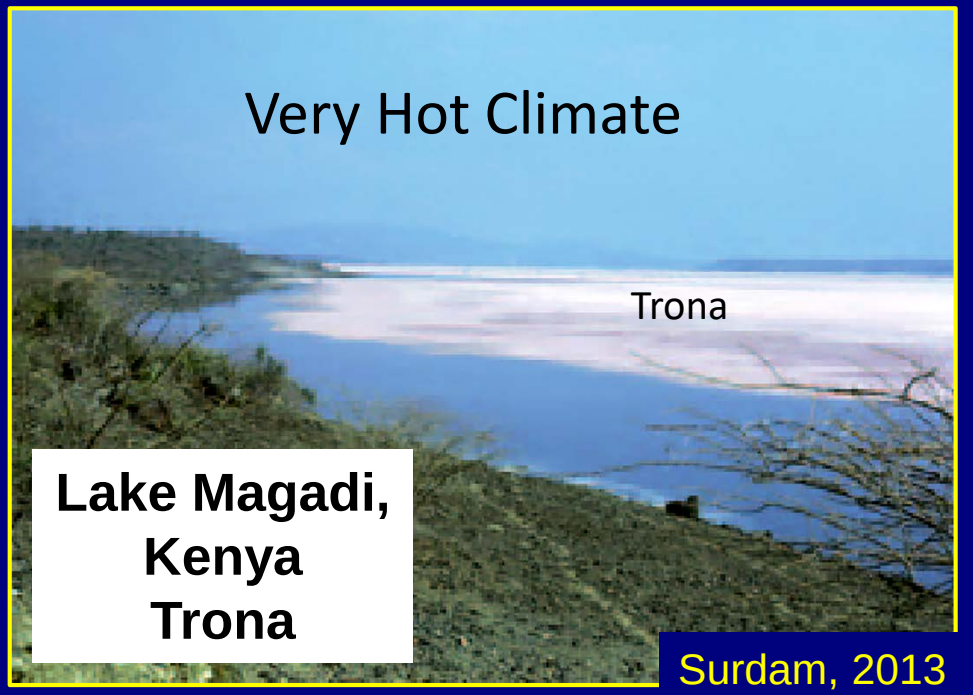


5000 Year Sequences in the Green River Formation, Southwestern Wyoming

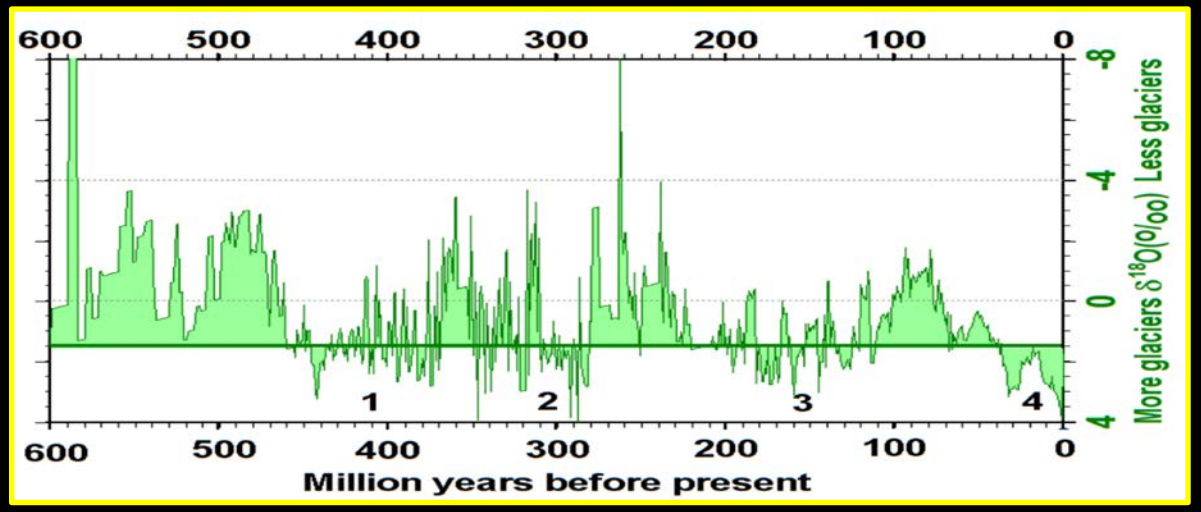
Around 50 Ma



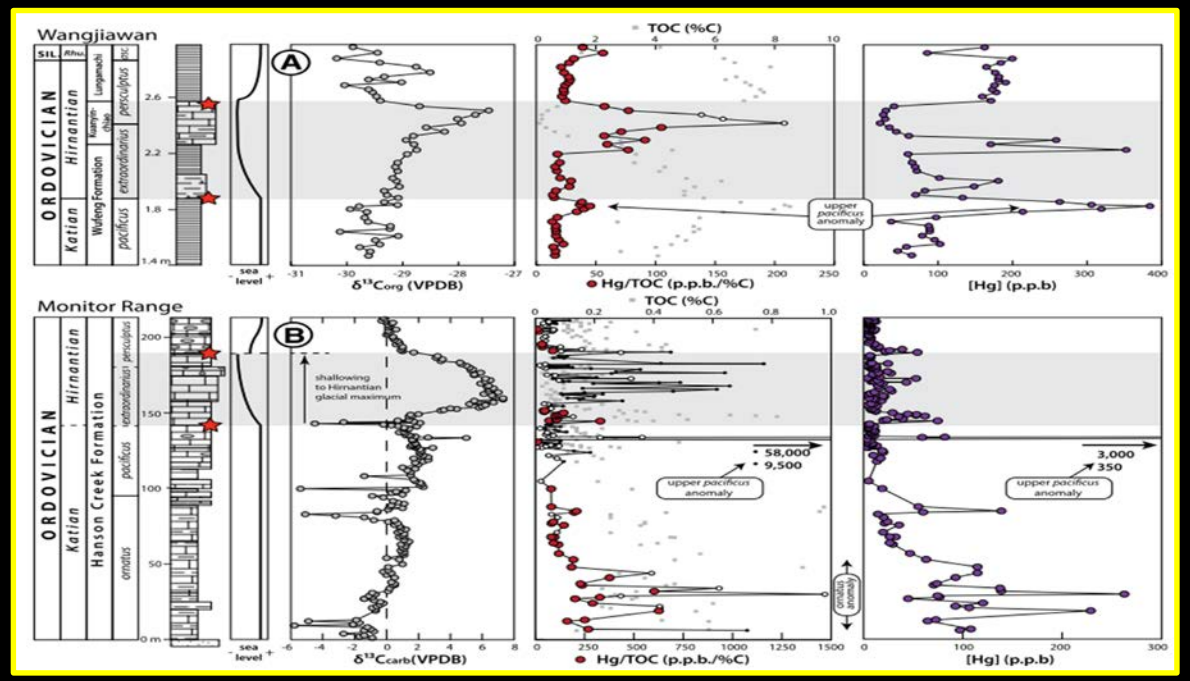




Surdam, 2013

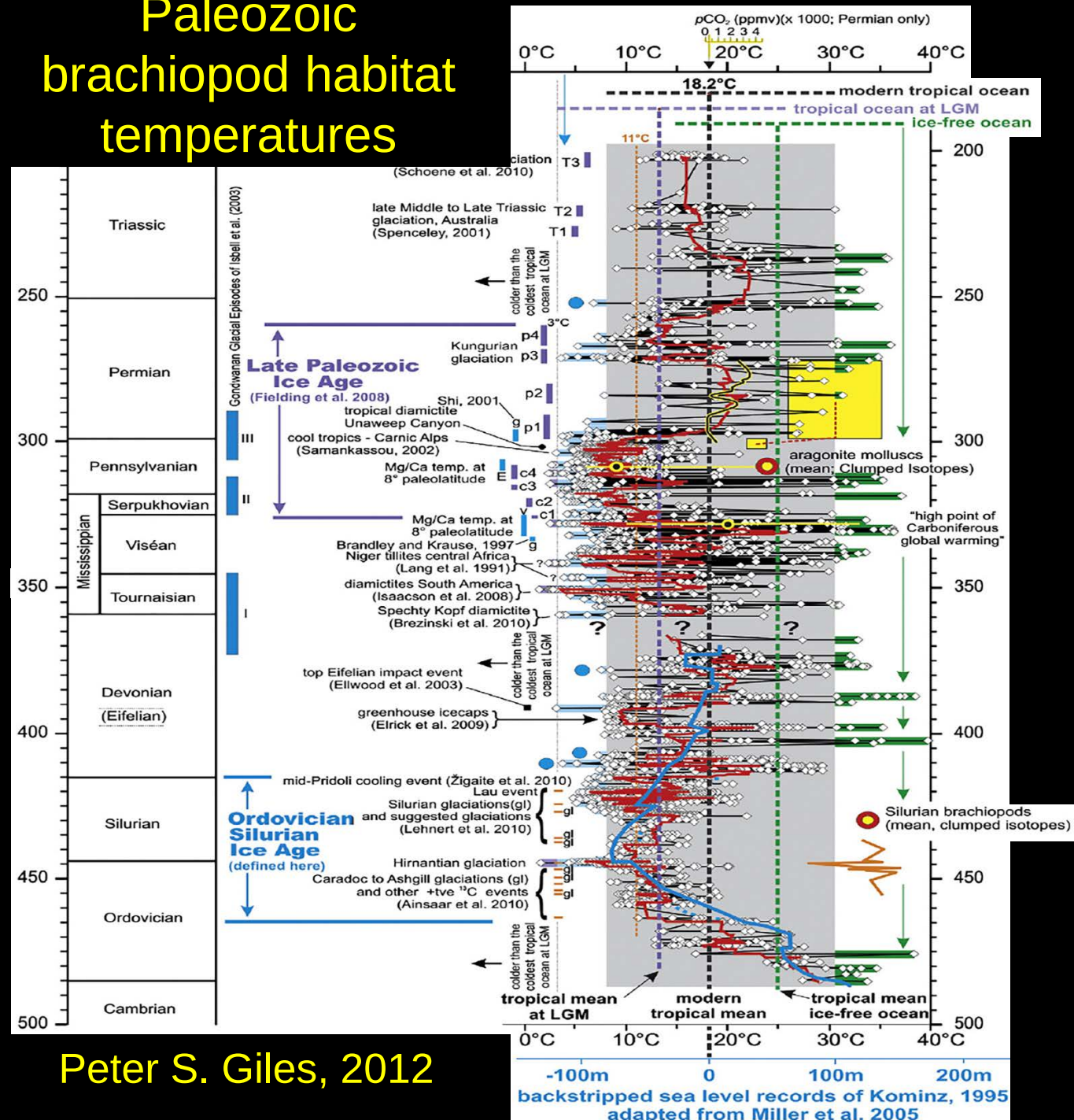


Ordovician mercury (Hg) enrichment by LIP basaltic volcanism



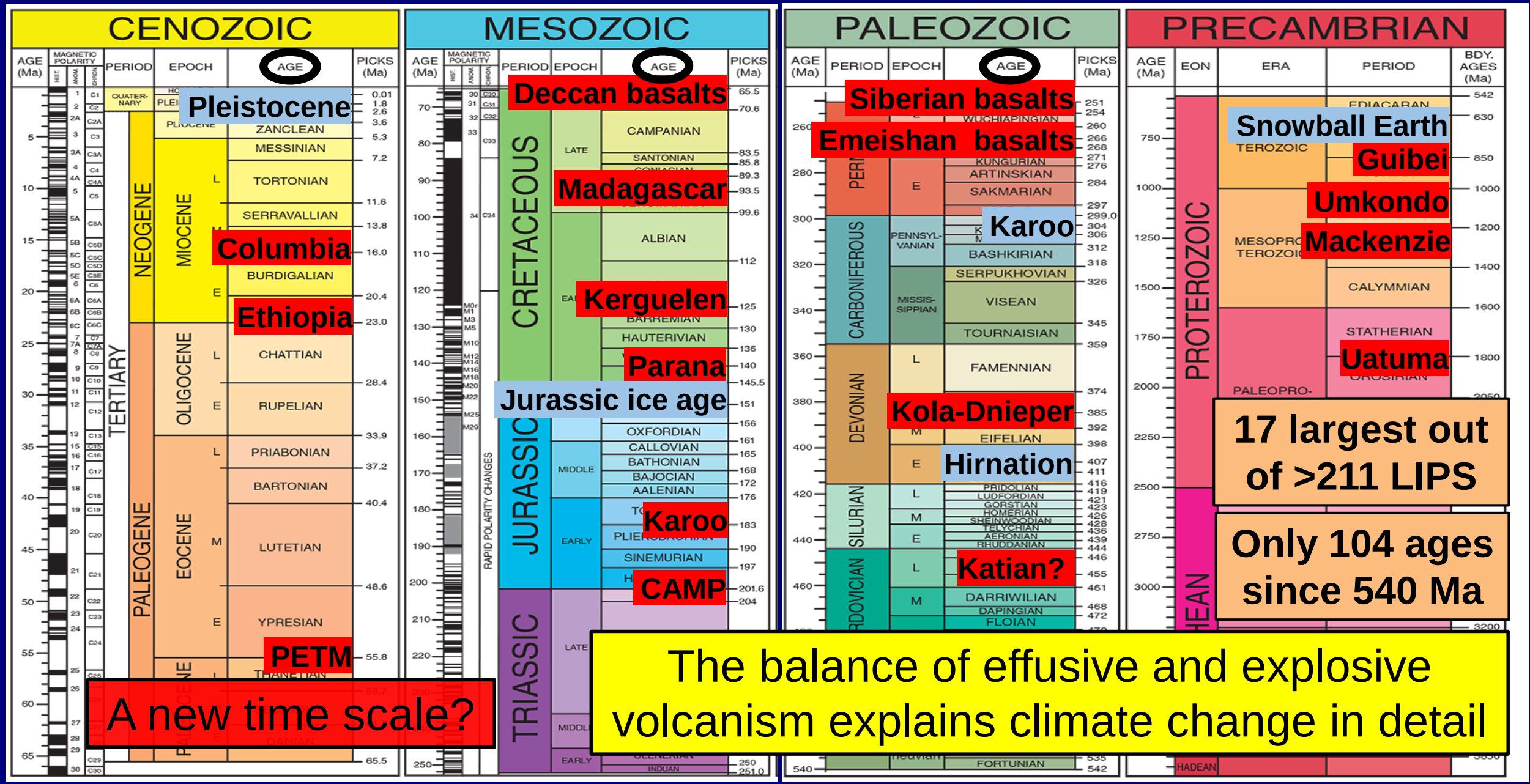
David S. Jones et al., 2017

Paleozoic brachiopod habitat temperatures



Peter S. Giles, 2012

Large Igneous Provinces punctuate the geologic time scale



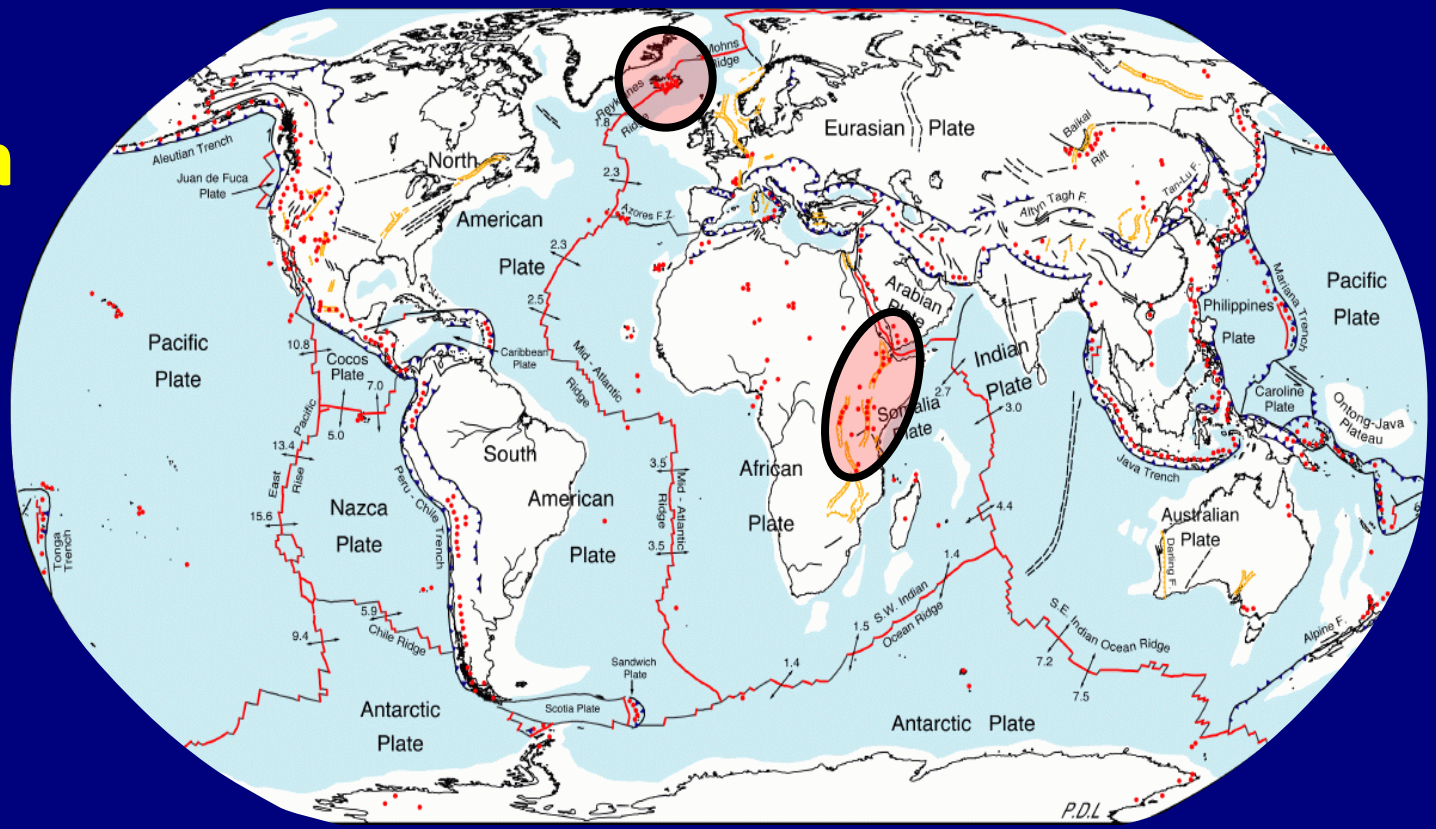
Geological Society of America Time Scale

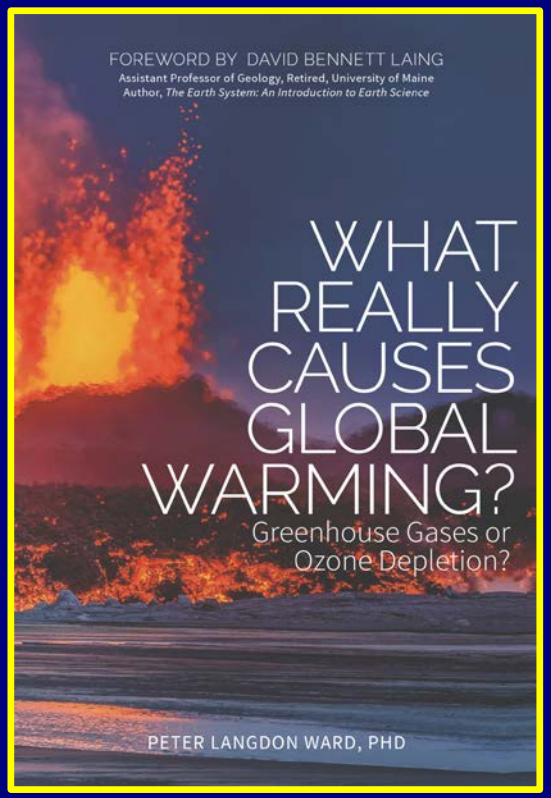
(LIPs from Ernst 2014)

Volcanoes Rule

WhyClimateChanges.com

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





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