Moving plate tectonics to the next level of detail

by understanding how plate tectonics controls
sudden global warming, slow incremental global cooling,
air temperatures, ocean temperatures, ocean acidification,
dominant species, mass extinctions, and
the major and minor subdivisions of
the geologic time scale

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Geologic Society of America
November 5, 2018

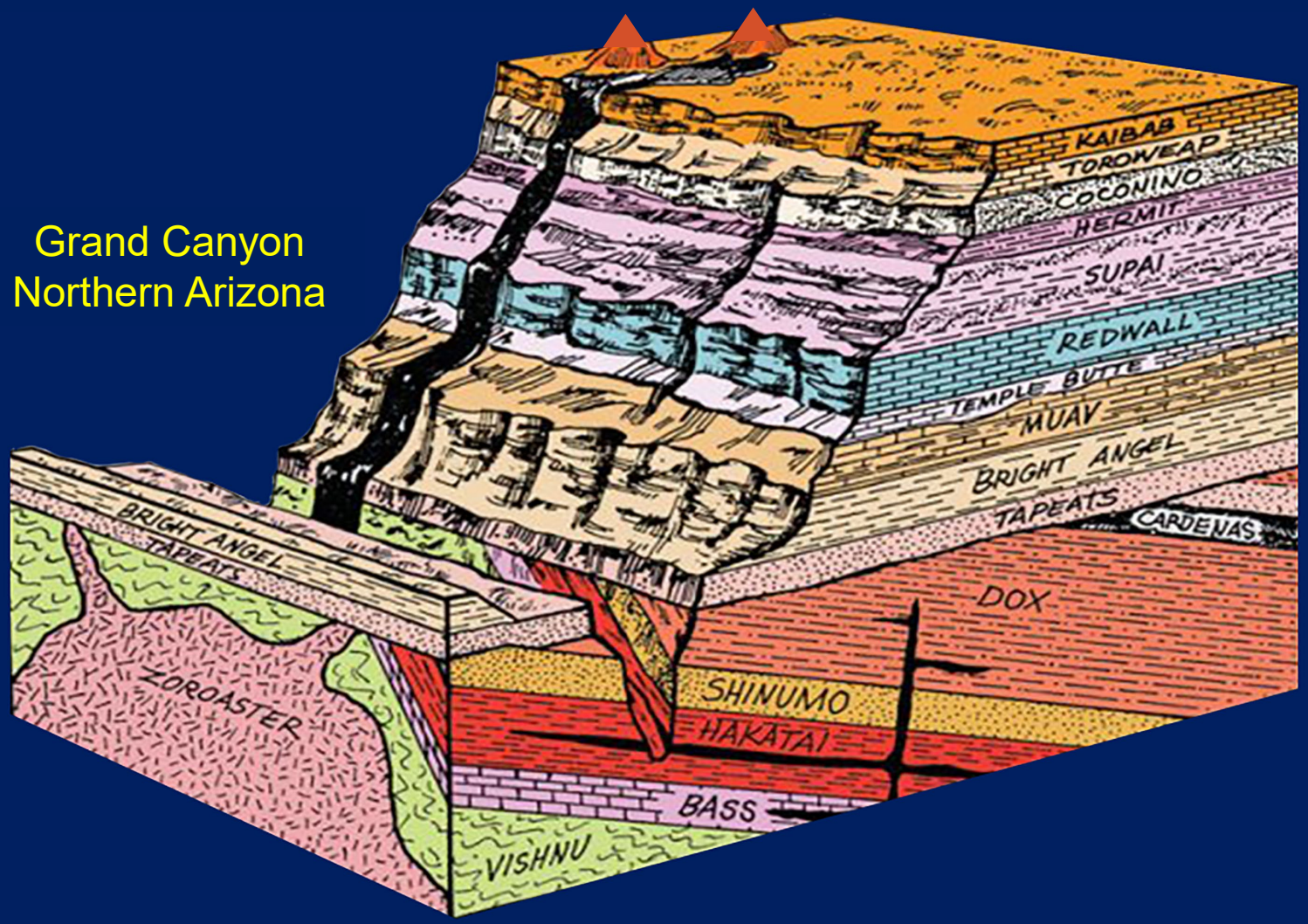
Perhaps the most fundamental observation in Earth science is that sedimentary rocks often come in distinct layers that can be tens to hundreds of meters thick.

Each layer is evidence of a distinct environment with distinct fossils, formed over millions of years. Then, in the blink of a geologic eye, the environment and fossils suddenly change.

Mapping these changes worldwide, geologists have developed a time scale gradually refining the precise times of these sudden transitions.
But what causes these sudden changes in environment?

Today I want to summarize the evidence suggesting that the majority of these sudden transitions are caused by sudden warming, even within years and sometimes lasting tens of thousands of years.

Grand Canyon
Northern Arizona



Limestone
Gypsum and shale
Eolian sandstone
Shale

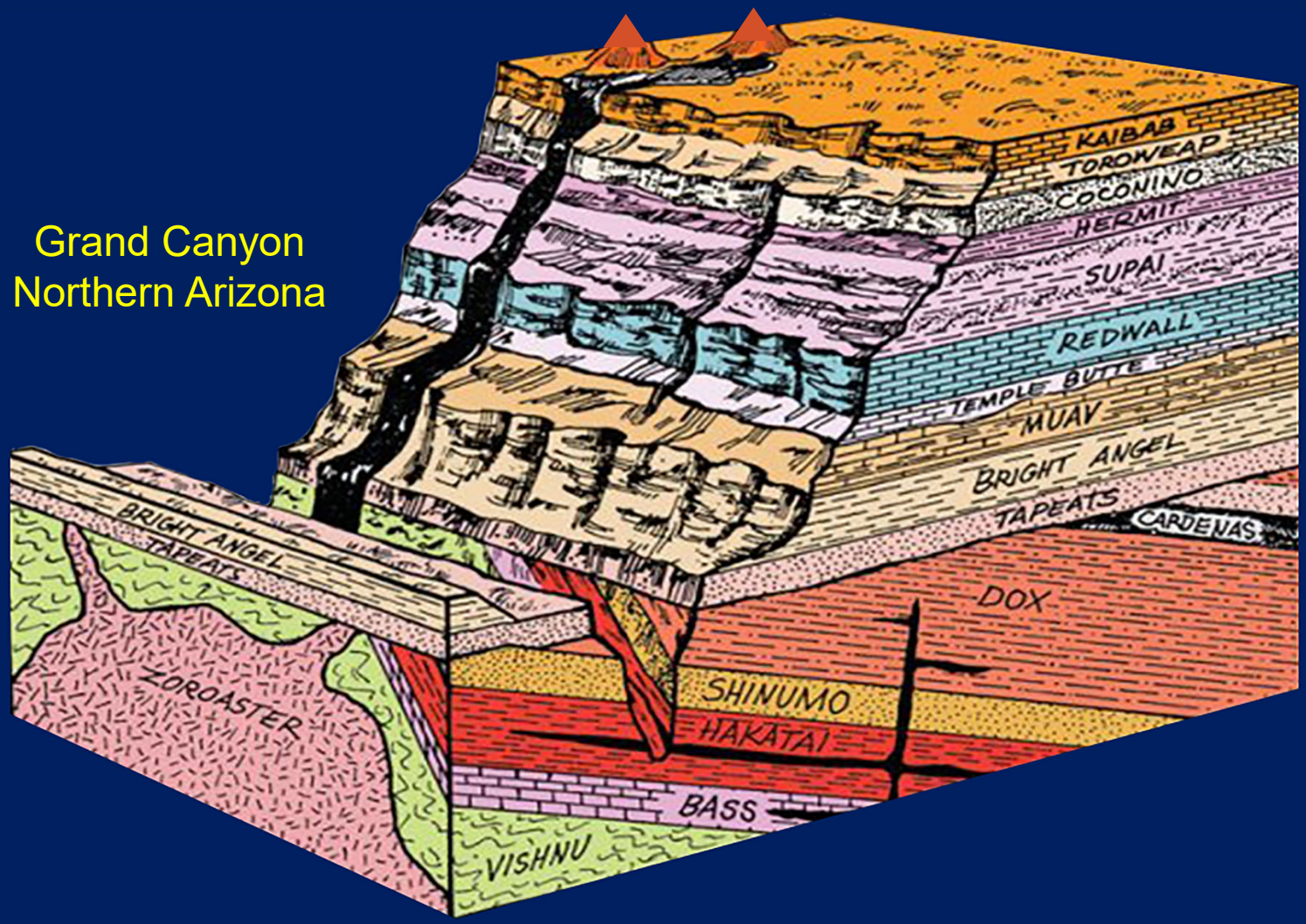
Mudstone, sandstone, limestone

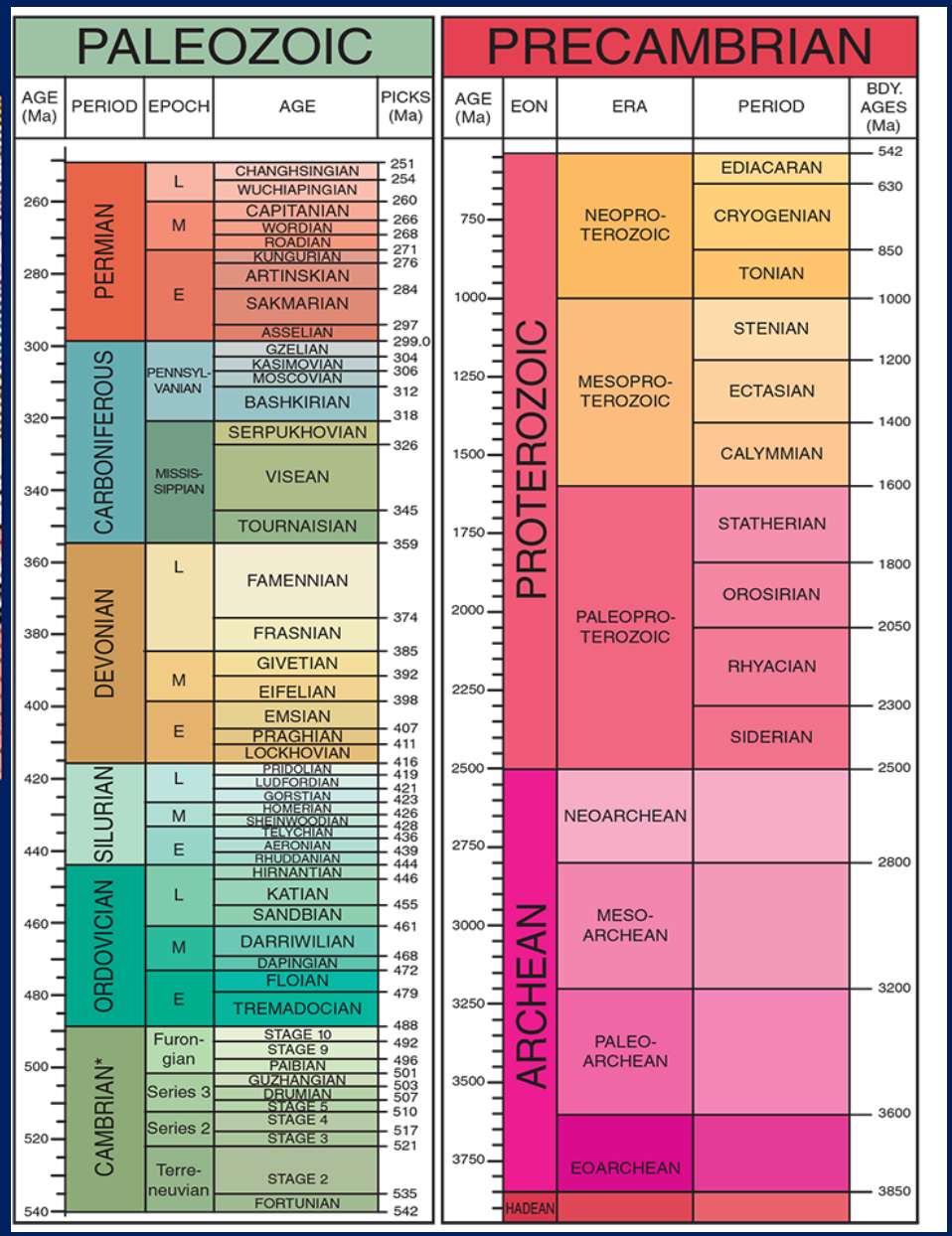
Limestone

Limestone, dolomite, mudstone

Shale
Sandstone

Grand Canyon
Northern Arizona

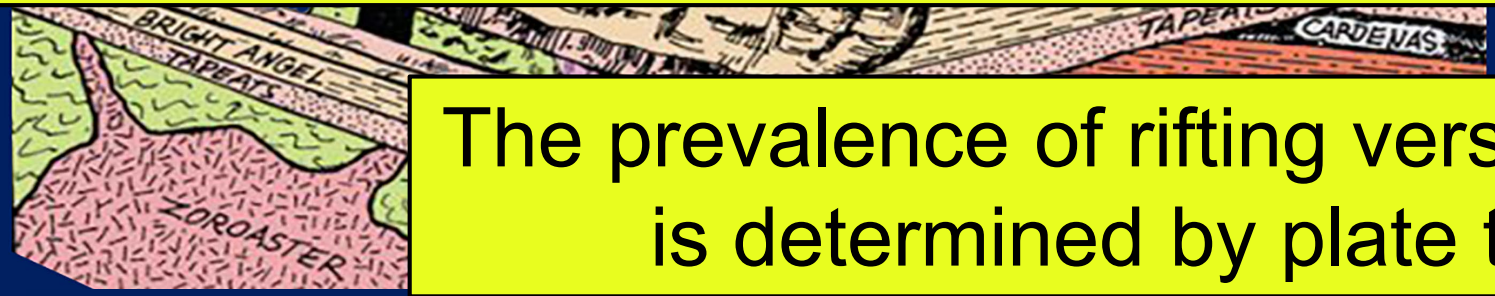




What causes these sudden changes in environment?

Basaltic eruptions are most voluminous in continental rift zones

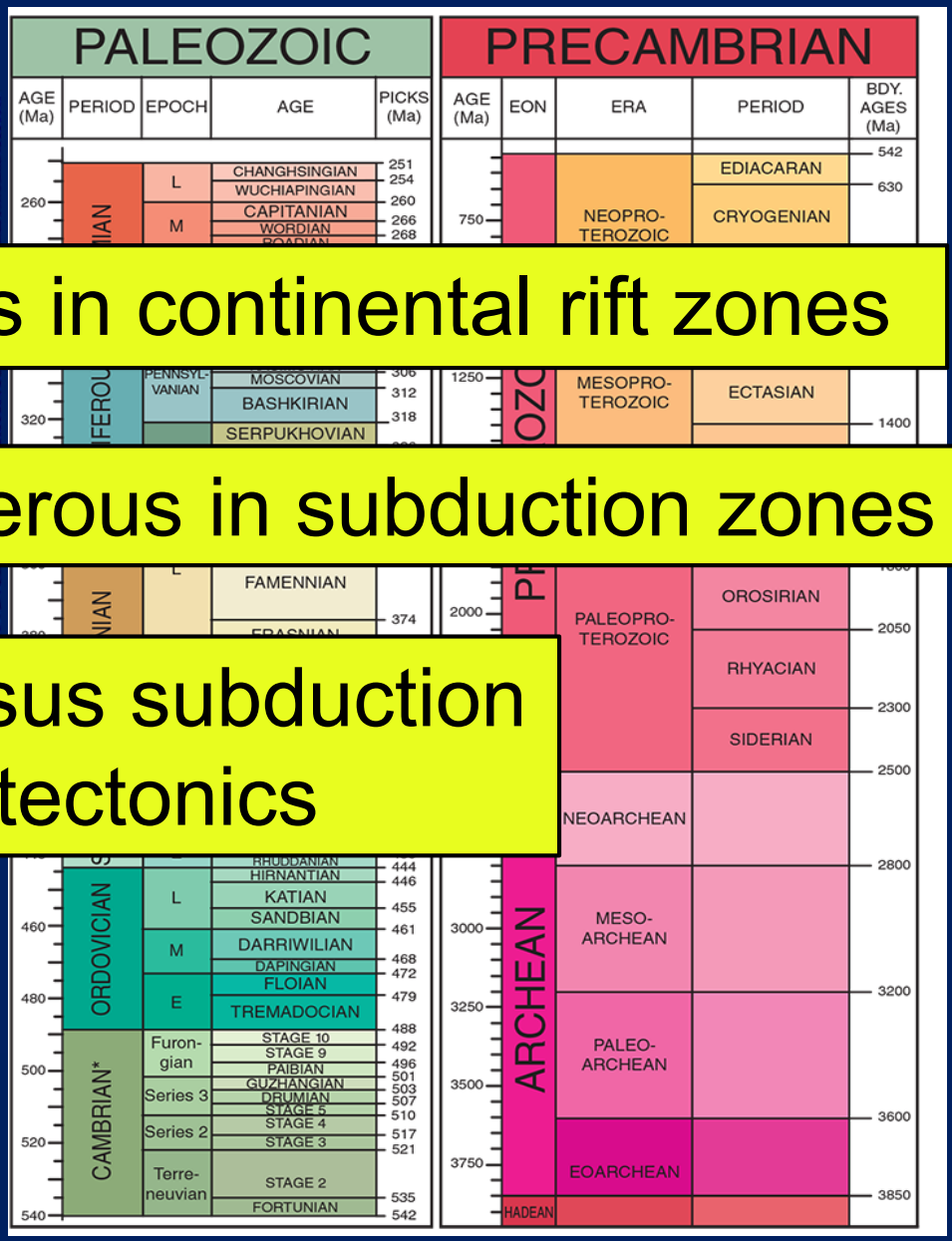
Major explosive eruptions are most numerous in subduction zones



The prevalence of rifting versus subduction is determined by plate tectonics

<u>Sudden warming</u> is caused by basaltic lava flows covering hundreds to <u>millions</u> of km^2. The more extensive the flow the greater the warming and the greater the sudden change

<u>Slow, incremental cooling</u> is caused by several major explosive, aerosol-forming volcanic eruptions per century for millennia



Sudden warming is caused by basaltic lava flows that cover hundreds to **millions** of square kilometers of land. The more extensive the sub-aerial flow the greater the warming and the greater the sudden change.

Slow, incremental cooling, on the other hand, is caused by several major explosive, aerosol-forming volcanic eruptions per century continuing on for millennia.

Basalts are most voluminous in continental rift zones. Major explosive volcanic eruptions are most typical related to subduction zones.

The prevalence of rifting versus subduction is determined by plate tectonics.

For example, snowball earth, in the Late Proterozoic may have been a time when subduction was widespread, with little to no continental rifting.

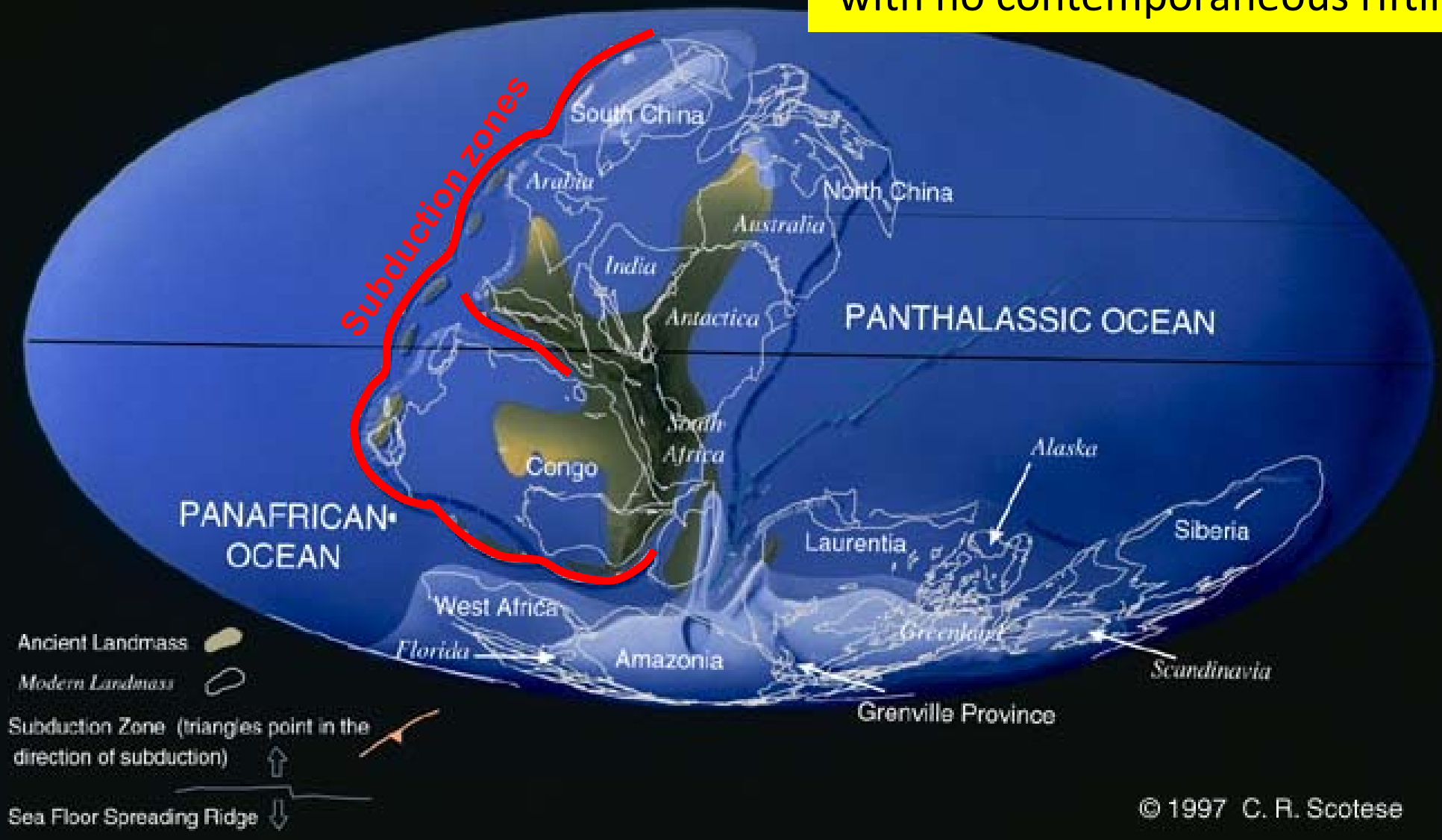
The end of the Paleozoic, on the other hand appears to be a time when continental rifting became prevalent in Siberia.

Continental rifting appears be initiated, in some cases, when a continent overrides a ridge-ridge-ridge triple junction. The Columbia River Basalts appear to have formed this way from 17 to 14 million years ago.

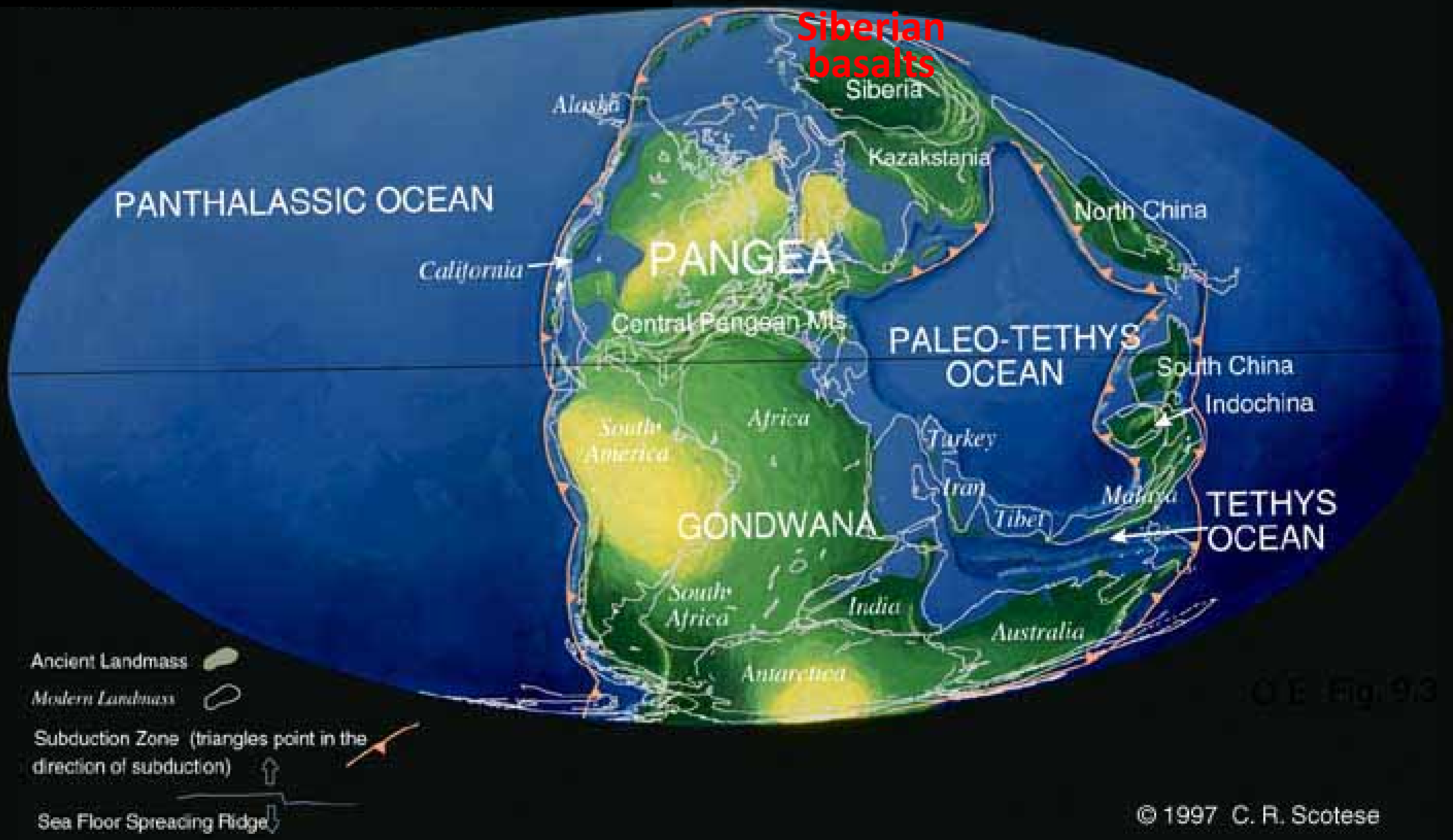
Three of the largest basalt flows were contemporaneous with the end of the Paleozoic, the end of the Triassic, and the end of the Mesozoic and the three largest known mass extinctions. These were also times of major ocean acidification. Large volumes of sulfur dioxide emitted from basalts plus water vapor forms sulfuric acid and sulfate is the most prevalent anion in the ocean after chlorine.

Snowball earth

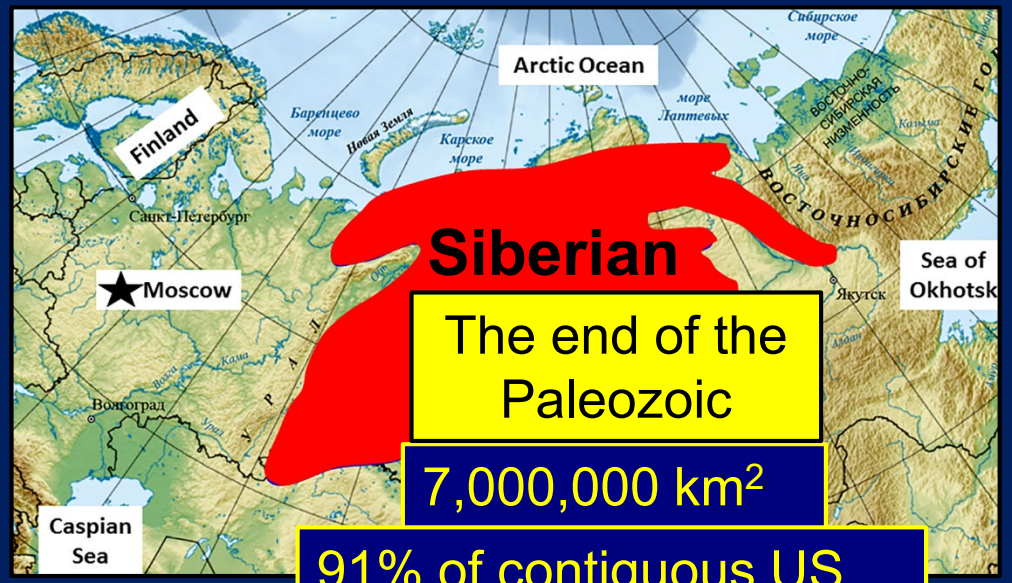
Snowball Earth appears to be the result of widespread subduction with no contemporaneous rifting

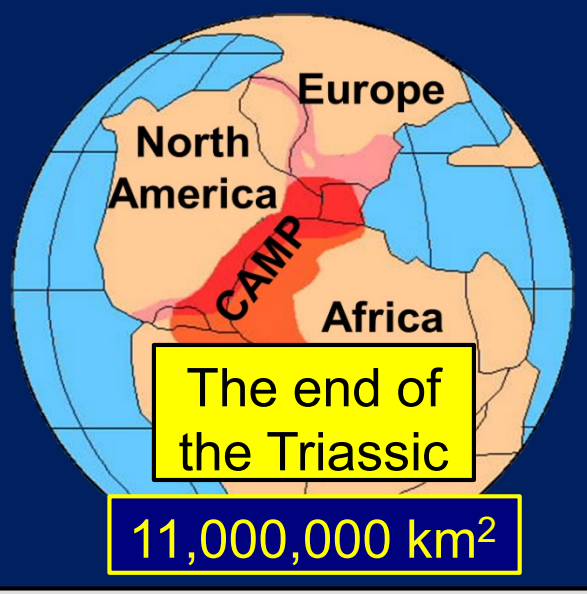


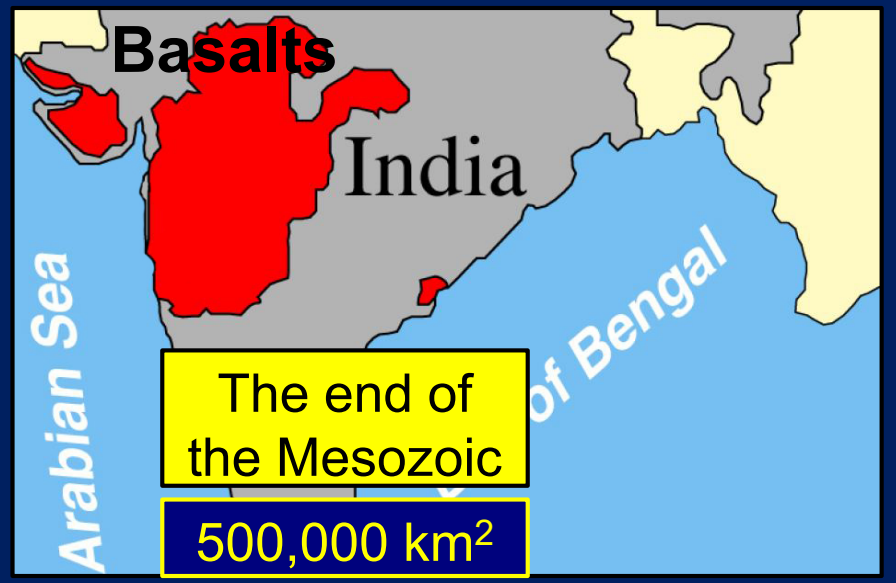
The End of the Paleozoic 252 Ma

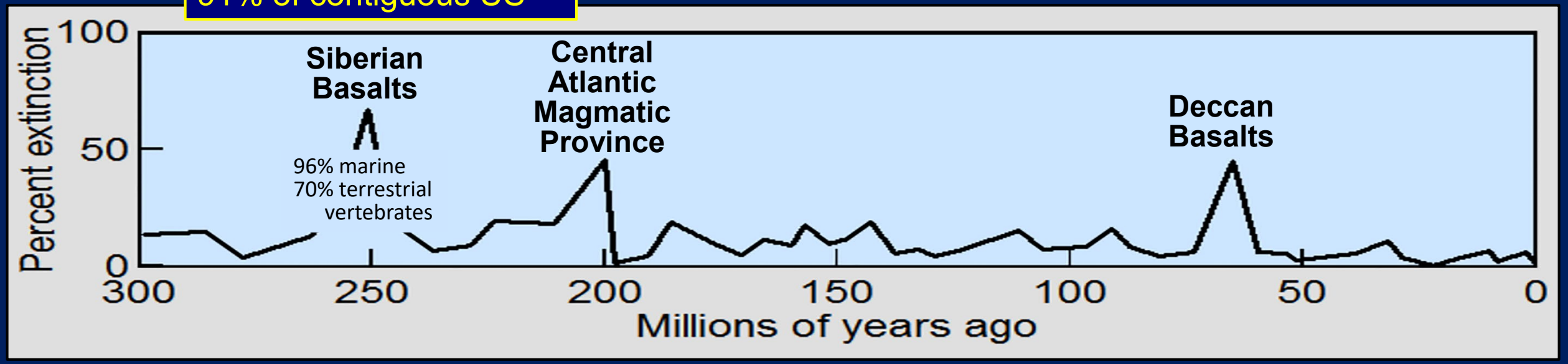


Three of the largest flood basalts were contemporaneous with three of the largest mass extinctions

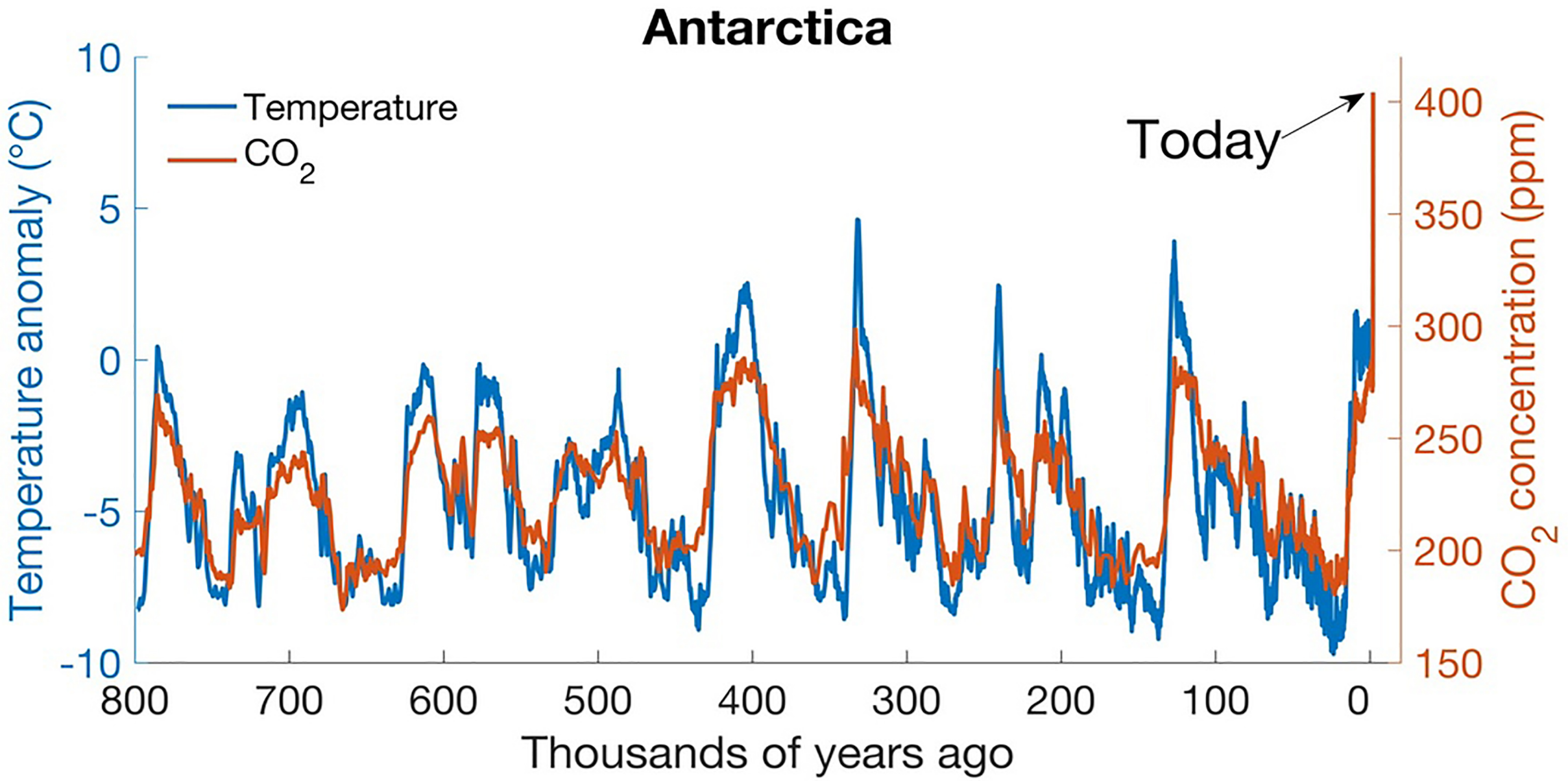








What about the correlation of CO_2 with temperature?



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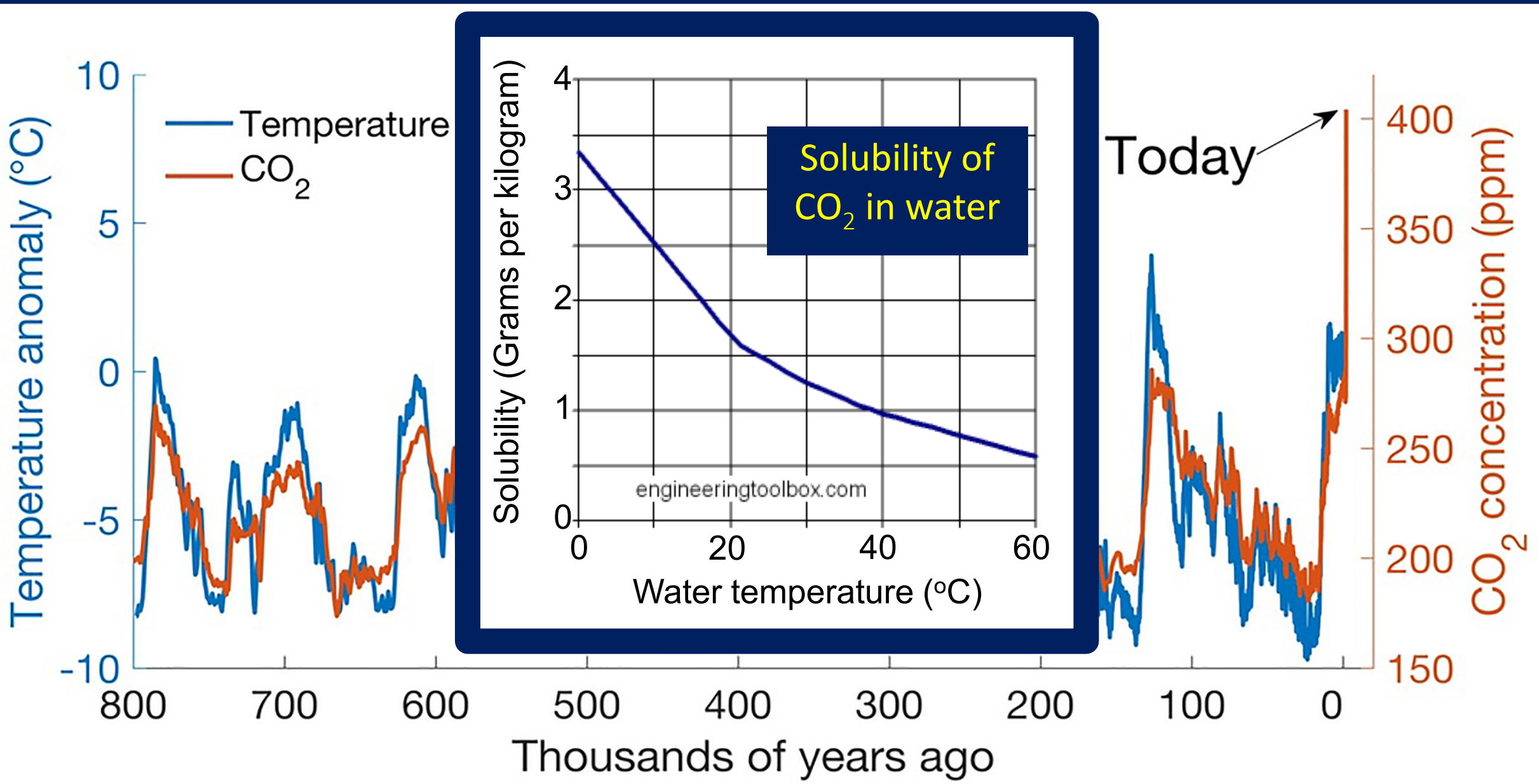

The globe has warmed one degree centigrade since 1970

But, greenhouse warming theory appears to be mistaken!

In fact, greenhouse warming theory is not even physically possible!

A body of matter cannot be heated by absorbing its own radiation

A blanket of greenhouse gases can slow cooling but cannot cause heating

Warming from 1970 to 1998 was caused by humans depleting the ozone layer, allowing more very hot solar ultraviolet-B radiation to reach Earth

Five times faster warming from 2014 to 2016 was caused by basaltic eruption of Bárðarbunga volcano in Iceland, the largest basaltic eruption since 1783

More information:

Physicially-Impossible.com

Booth 733 in the Exhibit Hall

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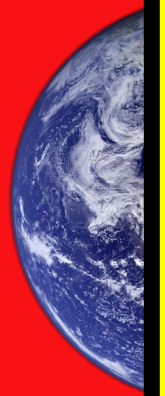

Recognizing that warming
is caused by ozone depletion
due to basaltic lavas
unlocks whole new vistas
into understanding
the geologic record

More information:

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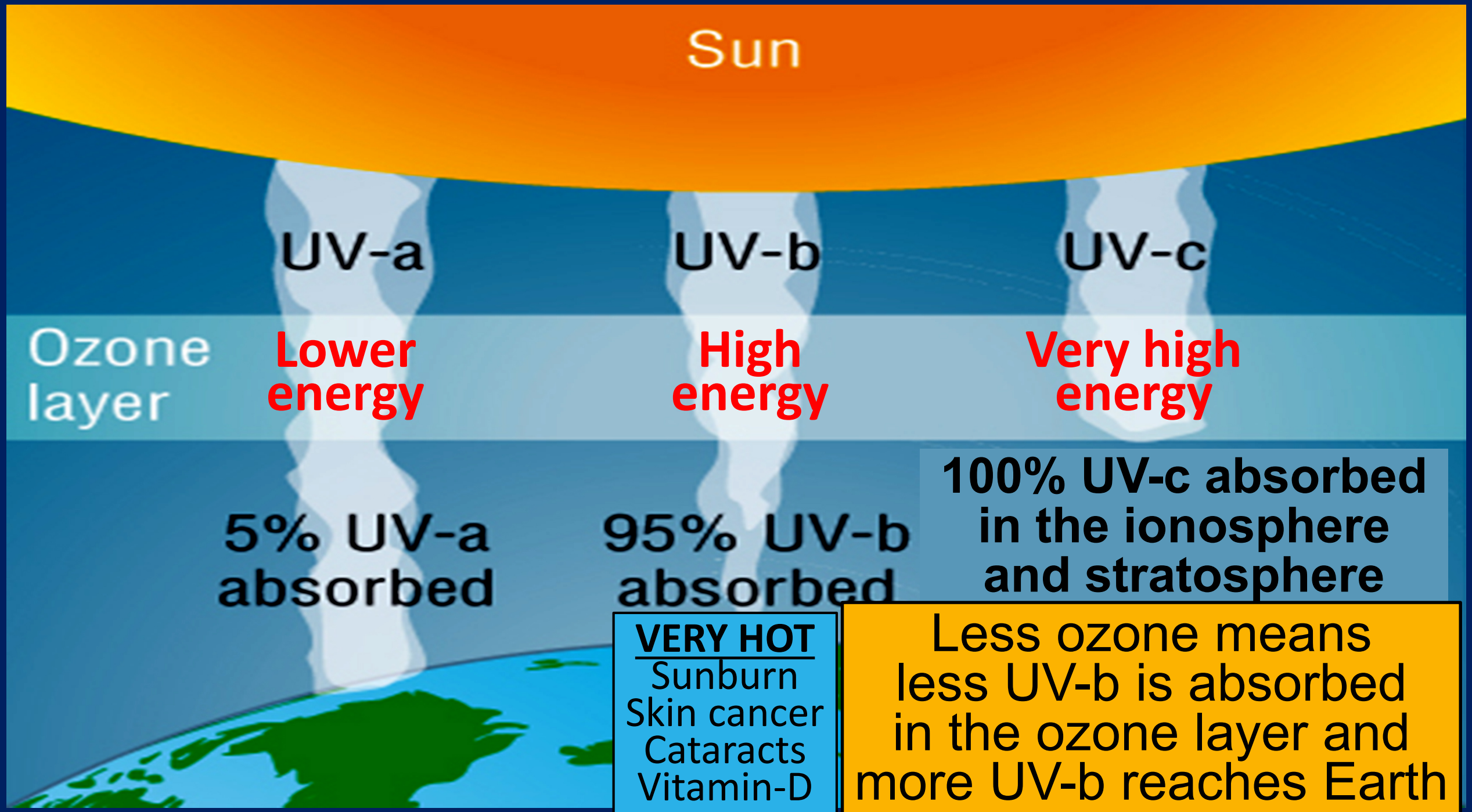
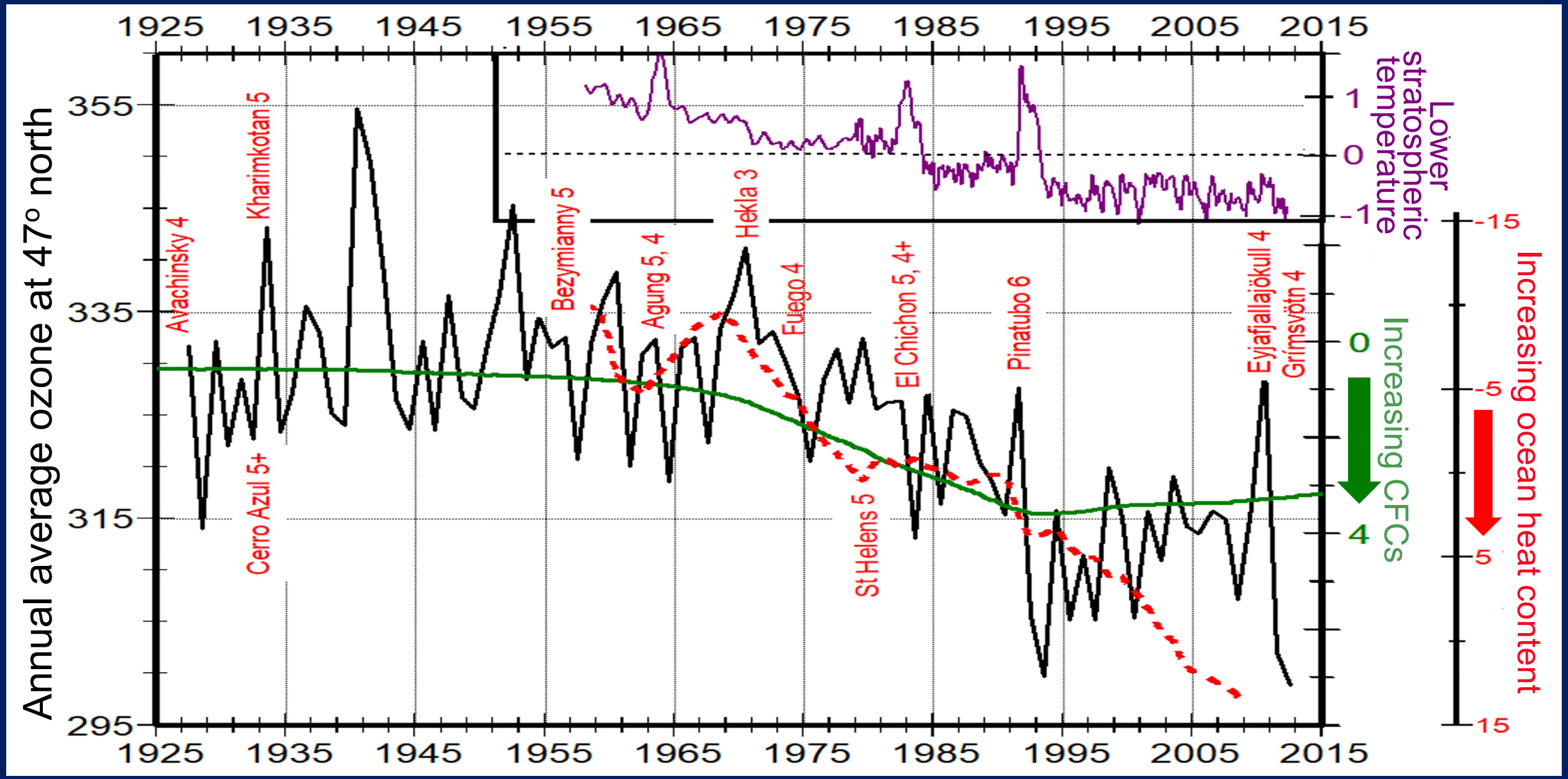
Booth 733 in the Exhibit Hall


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 in the ionosphere and stratosphere
VERY HOT
Sunburn
Skin cancer
Cataracts
Vitamin-D
Less ozone means less UV-b is absorbed in the ozone layer and more UV-b reaches Earth

Ozone depleted by humans and by volcanic eruptions



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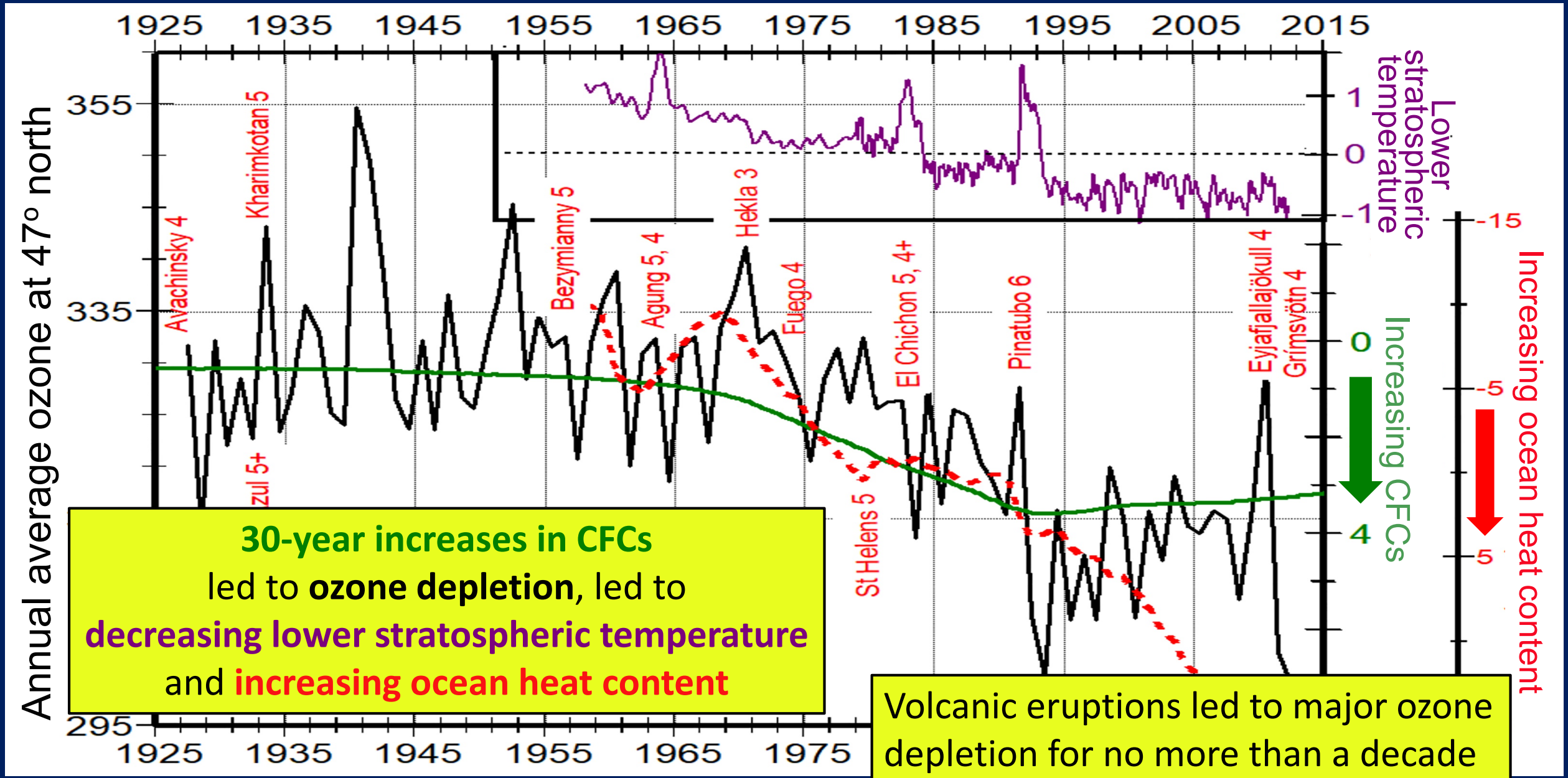


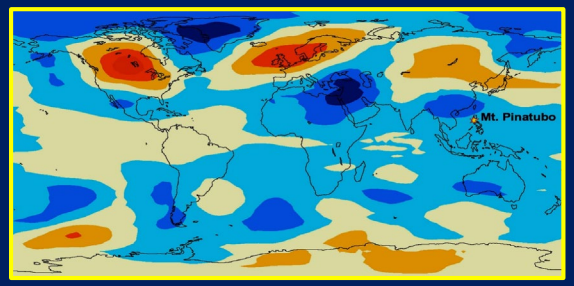
30-year increases in CFCs
led to **ozone depletion**, led to
decreasing lower stratospheric temperature
and **increasing ocean heat content**

Volcanic eruptions led to major ozone depletion for no more than a decade

Major explosive volcanic eruptions cause net cooling

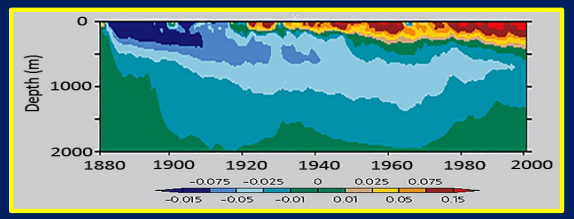
Forms aerosols in the lower stratosphere

Typical above subduction zones



Pinatubo warmed parts of the NH 3.5°C

Dec 1991 to Feb 1992



Krakatau (1883) cooled the ocean for more than 100 years

Multiple eruptions increment world into an ice age

Major effusive flows of basaltic lava that cause net warming

Emit Cl & Br causing rapid warming

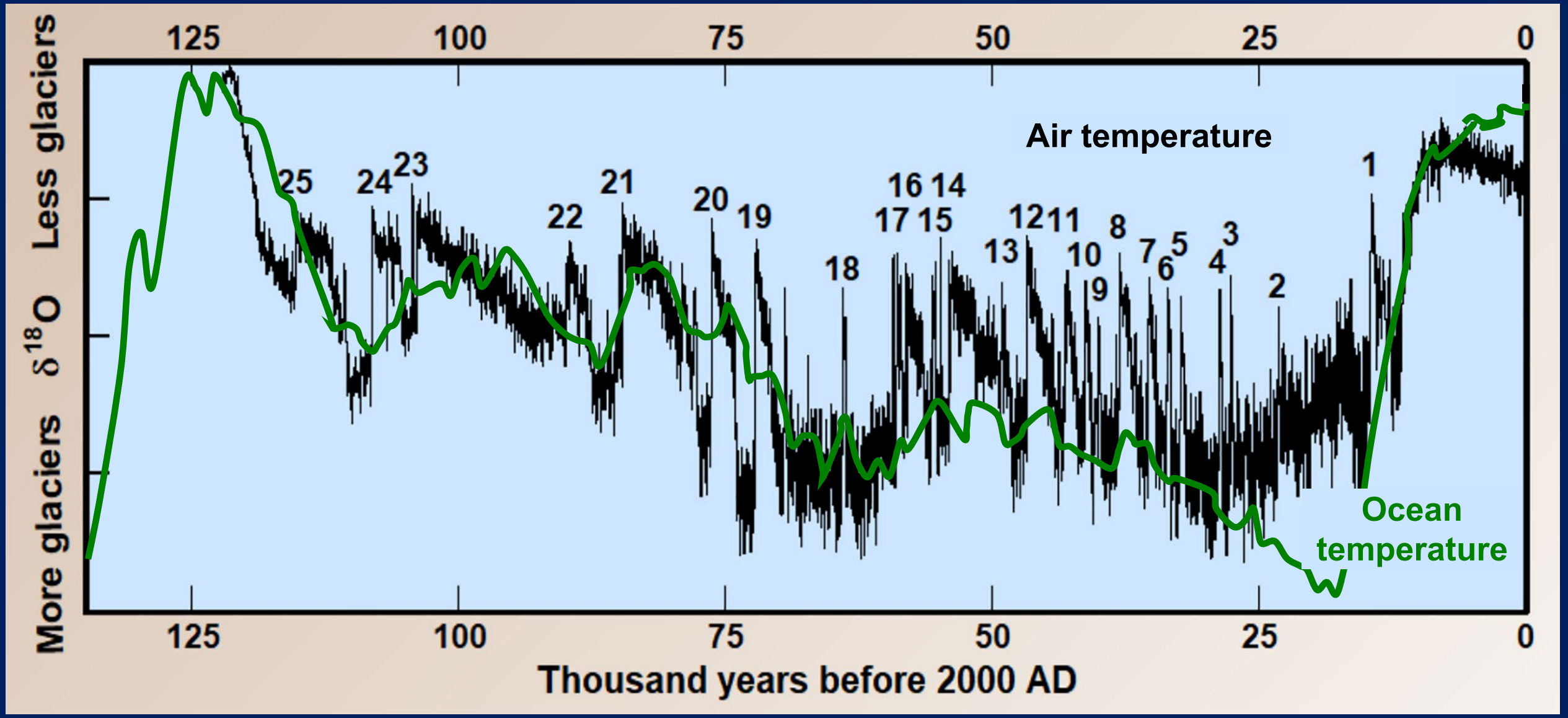
Typical in sub-aerial rift zones

Climate effect is determined by the aerial extent, which depends on the duration of eruption

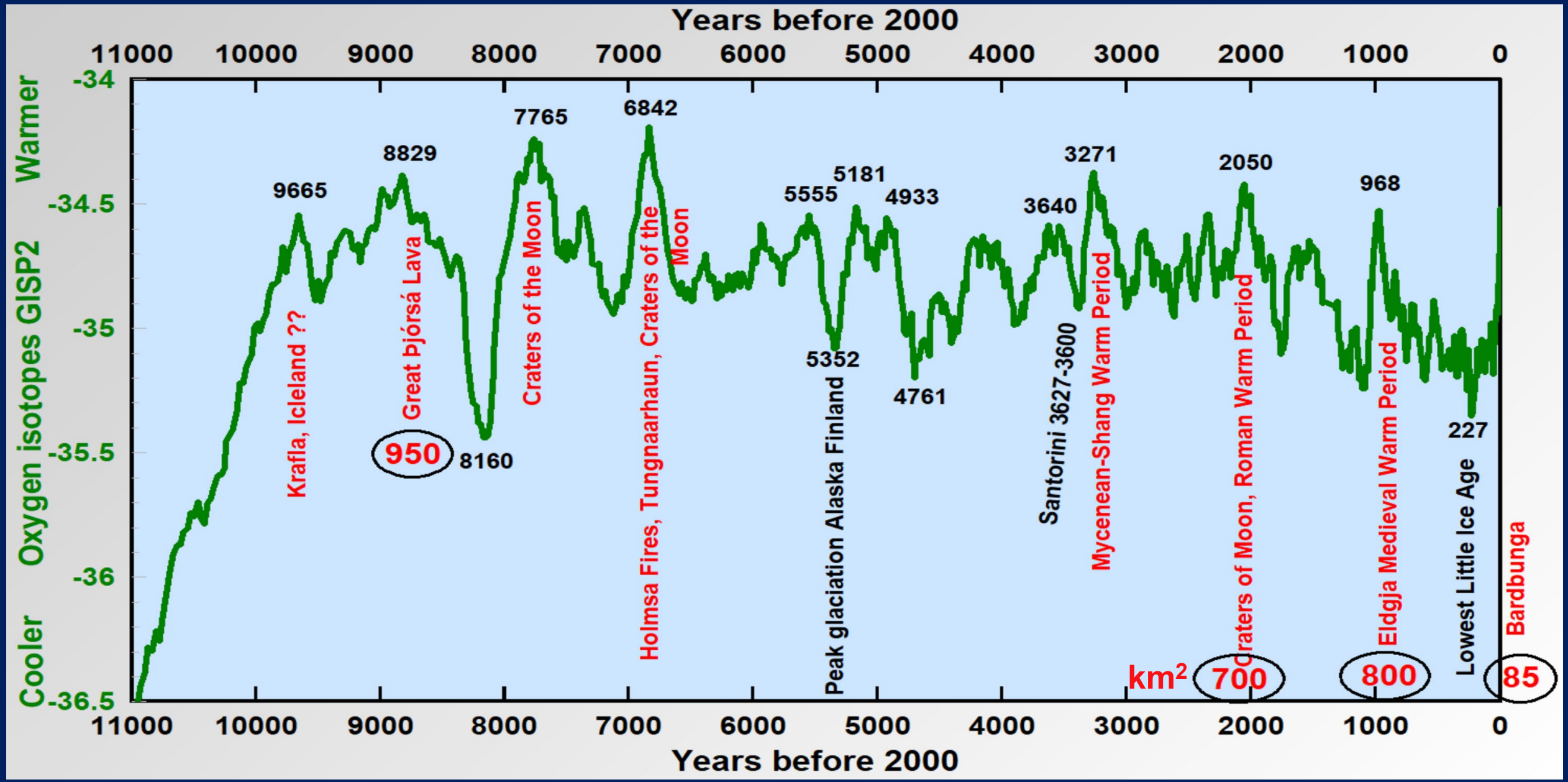
Bárðarbunga: 2014
covered 85 km^2
in 6 months

Siberian traps: 251 Ma
covered 7 million km^2
in more than 100,000 years

The footprints of climate change: Erratic sequences of rapid warming followed by slow, incremental cooling over millenia

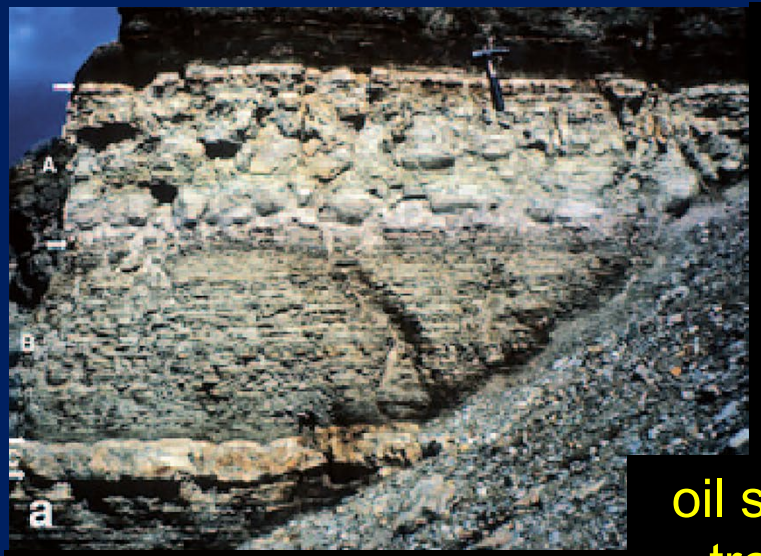


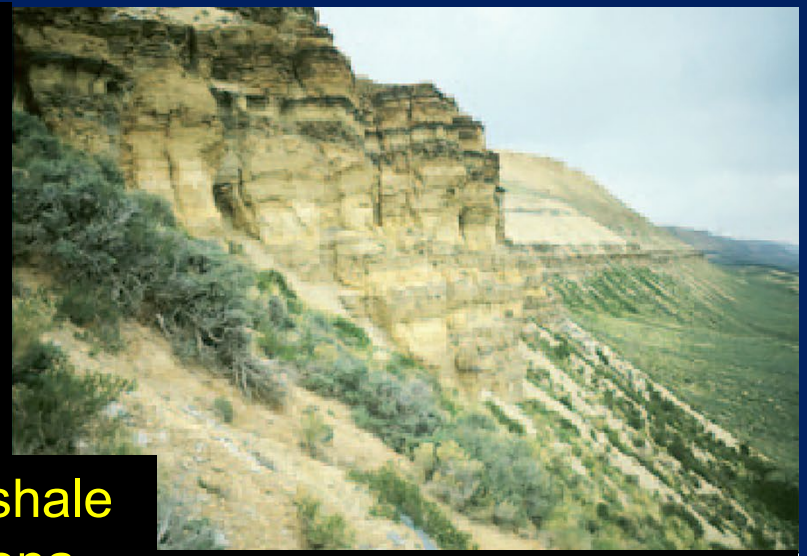
Holocene temperatures and volcanism



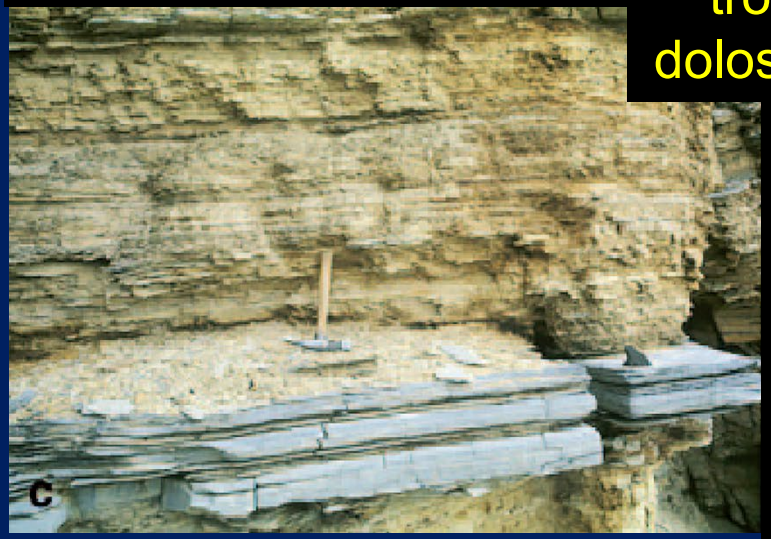
Eocene Green River Formation in Wyoming

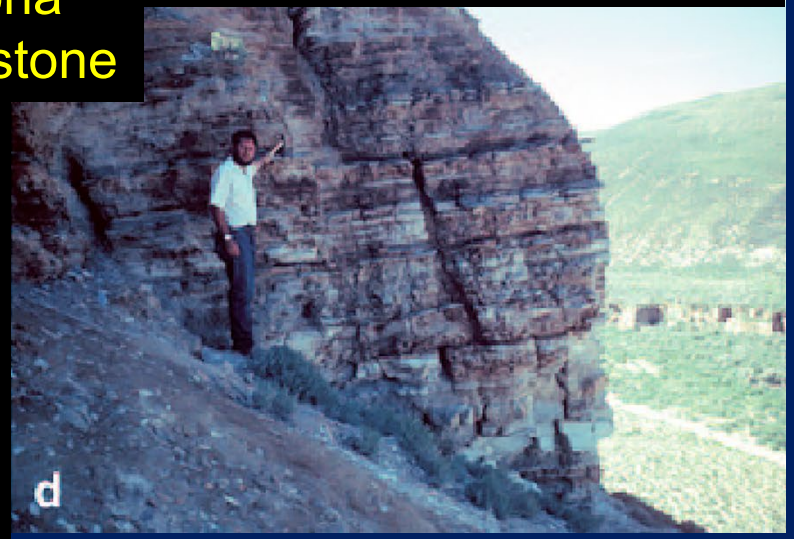
53 to 48 million years ago





oil shale
trona
dolostone





Mud Lake
Florida
Oil shale

Lake Magadi,
Kenya, Trona

Surdam, 2013

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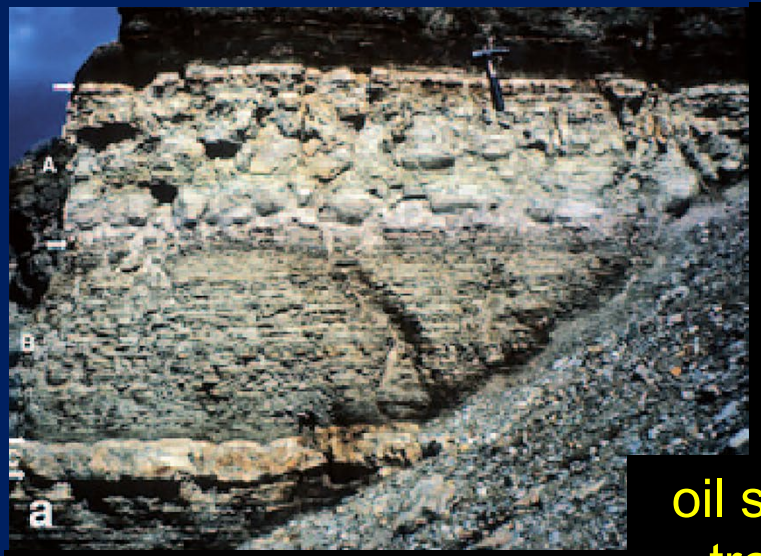

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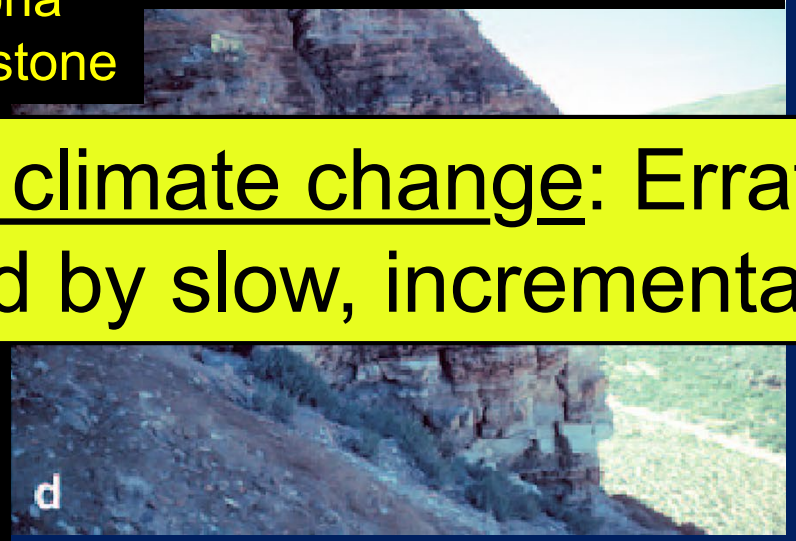

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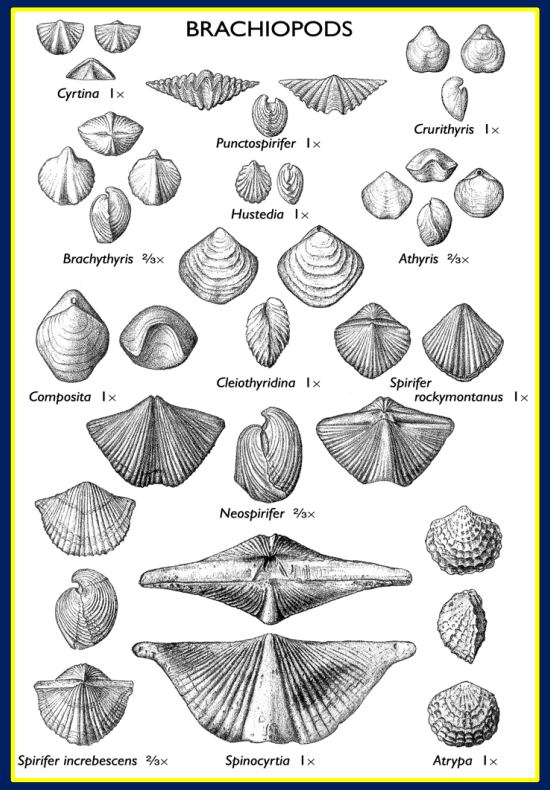
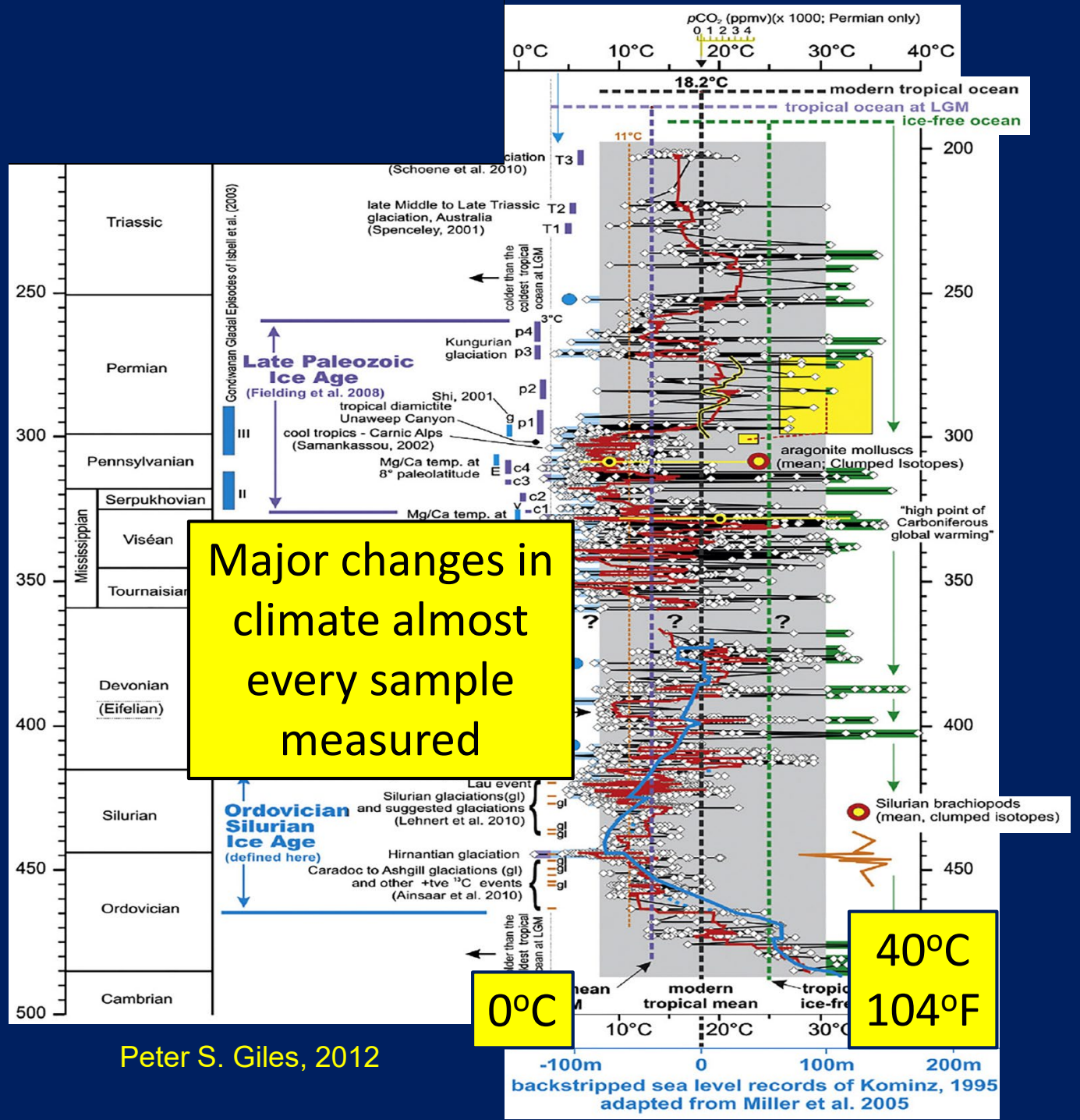
The footprints of climate change: Erratic sequences of rapid warming followed by slow, incremental cooling over millenia

Surdam, 2013

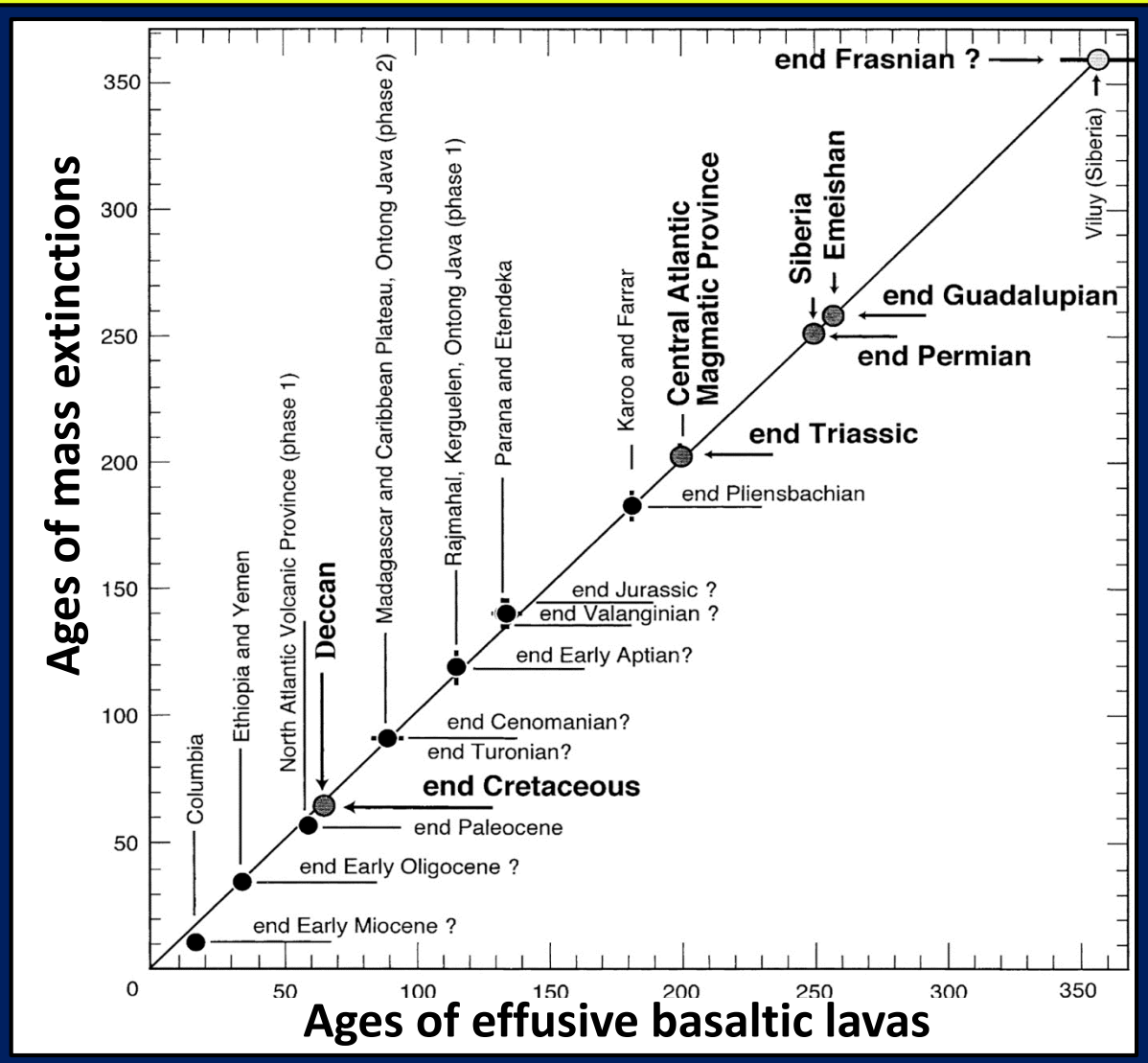
Paleozoic brachiopod habitat temperatures





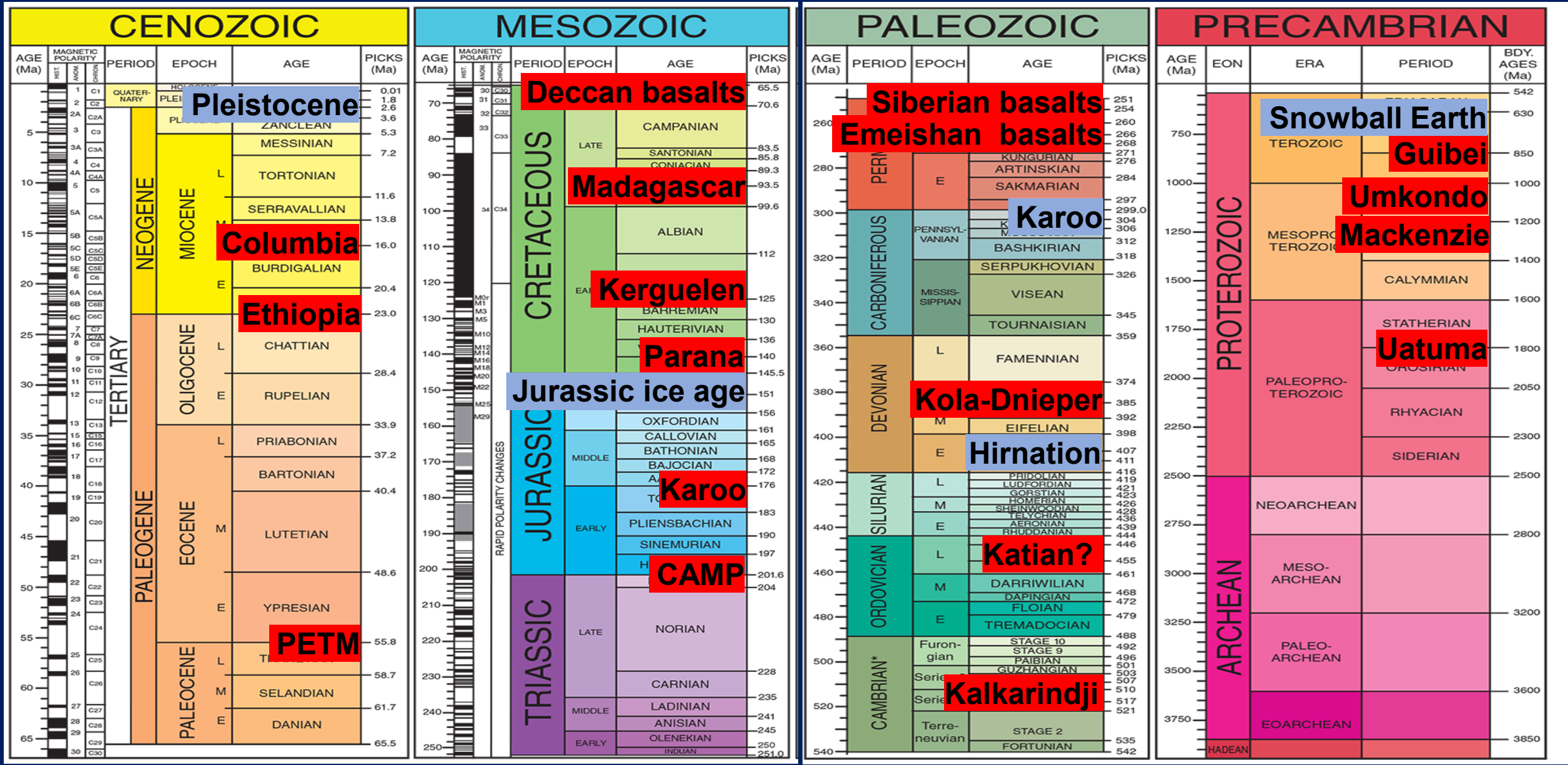
Peter S. Giles, 2012

Typically these basaltic lavas occur at the end of geologic time units



Courtillot and Renne 2003

Large Igneous Provinces punctuate the geologic time scale



Geological Society of America Time Scale

Ages of LIPs from Ernst 2014

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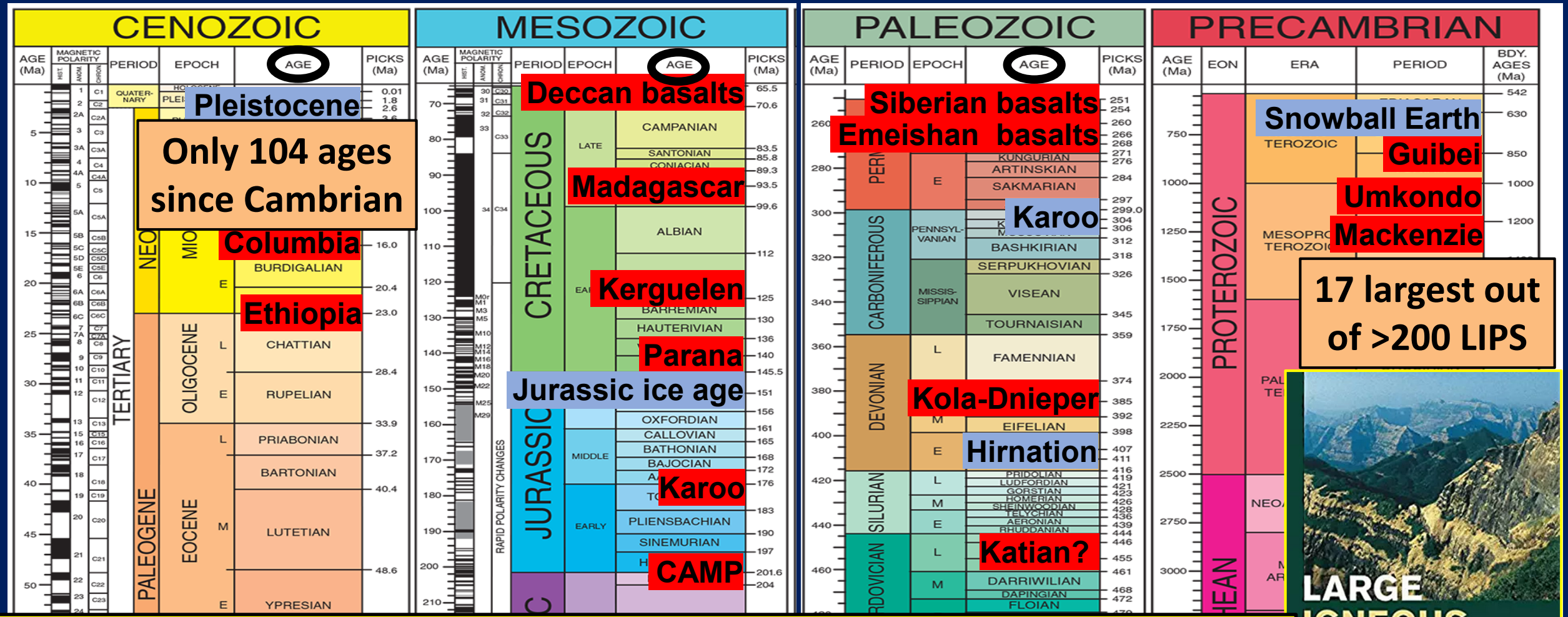


The balance of effusive and explosive volcanism due to plate tectonics explains climate change in detail

Geological Society of America Time Scale

Ages of LIPs from Ernst 2014

The blessing of oxygen isotope measurements, $\delta^{18}O$

10,000 living species

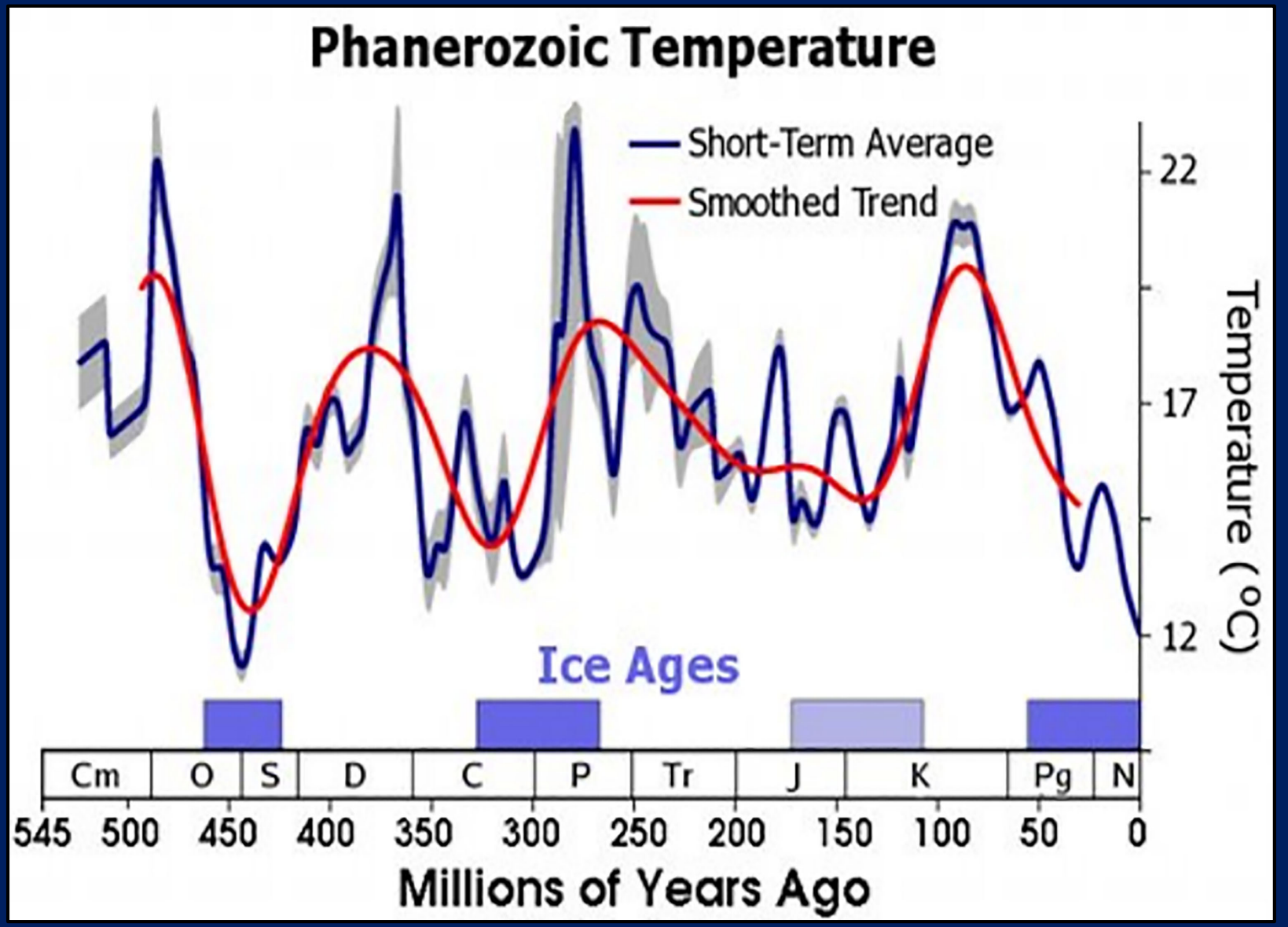
40,000 fossil species since Cambrian

Usually less than one millimeter in size

Individual critters live weeks to years

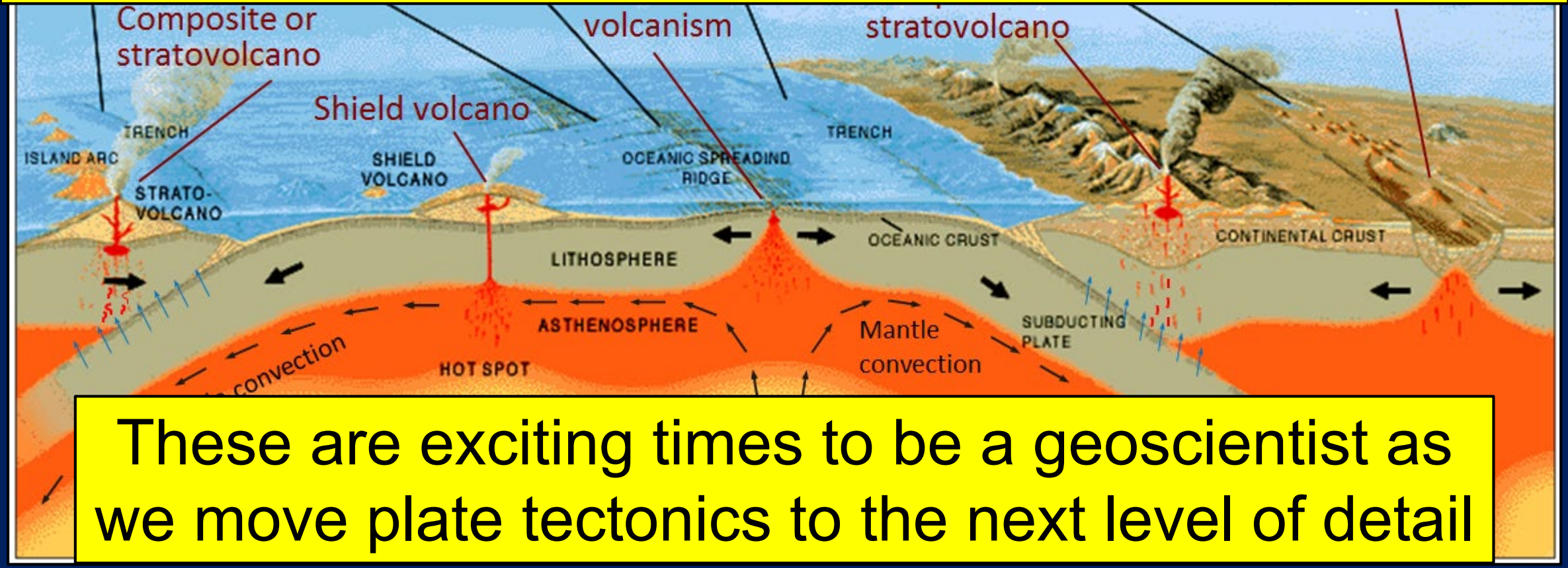
Can we recognize distinctive sequences with age?

The data are there for the taking



Volcanoes Rule Climate Change

Plate Tectonics Rules Volcanoes



These are exciting times to be a geoscientist as we move plate tectonics to the next level of detail