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.

Peter L. Ward
U.S. Geological Survey retired

peward@Wyoming.com

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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.
Limestone, dolomite, mudstone

Gypsum and shale

Eolian sandstone

Shale

Limestone, mudstone, sandstone, limestone

Shale

Sandstone

Grand Canyon
Northern Arizona
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.

**Sudden warming** is caused by basaltic lava flows covering hundreds to millions of km². The more extensive the flow the greater the warming and the greater the sudden change.

**Slow, incremental cooling** is caused by several major explosive, aerosol-forming volcanic eruptions per century for millennia.

What causes these sudden changes in environment?
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 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 CO₂ with temperature?
What about the correlation of CO\textsubscript{2} with temperature?
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: Physically-Impossible.com
Booth 733 in the Exhibit Hall
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!

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

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Booth 733 in the Exhibit Hall
VERY HOT

Sunburn
Skin cancer
Cataracts
Vitamin-D

Very high energy

High energy

Lower energy

Very high energy

100% UV-c absorbed in the ionosphere and stratosphere

Less ozone means less UV-b is absorbed in the ozone layer and more UV-b reaches Earth

5% UV-a absorbed
95% UV-b absorbed
Ozone depleted by **humans** and by volcanic eruptions

[Diagram showing annual average ozone at 47° north over time, with labels for significant volcanic eruptions and a trend line indicating decreasing ozone levels with increasing CFCs and ocean heat content.]
Ozone depleted by **humans** and by volcanic eruptions

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 1991

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

Bárðarbunga 2014

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

Siberian traps: 251 Ma covered 7 million km² in more than 100,000 years

Bárðarbunga: 2014 covered 85 km² in 6 months
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

Lake Magadi, Kenya, Trona

Mud Lake
Florida
Oil shale

Surdam, 2013

Oil shale
Trona
Dolostone
Eocene Green River Formation in Wyoming

53 to 48 million years ago

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

Major changes in climate almost every sample measured
Typically these basaltic lavas occur at the end of geologic time units.
Large Igneous Provinces punctuate the geologic time scale

<table>
<thead>
<tr>
<th>Large Igneous Provinces</th>
<th>CENOZOIC</th>
<th>MESOZOIC</th>
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<tr>
<td>Siberian basalts</td>
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Large Igneous Provinces punctuate the geologic time scale

The balance of effusive and explosive volcanism due to plate tectonics explains climate change in detail.
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
These are exciting times to be a geoscientist as we move plate tectonics to the next level of detail.