Science Topic 12-26-23

CliSciPol

Climate Science and Policy for Nonscientists

One picture is worth a thousand words.

Climate History I - from Earth's Formation (4.5 billion years ago) to the Holocene Interglacial (11,000 years ago)

Numerous and massive changes have occurred in the earth's climate over the years due to natural forces.

Scientists only started using modern instruments to measure the climate in very recent centuries. Most dates and data discussed in this post have large uncertainties and are subject to debate. In general, the older the dates, the greater the uncertainty. But the information is accurate enough to convey a reasonable sense of earth's climate history.

Abbreviations used: B = billion years ago. M = million years ago. K = thousand years ago

4.5 B The earth was formed as space rocks and ice comets coalesced. The process of coalescence created so much heat that the earth was a great molten ball of lava about 1,000-2,000 F in temperature. The sun was only 70-75% as bright as today. The earth was rotating so rapidly that the day was only 2-3 hours long.

4 B It took hundreds of millions of years for the earth's surface to cool enough to form a crust. By 4 B the surface was down to 100 C, the temperature of boiling water.

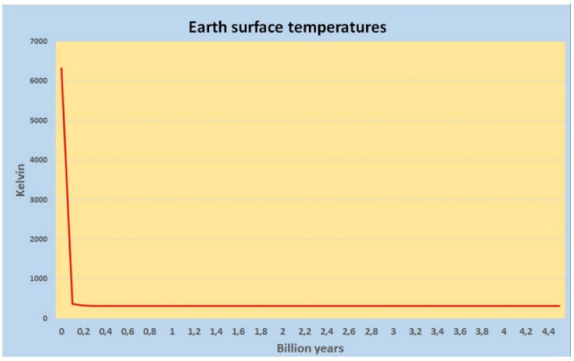
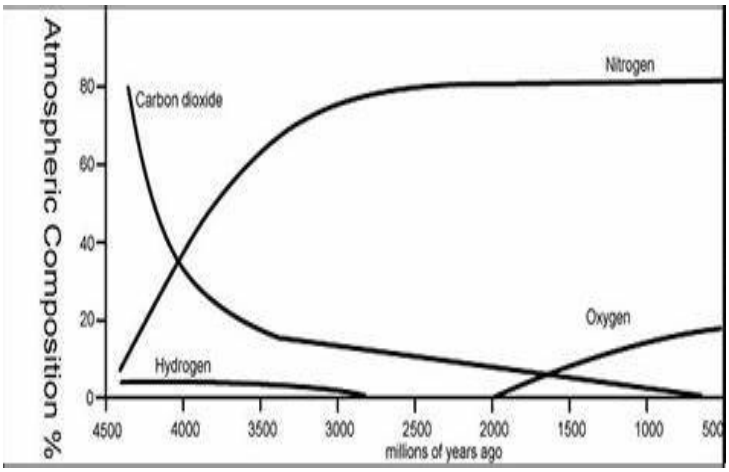
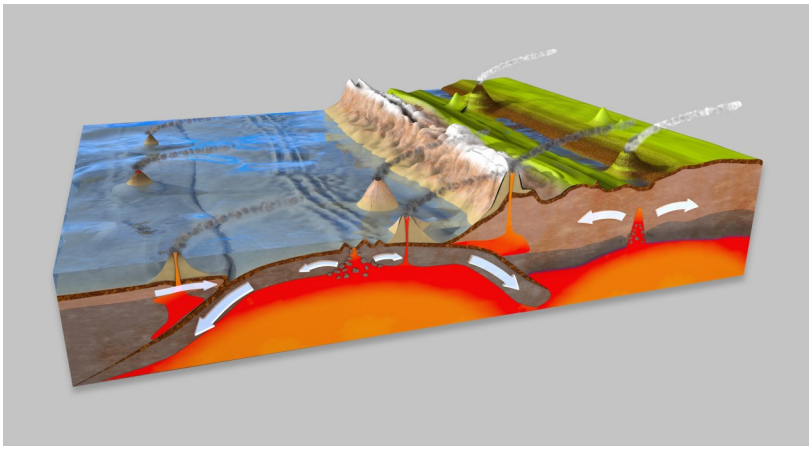


***Figure 2**. After earth had formed, temperatures dropped very quickly to below 100°C and remained within the narrow window that supports life ever since*

The atmosphere was as much as 80% CO2 versus 0.04% today. There was almost no nitrogen and no oxygen in the air (now 78% nitrogen and 21% oxygen).

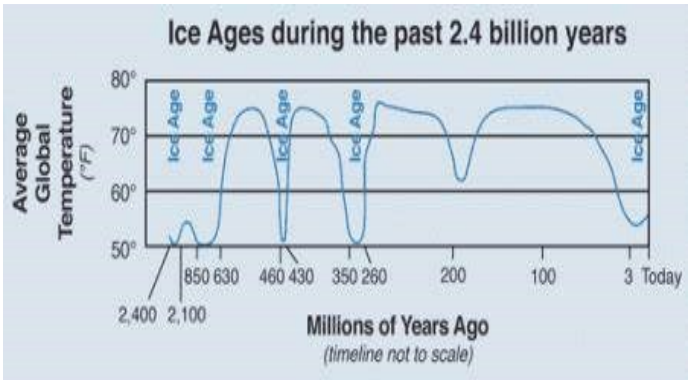


Volcanos are the eruption of lava from earth's hot core to the surface. As the earth has cooled its hot core has gotten smaller and smaller, and volcanic eruptions have become less and less frequent. In past millenia volcanic eruptions have been the largest source of the CO2 in the atmosphere.

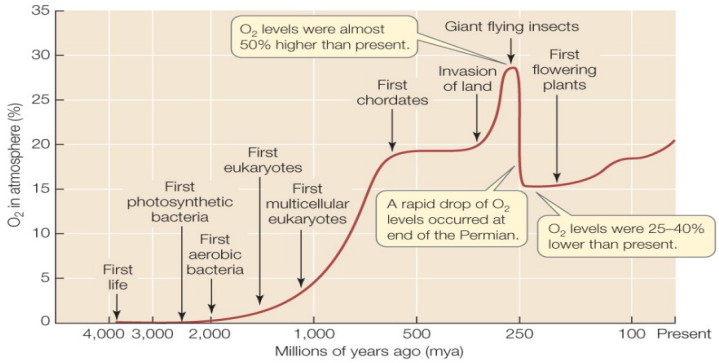


2.6 B CO2 was still 25-50% of the atmosphere, and there was still virtually no oxygen in the air or in the oceans. The spinning of the earth had slowed so that a day was roughly 19 hours.

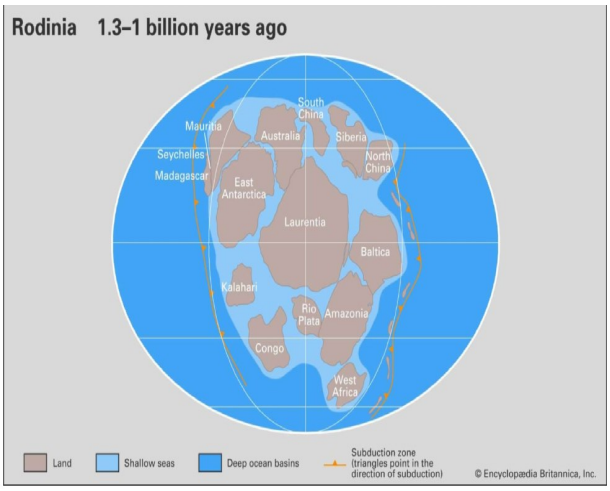
2.4 B The 1st of earth's five identified ice ages (the Huronian) began, lasting some 300 million years. The first "Snowball Earth" may have occurred with glaciers reaching from the poles all the way to the equator.



2.0 B For the first time oxygen began building up in the atmosphere (the "Great Oxygenation Event"), and multicellular life appeared. The amount of oxygen in the air has varied greatly over the years.

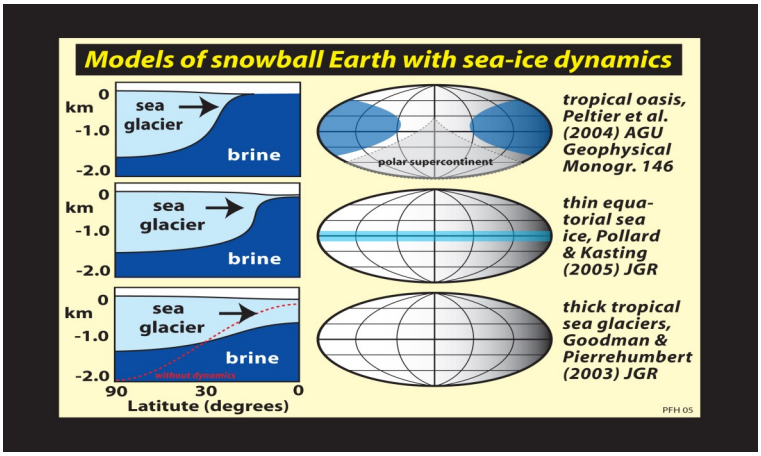


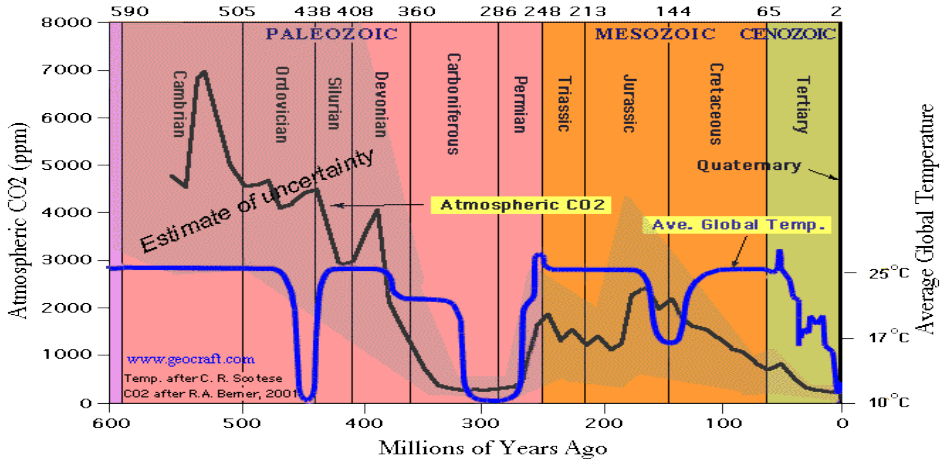
1.3 B All of earth's land formed a supercontinent named Rodinia, the first of two supercontinents. Rodinia broke up very slowly over hundreds of millions of years.



800 M The earth's first animals (probably sponge-like) appeared.

720 M The 2nd Ice Age (the Cryogenian) began and lasted almost 90 million years. This was the most severe ice age Glaciers may have reached from the poles to the equator twice. Oceans were covered with ice and were uninhabitable due to lack of oxygen. Scientists wonder how life survived.





600 M Scientists' reconstructions of earth's temperatures and atmospheric CO2 levels go back to this date. Such reconstructions suggest: (1) that the earth has had a usual temperature of around 25 C (77 F) versus a present earth temperature of 15 C (59 F), and (2) that CO2 levels have varied widely with a long term descending trend from a high of around 7,000 ppm 550 million years ago. For most all of the last 600 million years CO2 levels have been much higher than the present level of 420 ppm. The average CO2 level has been over 2,600 ppm. The main source of CO2 in the atmosphere has been volcanic eruptions, and, as the frequency of volcanic eruptions has diminished, particularly over the last 150 million years, the CO2 in the air has trended downwards, because plants eat massive amounts of CO2, and the oceans absorb massive amounts of CO2, processes that continue to the present day.

540M There began an explosion of multicellular complex life forms known as the Cambrian Explosion, the biggest emergence ever of animal species.

When life exploded

Scientists probe what happened 540 million years ago to trigger the biggest emergence ever of animal species

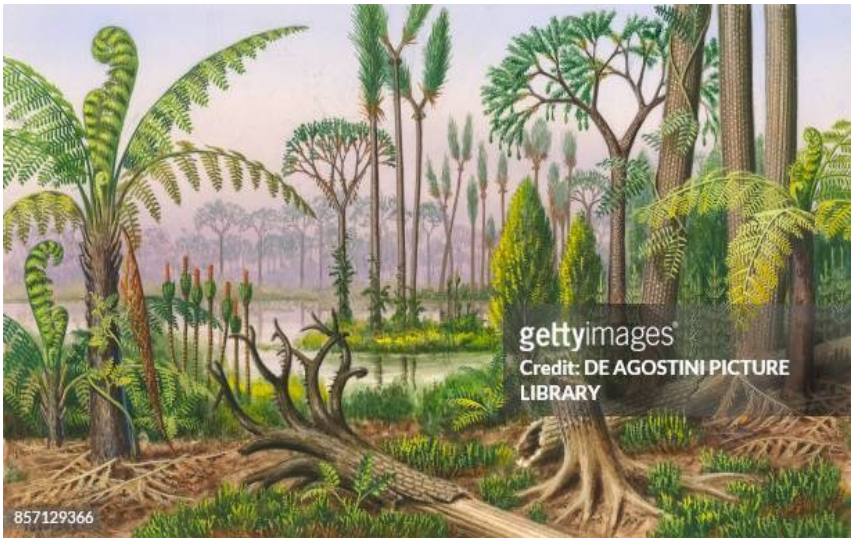
In this artist's conception of an ocean scene during the Cambrian Period, the fearsome predator at upper left, called *Anomalocaris canadensis* — or "unusual Canadian shrimp" — chases three trilobites.

460M Plants first appeared on land, very different from plants today.

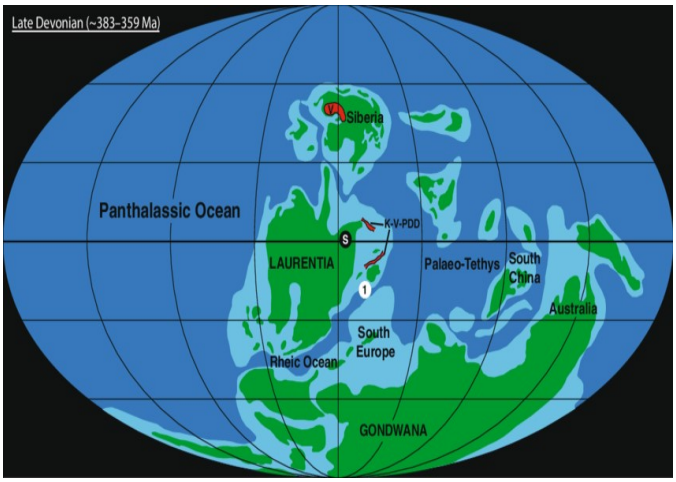
450M The 3rd Ice Age (the Andean-Saharan) began. This was the shortest of the earth's four completed ice ages, lasting only 30 million years.

440M The Ordovician Mass Extinction began. This was first of the earth's five mass extinctions, which are defined as periods where the extinction rate was 75% or more. During this extinction 85% of all species became extinct, probably caused by the massive glaciation that accompanied the Andean-Saharan Ice Age.

420M The Devonian Period began, during which there was a vast spread of forests and a massive increase in biomass. Trees are almost 50% carbon. Trees and plants grow by eating CO2. During this period earth's CO2 level decreased from a high of 4,000 ppm down to 1,000 ppm.



375M In the late Devonian most of the earth's land was concentrated in the Southern Hemisphere.

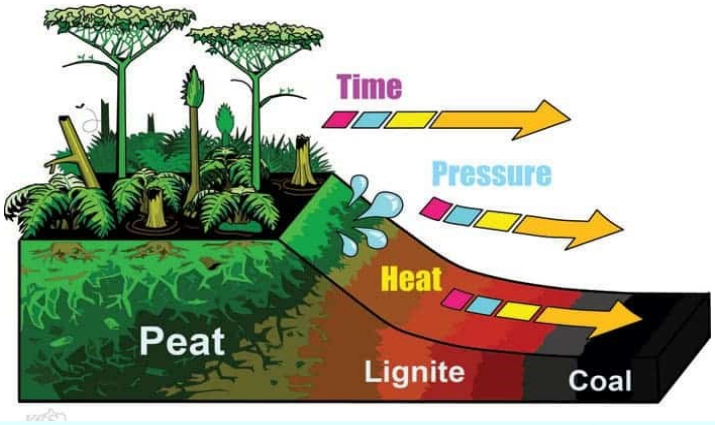


Also the 2nd Mass Extinction (the Late Devonian Extinction) began, eventually killing 75% of all species. This was caused by decreases in the oxygen levels in the oceans, but the reason these decreases occurred is unsettled.

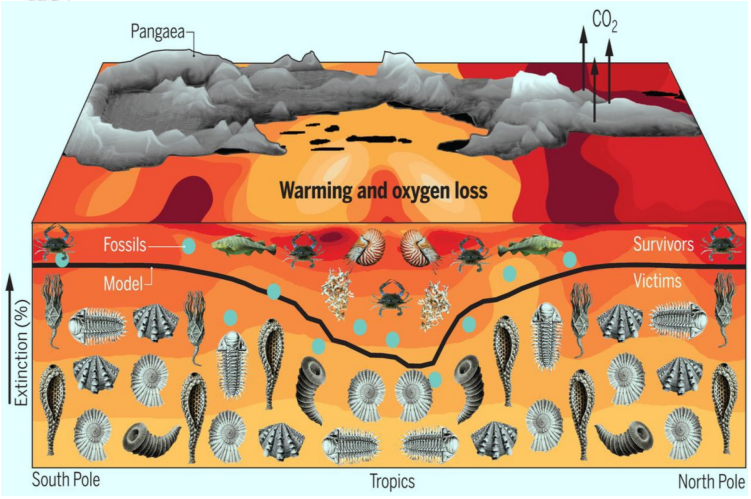
360M The 4th Ice Age (the Karoo) began, lasting nearly 100 million years.

320M The second supercontinent, Pangea, was formed. It started to break up around 200 M.

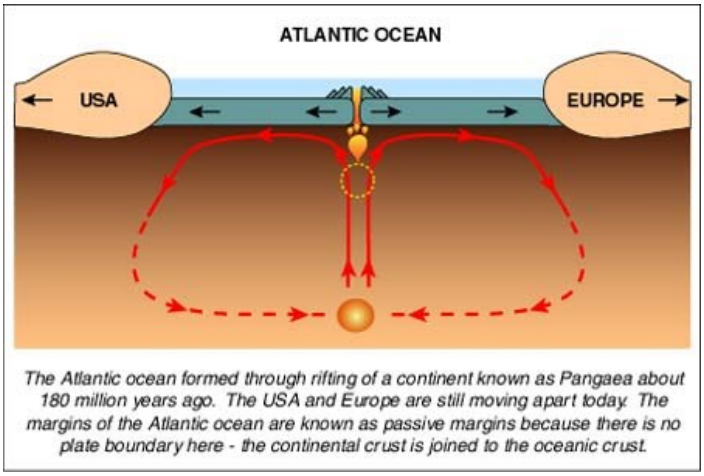
300M The ice age cooling and drying climate devastated vast amounts of tropical rain forests. Huge amounts of biomass were covered over leading to massive amounts of coal formation. This period is named the Carboniferous, which means producing or containing carbon or coal. Around this time the earth's rotation had slowed so that the day was 22 hours.



253M The 3rd Mass Extinction, the End-Permian Extinction, the most severe of the five mass extinctions, began and killed 96% of marine species and 70% of land species. There is no agreement on the causes of this extinction.



201M The 4th Mass Extinction, the Triassic-Jurassic Extinction, began and killed 80% of all species. Again there is no agreement on the causes, but a leading theory is that volcanic eruptions brought about a global winter.



The Atlantic ocean formed through rifting of a continent known as Pangaea about 180 million years ago. The USA and Europe are still moving apart today. The margins of the Atlantic ocean are known as passive margins because there is no plate boundary here - the continental crust is joined to the oceanic crust.

180M Lava rising along the Mid-Ocean Ridge pushed the Western Hemisphere apart from Europe and Africa, creating the Atlantic Ocean.

100M Australia started to separate from Antarctica. Sea levels were higher than today by 250-300 meters (820-980 feet).

66M The 5th Mass Extinction, the K-T Extinction, began and killed 75% of all species, including all of the dinosaurs. This was caused by an asteroid over 8 miles in diameter crashing into what is now Mexico. The debris in the air blackened the sky causing a global winter.

50M Forests covered the world from pole to pole during the Eocene Thermal Maximum. Then the earth started a long-term trend of becoming colder and colder.

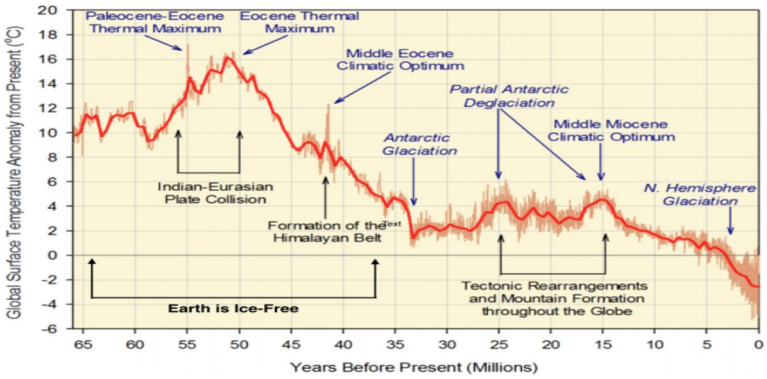
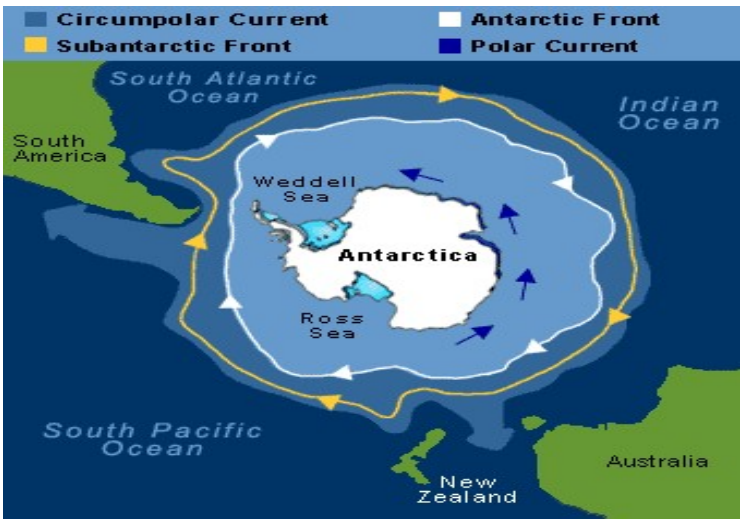
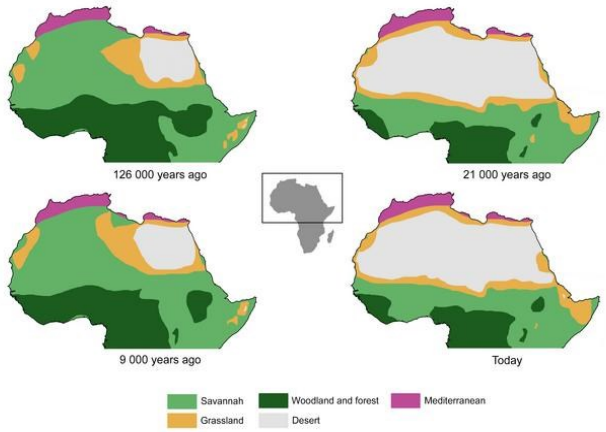


Figure 5. Global surface temperature from 65 million YBP showing the major cooling trend over the past 50 million years. While the poles were considerably warmer than they are today, there was much less warming in the tropics, which remained habitable throughout. The Earth is in one of the coldest periods during the past 600 million years.[24]

35M Antarctica was enough separated from Australia and South America to allow the formation of the Antarctic Circumpolar Current, the earth's fastest and strongest current. The Antarctic Ice Sheet started to form.



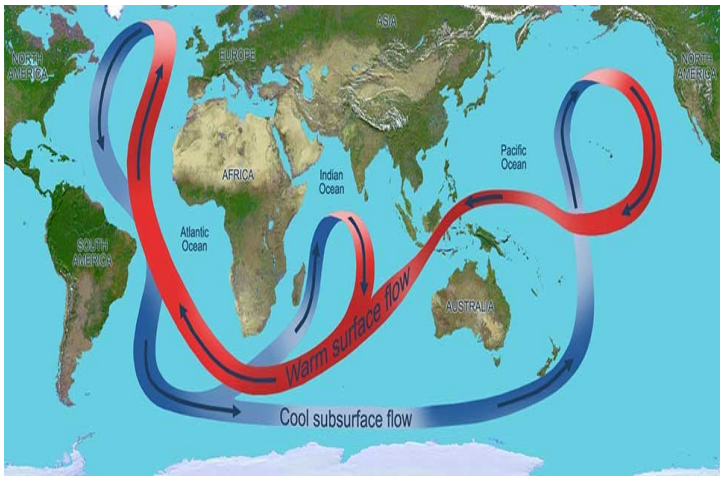
7 M The Sahara Desert Cycle began. Every 20,000 years the Sahara has a wet period, lasting 6,000 years, during which the Sahara turns green. The most recent wet period ended 5,000 years ago. It is speculated that this drove the inhabitants of the Sahara into the Nile Valley and led to the rise of Egyptian civilization.



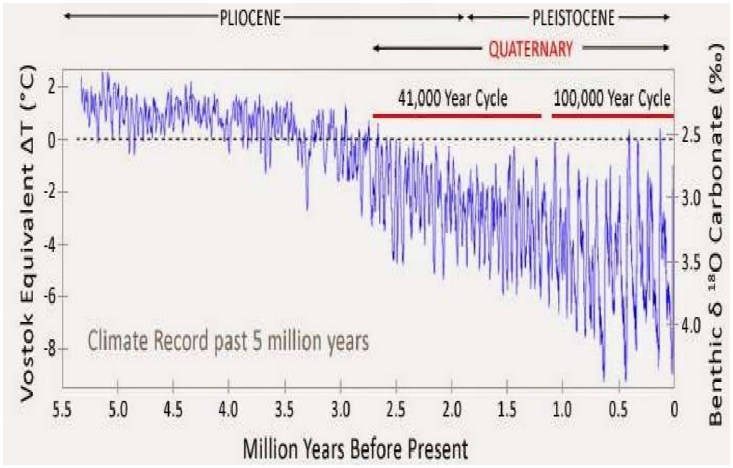
6 M The strait of Gibraltar closed, leading to the Mediterranean drying out and leaving a salt desert. The Mediterranean has dried out several times, leaving salt deposits as much as 1.9 miles thick.

5.3M Gibraltar reopened causing the largest flood in earth's history, the Zanclean Flood, as the Mediterranean refilled.

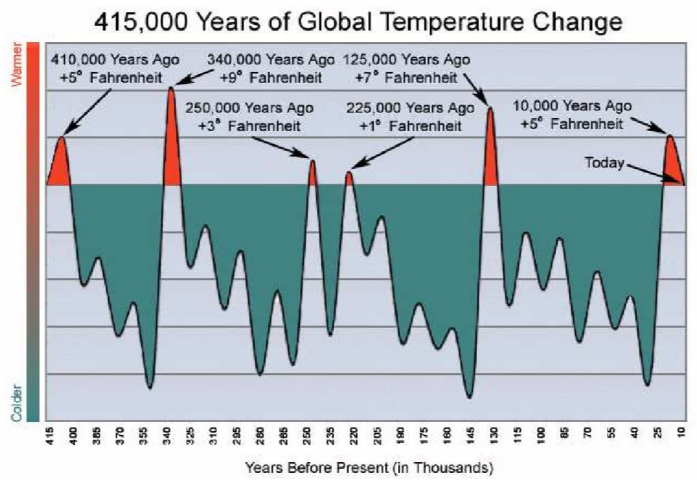
3 M North and South America were connected by Central America resulting in the redirection of the main Atlantic current, which had previously flowed Westward between North and South America. This current now flows Northward and includes the Gulf Stream, which warms Europe. The Antarctic Circumpolar Current prevents warm water from the tropics from reaching Antarctica and keeps Antarctica the earth's coldest spot.



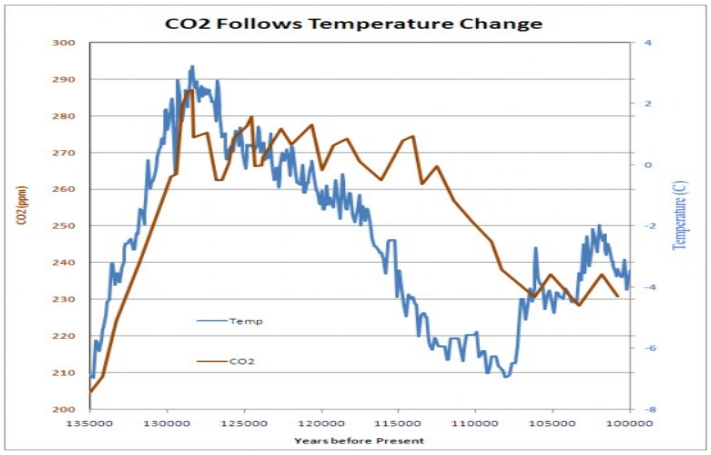
2.6M The 5th Ice Age, the Quaternary (or Pleistocene), began as an ice sheet began to form on Greenland. Since the shortest prior ice age lasted 30 million years, this ice age is still relatively young. Over the last 2 million years not only have temperatures fallen, but also the climate has become much more variable. There have been over 40 massive temperature cycles with temperatures varying as much as 8 C or 15 F.



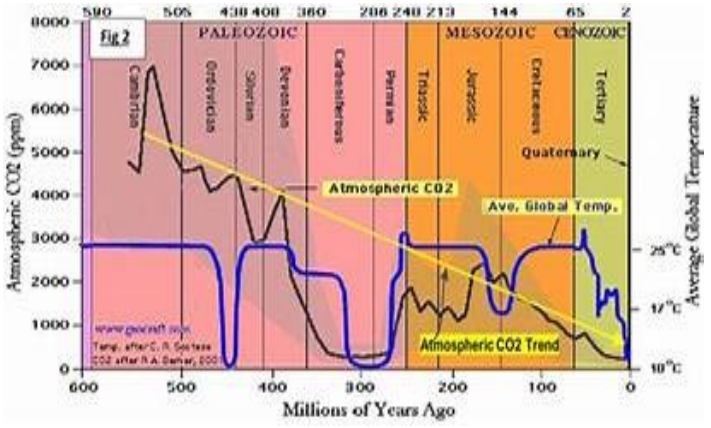
415K In the last one million years the cycles have lasted about 100,000 years. The graph shows the 4 cycles since 415 K. Each cycle consists of a short warm period of about 10,000 years, called an interglacial, between 90,000 year periods of glaciation. Fortunately for us, we are living in one of the warm interglacials, named the Holocene. As shown, prior interglacials have been warmer than our present interglacial.



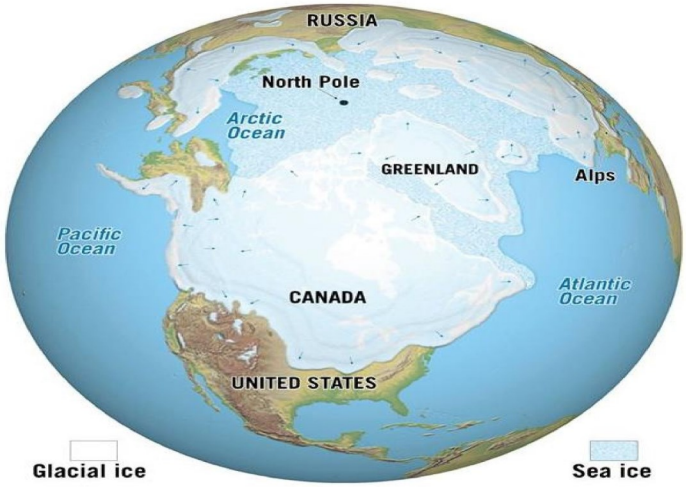
130K The Eemian Interglacial, the interglacial prior to our present interglacial, began. The Eemian was several degrees warmer than today, and sea levels were 15-25 feet higher than today. As shown, CO2 levels *followed* temperature levels both rising and falling, rebutting the modern theory that CO2 is the "control knob" of earth's climate.



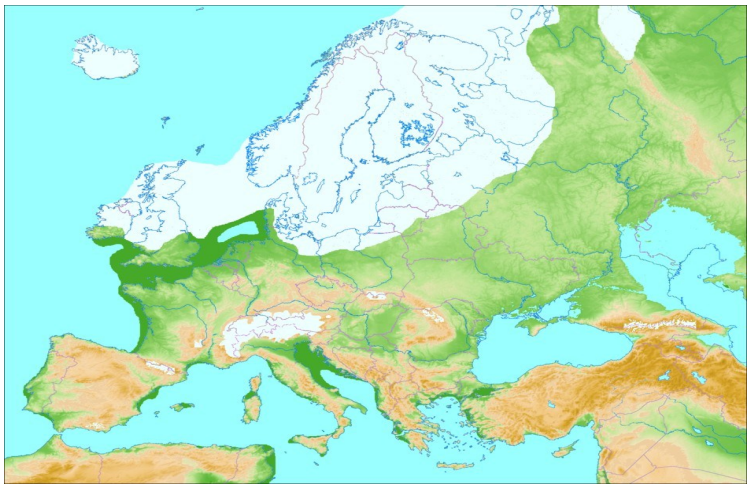
There is much historical data that rebuts the "control knob" theory. For example, CO2 levels rose dramatically during the Cambrian, the Devonian, and the Jurassic Eras, but temperatures did not rise. During the Permian Era temperatures rose dramatically and CO2 followed, as during the Eemian Interglacial, previously discussed.



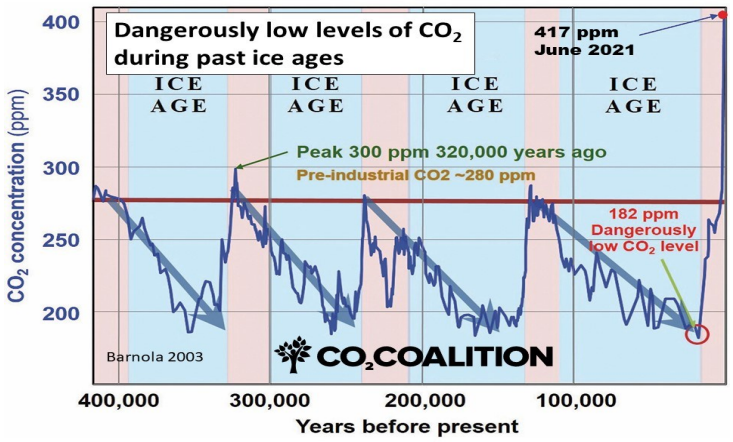
20 K Temperatures bottomed out in the most recent glacial maximum. The Laurentide Glacier covered all of Canada and large areas of the Northern US. New England was covered by a glacier nearly a mile thick. Sea levels were nearly 400 feet lower than today.



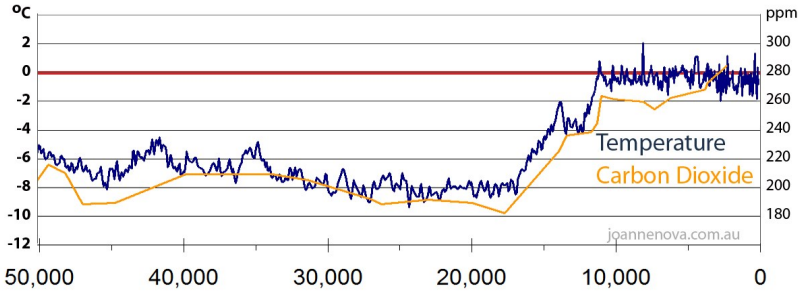
In Europe most all of Great Britain and all of Scandinavia was covered as well as substantial other areas. Glaciers from the Alps extended into South-Eastern France almost to Avignon.



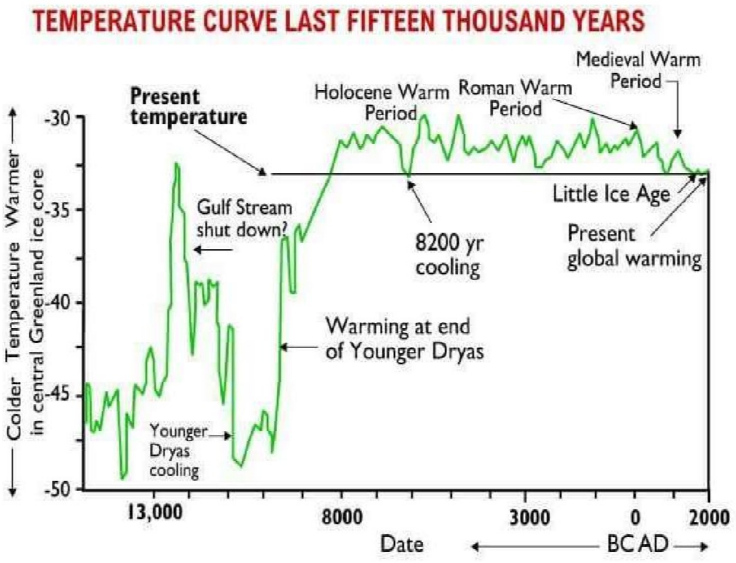
Falling temperatures cause falling atmospheric CO2 levels. Plants starve to death if CO2 falls to 150 ppm. During the recent glacial maximums CO2 levels fell as low as 182 ppm, which causes plants to be seriously undernourished. During the recent glacial maximums many areas of the world that are now green were deserts, experiencing major dust storms. Optimum CO2 levels for plant growth are 1,500-2,000 ppm. The lows at the recent glacial maximums are the lowest that CO2 levels have ever been in earth's history.



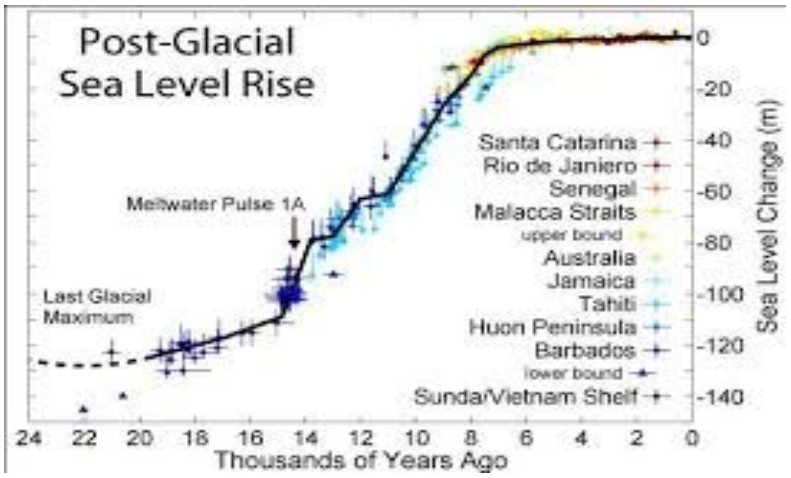
17 K From this time through 11 K world temperatures rose dramatically (8 C or 14 F). Since then, temperatures have remained relatively constant. The temperature rise preceded the rise in CO2 levels, so the temperature rise could not have been caused by the CO2 rise.



A more detailed reconstruction covering just the last 15,000 years shows the temperature rise as occurring from 15 K to 8 K and shows the speed of the rise and also the Younger Dryas Cooling Period, for which there is, as yet, no agreed explanation. It also shows relatively stable temperatures over the most recent 8,000 years.

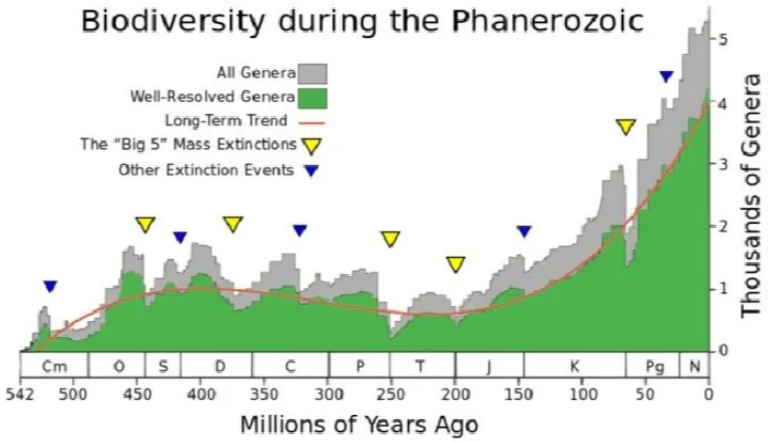


As temperatures dramatically rose, sea levels rose nearly 400 feet (120 meters) and for the last 8,000 years have remained relatively stable.



11 K Our present geological period, the Holocene Interglacial or Epoch, began, a short period of relative warmth in the midst of the Quaternary Ice Age.

An estimated 95-99% of all species that ever existed have become extinct. The earth has passed through 5 Mass Extinctions. Five "other extinction events" are noted. But despite these losses earth's biodiversity is now greater than ever with over 5,000 total genera. Extinctions in the modern era are discussed on this web site in the Science Topic: Extinctions.



The earth's climate history will continue in the post: Climate History II.

When will the next 90,000 year period of glaciation begin? Scientists have no answer. They though it might have begun back in the 1972. (see the following letter that states, in part, that "The cooling now under way in the Northern Hemisphere...seems fast enough to bring glacial temperatures in about a century.")

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DEPARTMENT OF GEOLOGICAL SCIENCES

(401) 863-2240

December 3, 1972

The President
The White House
Washington, D. C.

Dear Mr. President:

Aware of your deep concern with the future of the world, we feel obliged to inform you on the results of the scientific conference held here recently. The conference dealt with the past and future changes of climate and was attended by 42 top American and European investigators. We enclose the summary report published in Science and further publications are forthcoming in Quaternary Research.

The main conclusion of the meeting was that a global deterioration of climate, by order of magnitude larger than any hitherto experienced by civilized mankind, is a very real possibility and indeed may be due very soon. The cooling has natural cause and falls within the rank of processes which produced the last ice age. This is a surprising result based largely on recent studies of deep sea sediments.

Existing data still do not allow forecast of the precise timing of the predicted development, nor the assessment of the man's interference with the natural trends. It could not be excluded however that the cooling now under way in the Northern Hemisphere is the start of the expected shift. The present rate of the cooling seems fast enough to bring glacial temperatures in about a century, if continuing at the present pace.

The practical consequences which might be brought by such developments to existing social institutions are among others:

1) Substantially lowered food production due to the shorter growing seasons and changed rain distribution in the main grain producing belts of the world, with Eastern Europe and Central Asia to be first affected.

2) Increased frequency and amplitude of extreme weather anomalies such as those bringing floods, snowstorms, killing frosts etc.