The Past is the Key to the Present:
Greenhouse and Icehouse over Time

IAN PLIMER

IN THE LONG AGO

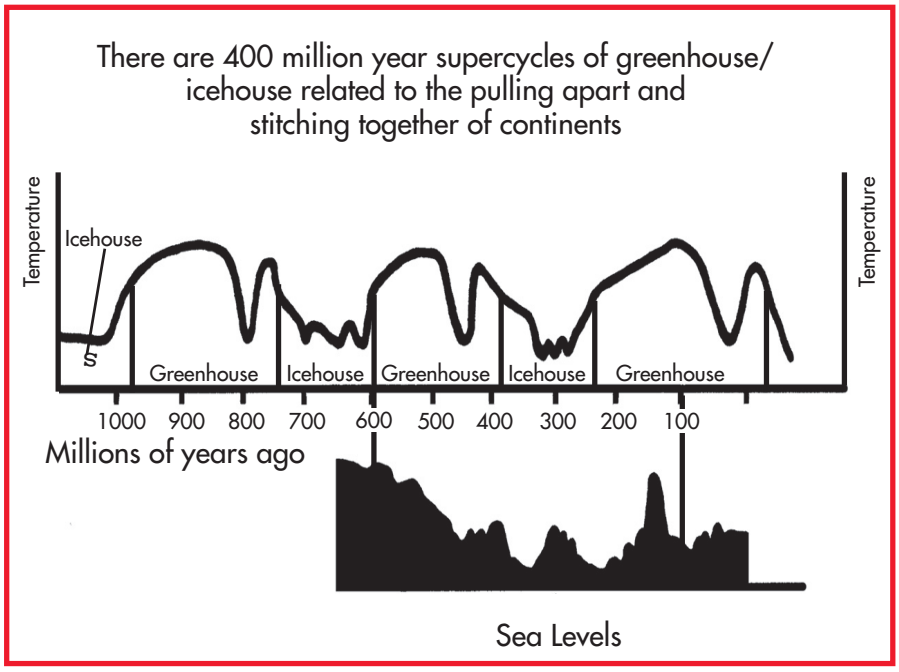
Planet Earth condensed 4,550 million years ago (Ma) from recycled stardust. Since that time, the continents have been enlarging, Earth materials have been constantly recycled and the Earth and all associated systems have been dynamically evolving. The Earth has not stopped being an evolving dynamic system just because humans now live on the continents.

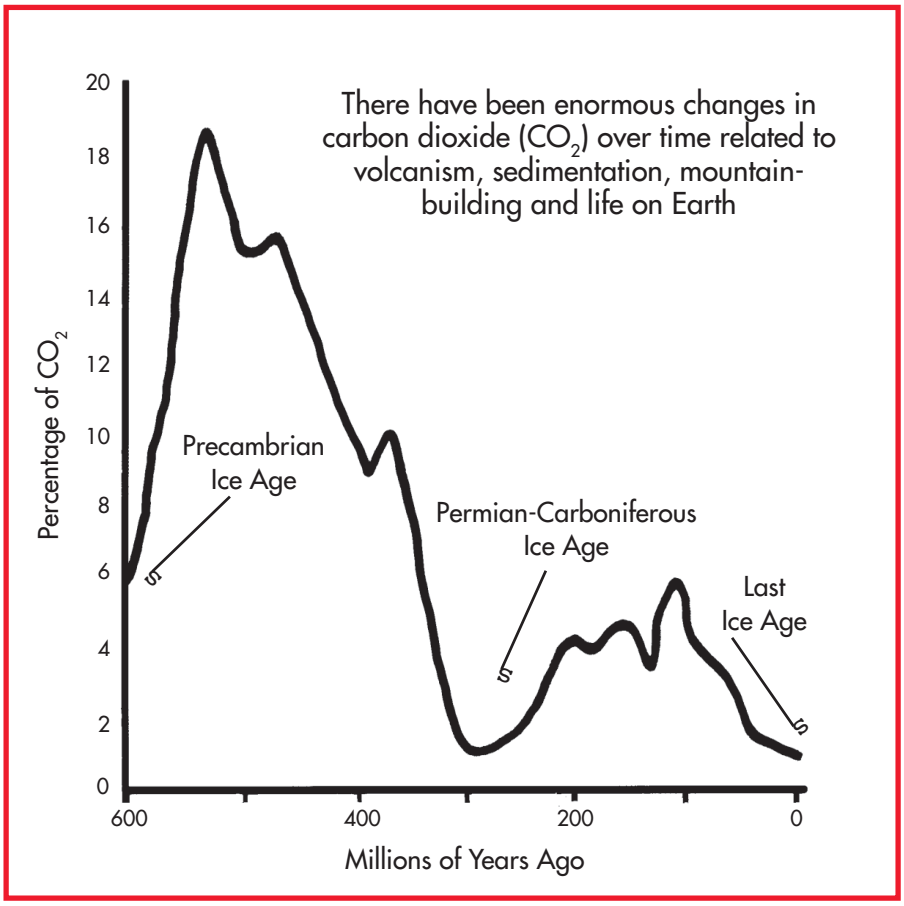
As soon as there was liquid water on Earth, there was life. Bacteria slowly diversified and, by the time the Earth was middle aged, one group of bacteria had emitted such large quantities of oxygen (O_2), that the atmosphere contained minor O_2. Some of this excess O_2 was trapped in rocks by weathering, most dissolved in the oceans resulting in the precipitation of iron oxides. It is these iron oxides that form the great iron ore fields of planet Earth (for example, in the Hamersley Basin). Life, the atmosphere, the oceans and the rocks interacted, a process that has been occurring for at least 2,500 million years on our dynamic evolving planet.

For at least the last 2,500 million years, the continents have been pulled apart and stitched back together. Every time the continents are pulled apart, huge quantities of volcanic water, carbon dioxide (CO_2) and methane (CH_4) are released into the atmosphere and greenhouse conditions prevail. When continents stitch together, mountain ranges form. Mountains are stripped of soils, new soils form and remove CO_2 from the atmosphere, these soils are stripped from the land and the CO_2 becomes locked in sediments on the ocean floor. When atmospheric CO_2 is low, glaciation occurs. Large climate cycles can be related to plate tectonics.

The origin of the greatest climate change on Earth is an enigma. Between 750 and 600 Ma, there were two major glacial events and numerous smaller events. Sea level changed by up to 400 metres and interglacial sea temperatures were 40°C. After glaciation, the atmosphere had some 20 per cent CO_2 and bacteria thrived and diversified in the warm oceans. Multicellular life appeared, diversified and used the CO_2 to make shells and skeletons. This explosion of life from 580 to 520 Ma gave us all of the major life forms currently present on Earth.

Plants appeared at 470 Ma and there was a major mass extinction of multicellular life at 430 Ma. The origin of this mass extinction is not known. Vacated ecologies were quickly filled and life continued diversifying. Between 368 and 248 Ma, massive coal deposits formed, there was a major 50 million-year period of glaciation and the atmosphere was blessed with a very high CO_2 and O_2 content. Life continued to diversify. Minor mass extinctions continued and, at 248 Ma, the biggest major mass extinction on Earth took place. Some 96 per cent of species became extinct. Life diversified quickly to fill the vacated ecologies. The record written in stone by fossils in the period 520Ma to the present shows that the planet is a warm, wet, greenhouse, volcanic planet with the normal cycles of rising and fall-





ing sea levels, rising and falling land levels and changing climates.

THE DAY BEFORE YESTERDAY

Some 120 million years ago, Australia was at the South Pole enjoying a temperate climate. Global sea level was more than 100 metres higher than at present, the sea surface temperature was 10–15° C higher than now and many continents were covered by shallow tropical seas. Planet Earth was a warm, wet, greenhouse paradise and thick vegetation covered the land masses. Atmospheric CO_2 was about 1 per cent when the world's major coal deposits formed 368 to 248 Ma.

From 250 to 120 Ma, the global CO_2 content varied greatly and increased to a peak 6 per cent CO_2 120 Ma. This derived from intense volcanic activity associated with continental fragmentation. Thick vegetation covered the land masses.

Australia started to pull away from Antarctica at about 100 Ma. It drifted northwards, the Tasman Sea opened and the Indian Ocean opened with India starting to drift away from Western Australia. The opening of the Tasman Sea produced the rise of the Great Dividing Range, the diversion of the major river systems and changes to the climate of eastern Australia.

A minor mass extinction of life 90 million years ago was the result of volcanoes in the Indian and Pacific Oceans belching out CO_2 and other gases into the oceans and atmosphere. There was a runaway greenhouse until volcanism waned. But volcanic emissions of CO_2 are common. In 1984 and 1986, burps of CO_2 from the volcanic crater lakes of Monoun and Nyos respectively killed thousands and added CO_2 to the atmosphere. Near Mt Gambier, volcanic CO_2 is commercially extracted from rocks, one small hot spring on Milos contributes 1 per cent of the planet's volcanic CO_2 and huge quantities of CO_2, the planet's second most common volcanic gas, constantly leak from unseen submarine volcanoes.

Another minor mass extinction at 55 Ma was caused by a Caribbean volcano. There was a rise in sea temperatures by up to 8°C for 100,000 years and atmospheric CO_2 was 10 times that of today. During this greenhouse, plankton sucked up the atmospheric CO_2, mammals thrived and life filled the vacated ecologies. Atmospheric CO_2 decreased from 3500 to 700 ppm within a million years, stayed low until 47 Ma and went up and down to about the present level (365 ppm) at 40 Ma.

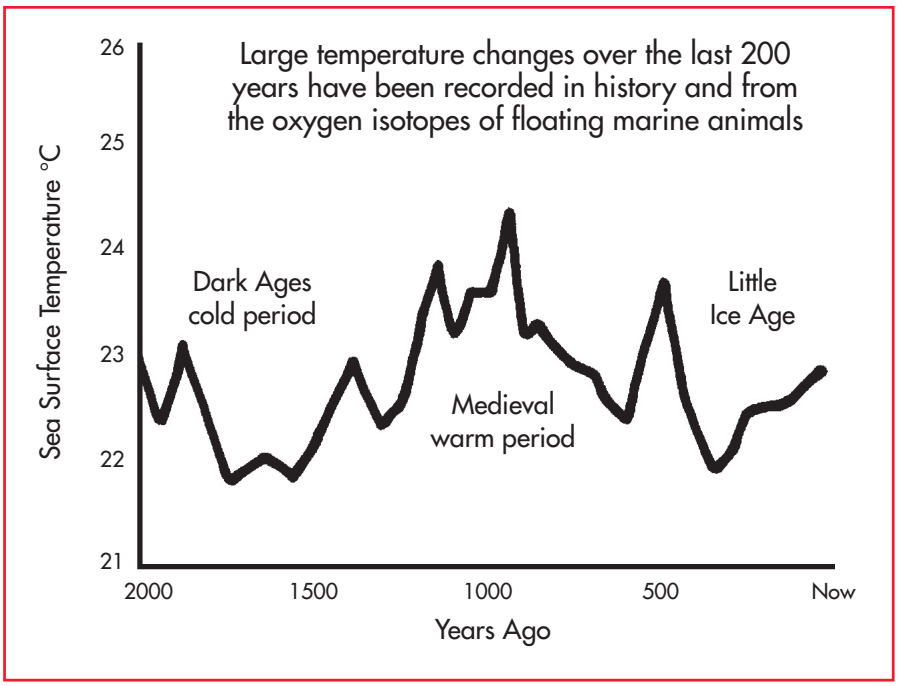
India collided with Asia at 50 Ma. Uplift produced the Tibetan Plateau which started to scrub CO_2 out of the atmosphere. The Tibetan plateau is still rising and CO_2 is still being scrubbed out of the atmosphere. The Drake Passage opened as South America drifted from Antarctica, a circumpolar current developed and Antarctica refrigerated. Southern Australia, from 17 to 14.5 Ma, was again tropical with mid-latitude temperatures 6°C warmer than today. Atmospheric CO_2 was 180–290 ppm. This greenhouse occurred when atmospheric CO_2 was 30–50 per cent lower than today!

By 5 Ma, Earth cooled, and was so cool that very slight orbital wobbles now had a bearing on climate, and every 100,000 years was characterized by 90,000 years of glaciation and 10,000 years of interglacial. We are currently in one of those interglacial periods.

The penultimate interglacial was 120,000 years ago. *Homo erectus*, *Homo neanderthalensis* and *Homo sapiens* coexisted, sea level was 6 metres higher than at present, the planet was far

warmer and wetter than now and atmospheric CO_2 was 78 per cent of that today. After warming, the atmospheric CO_2 and CH_4 content increased, suggesting that atmospheric temperature rise drives an increase in atmospheric carbon dioxide and methane contents. During the history of the latest glaciation, armadas of ice were released into the sea every 7,000 years resulting from the physical failure of thick ice sheets. These had a profound effect on climate. Small cool periods occurred every 1,100 to 1,300 years.

The zenith of the last glaciation was 18,000 years ago. Sea level was 130 metres lower than today, temperature was 10–15°C lower than today and the northern hemisphere was covered by ice to 38°N, up to 3 kilometres thick.



YESTERDAY

The northern polar ice sheet started to melt 14,700 years ago. There were very rapid and major temperature fluctuations, sea levels rose and fell and the total sea level rise over the last 14,700 years has been at least 130 metres. Sea level rise resulted in the breaching of the Mediterranean into the Black Sea Basin some 7,600 years ago and is probably the origin of the Sumarian, Babylonian and biblical stories of a great flood.

One of the consequences of a massive sea level rise over the last 14,700 years is that the West Antarctic Ice Sheet was no longer underpinned by the land. Two thirds of the West Antarctic Ice Sheet collapsed into the oceans and sea level rose 12 metres. The final third of the West Antarctic Ice Sheet has yet to collapse to produce a 6 metre sea level rise as part of the dynamic post-glacial climate on Earth. Climate changes induced by changes in ocean currents cooled North Africa, grasslands changed to a desert, humans migrated and the great Mesopotamian cities were established.

Sea levels were 1–3 metres higher in a greenhouse 6,000 years ago. There was 20 per cent more rainfall. Cold dry periods, glacier expansion and crop failures between 5,800 and 4,900 years ago resulted in deforestation, flooding, silting of irrigation channels, salinization and the collapse of the Sumerian city states. Long periods of El Niño-induced drought resulted in the abandonment of Middle Eastern, Indian and North American towns. In 1470 BC (?), Thira exploded, weakened the dominant Minoans and changed the course of western history.

Global cooling from 1,300 to 500 BC gave rise to the advance of glaciers, migration, invasion and famine. Global warming commenced again at 500 BC, there was an excess of food and great empires such as the Ashoka, Ch'hin and the Romans grew. Contemporary records and Roman clothing shows that conditions were some 5°C warmer than today.

In 535 AD Krakatoa exploded, as did Rabaul in 536 AD. The Earth passed through cometary dust in 536 AD. The dusty atmosphere reflected heat, and darkness prevailed. As a result, the climate cooled and there was famine and warfare. Changes in ocean currents resulted in the Medieval Warm Period from 900 to 1300 AD. The first to feel the change were the Vikings, who were able to navigate the northern waters, colonized Newfoundland, colonized Greenland and established extensive trade routes as far south as the modern Gulf States. On Greenland, crops were grown and there were cattle. This would not be possible today. The warmer, wetter climate of Europe produced excess crops and wealth which resulted in the building of castles, cathedrals and monastries. As with previous greenhouse events, there was great prosperity.

In 1280 AD, volcanic eruptions on Iceland and a change in ocean currents started the Little Ice Age which finished in 1920. The North Sea froze in 1303 and 1306–1307, there was massive famine in 1315, and the plague

pandemic attacked the weakened population in 1347–1349. There was massive depopulation and it took Europe 250 years to reach the population of 1280 AD. During the Little Ice Age, there were warmer periods associated with sunspot activity. During minimum sunspot activity (1440–1460, 1687–1703 and 1808–1821), the intensely cold conditions were recorded by the Dutch masters, and King Henry VIII was able to roast oxen on the frozen Thames. There were food shortages. Short cold periods occurred after the eruptions of Tambora (1815) and Krakatoa (1883) respectively. In fact, 1816 was known as the 'year without a summer'. This was the time when Turner painted stormy oceans and skies full of volcanic dust, Mary Shelley wrote *Frankenstein* and Byron wrote *Darkness*.

TODAY

The twentieth century and early twenty-first century AD are times of natural post-glacial rebound. Ice sheets, a rare phenomenon in the history of time, still exist. Sea level is relatively low, as are global temperatures and atmospheric CO_2. Between 1920 and 1945, there was a period of warming (0.37°C) and another that commenced in 1976 (0.32°C). In 1976–1977, global temperatures in the lower atmosphere jumped 0.3°C, sea surface temperature in the equatorial Pacific jumped 0.6°C, sea surface temperature during upwelling increased 1.5 to 3°C but there was reduced upwelling, the heat content of the upper 300 metres of the world's oceans increased, there was increased wave activity in the North Sea and the length of the day changed. The stepwise increase in temperature in 1976–1977 shows that there was a major re-ordering of the ocean heat transport, coinciding with an orbital change expressed as a change in the length of the day. Maybe the global warming of the twentieth century is just a measure of the variability on a dynamic evolving planet?

To put such measurements into perspective over the history of time, changes in atmospheric temperature in the twentieth century can only be considered small and slow. A 24-year global coverage of satellite atmosphere temperatures shows only modest warming in the Northern Hemisphere and a slight cooling in the Southern Hemisphere. Temperature measurements from balloons agree with the satellite measurements for the period of overlap. Because greenhouse warming is a phenomenon of the atmosphere, significant changes should have been recorded. They have not.

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CONCLUSIONS

Underpinning the global warming and climate change mantra is the imputation that humans live on a non-dynamic planet. On all scales of observation and measurement, sea level and climate are not constant. Change is normal and is driven by a large number of natural forces. Change can be slow or very fast. However, we see political slogans such as *Stop Climate Change* or government publications such as *Living with Climate Change*, demonstrating that both the community and government believe that climate variability and change are not normal. By using the past as the key to the present, we are facing the next inevitable glaciation, yet the climate, economic, political and social models of today assess the impact of a very slight warming and do not evaluate the higher risk of yet another glaciation. Geology, archaeology and history show that during glaciation, famine, war, depopulation and extinction are the norm.

In 1831, Admiral Sir James Robert George Graham had the Union Jack hoisted on a volcanic land mass that suddenly appeared near Sicily. It was called Graham Bank and was claimed by England. It was also claimed by the Kingdom of the Two Sicilies who called it Isola Ferdinandea, the French (L'Isle Julia) and other powers. In the subsequent dispute over ownership, France and the Kingdom of the Two Sicilies almost came to war and England and the Two Kingdoms of Sicily had a diplomatic row. During the intense diplomatic dispute, the island quietly slipped back underwater. Graham Banks serves to show that whatever political decisions we humans make, the land rises and falls, sea levels rise and fall, and climates change as they have done since the dawn of time.

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This article is an edited version of his recent paper to the IPA's Climate Conference, delivered on 28 February 2003, a full version of which can be found on the IPA's Website.

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