CO_2 INCREASE: QUESTIONS BEYOND CLIMATIC CHANGE

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CP-90-01
January 1990

IIASA

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This Report is an English translation of *CO_2-Anstieg in der Troposphäre — Ein Kardinalproblem der Menschheit*, which appeared in *Der Lichtbogen*, July 1989, no. 208:4-31. Published with the kind permission of Hüls AG, Marl, BRD.

FOREWORD

The "climatic change problem" is a political reality. CO_2 as a waste gas from fuel combustion and from other sources plays a major role. Human activities have caused a rise of some 30% in the natural levels of CO_2 in the atmoshphere so far with the expectation that a doubling seems a plausible occurrence during the first half of the next century.

From a chemical-biological point of view it is reasonable to consider consequences other than, or in addition to, climatic changes due to such enormous anthropogenic changes in the CO_2 concentrations. The authors of the present paper have gathered interesting evidence to show that, potentially, biological consequences could far outweigh the concerns about climatic changes. We put this paper before you as an attempt to stimulate a necessary discussion. Any comments are most welcome.

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Günter Beckmann and Burkhard Klopries

The increase of the tropospheric CO_2 (carbon dioxide) concentration is considered by scientists all over the world to be an alarming signal, as becomes evident from the huge amount of literature on the subject. The so-called greenhouse-gas effect, or, more precisely, its anthropogenic component, is mainly caused by the CO_2 increase. However, other trace gases have also contributed their share. Far-reaching climatic changes, a temperature increase in the tropospheric air, especially in the polar region, as well as a gradual melting of the Greenland and Antarctic ice with a simultaneous rise of the seawater level, are being predicted as a consequence of the greenhouse effect.

In addition to these gloomy prospects a new hypothesis has developed: The biological consequences of the evolution of a changed composition of the air could be hazardous to man and nature.

INTRODUCTION

According to numerous predictions, oil production will, within the next few decades, have reached its peak. Then there will be a shortage of easily producible oils. This situation is even aggravated by the fact that the oil reserves are mainly situated in politically instable regions.

Although there are longer-term reserves of unconventional oils (tar sands, oil slate, heavy oil residues), their production involves considerably higher costs, which, calculated at the present dollar value, would result in a price level of approximately 30 US$ per barrel (1 barrel = 159 liters). The gas reserves will, at the present utilization rate, probably last another 150 years and the coal reserves more than 2000 years. The estimates call for an economic utilization of natural gas, and particularly of oil. However, the fossil fuel reserves cannot yet be considered critical.

In addition to these considerations of the future availability of resources we are, at present, faced with the question of the effects of atmospheric pollutants on the earth. These two concerns point into the same direction; the latter is, however, of increasing importance in view of appropriate measures to be taken.

DIRECT EFFECTS OF ATMOSPHERIC POLLUTANTS

With regard to its effects on the atmosphere, gas is a relatively clean fuel, followed by oil and coal. But the present, high utilization rate of all three fuels poses a significant burden on the atmosphere. Figure 1 gives an overview of the anthropogenic effects of pollutants on the atmosphere.

The basic problem lies in the influence of trace gases, and especially of CO_2, on the heat balance of the atmosphere. The increase of the CO_2 concentration in the air is considered to be the main cause of the so-called greenhouse effect. The atmospheric CO_2 acts as an insulating cover. It can be penetrated by the short-wave solar radiation, but shields off the

Type of Pollutant	Dust	SO_x, NO_x Other Trace Gases	CFCs	Radioactive Substances	CH_4 (NH_3)	CO_2 CO
	Flue gases Traffic Industrially produced dust	Flue gases Exhaust gases	Propellant gases Coolants	Flue gases Nuclear power plant emissions	Swamp gases (cultivation of rice) Gases from the rumen of ruminants	Flue gases Rotting gases Exhaust gases Exhaled air
Damage	In exceptional cases deseases of the respiratory system (silicates, asbestos, soot) Inconvenience	Deseases of the respiratory system Inconvenience Soil acidity Damage to works of art	Destruction of the ozone layer of the atmosphere	Increased incidence of cancer, Mutations	Greenhouse gas effect Influence on the evolution of micro-organisms	
Remedy	Filtering Scrubbing Cyclone depositing	Catalysts Prepurification of fuels Optimization of combustion	Replacement by other substances or technologies	Filtering Depositing Strict control of nuclear power plants	?	

Figure 1. Anthropogenic Pollution of the Atmosphere

longer-wave heat radiation reflected from the surface of the earth. This leads to an increase in the mean temperature of the troposphere and a simultaneous decrease in the temperature difference between the equator and the polar regions, which does, in turn, result in a reduction of oceanic flows, in climatic changes and in a rising water level of the oceans.

Efforts were taken to make a quantitative assessment of the increase of the mean atmospheric temperature with the help of computer calculations. According to these calculations—which are, however, not yet generally accepted—a doubling of the CO_2 concentration would result in an average temperature increase of 2.5 to 4.4K.[1] Taking also the prospective influence of the other trace gases into account, this would result in a mean temperature increase of 3.0-5.4 K [1] for the same time period.

In the polar regions the atmospheric temperature will probably rise by more than 10K [2]. In the stratosphere, at a height of approximately 30 kilometers, there would, on the other hand, be a temperature decrease of some degrees [3]. The increased polar temperature would cause an eventual melting of the polar ice. The melting of the ice layer on the land (Antarctic, Greenland) would lead to a rise in the seawater level. This does, however, not apply to the Arctic ice, which floats on the water.

The mass of the Antarctic land layer is approximately ten times bigger than that of Greenland, and this is why the latter will melt first. The expansion of the ocean water due to the temperature increase will result in an additional, small rise of the seawater level. It will, however, take a very long time before a higher sea level, caused by the melting of the ice and the expansion of the water, will reach a point of serious concern—maybe 1 or 2 meters in 2000 years; this is due to the enormous "negative heat reserves" of the gigantic ice layers and the inertia of the oceanic heat balance [4].

The most serious aspect of the climatic change will most likely be the extension of the subtropical arid zones. It was, e.g., assumed that the Mediterranean region will, at a simultaneous temperature increase, have a considerably lower precipitation than today. On the other hand, there seem to be areas which could profit from the climatic changes, as, e.g., Siberia, where higher temperatures and a higher precipitation can be expected.

The increase in trace gas concentration as such is less problematic than the increase in CO_2 concentration. With some effort the former may, at least to a considerable extent, be alleviated by technical measures, such as, e.g., exhaust gas catalysts. The CO_2 emission is, however, inseparably connected with the combustion of fossil fuels. The elimination of CO_2 from combustion gases—an idea which is sometimes proposed—does not bring any improvement, as the chemical binding[2] and the subsequent depositing of the CO_2 generally requires more energy than is gained in the combustion process. Depositing of CO_2, which is produced as a pure gas in some chemical processes, in exhausted gas or oil caverns, salt mines or similar sites, or the depositing of CO_2 in the deep sea may be possible in individual cases and for limited quantities, but such processes are undoubtedly expensive, extremely limited in their application and thus not suited to make a significant contribution to the solution of the CO_2 problem.

The negative impact of CO_2 on the atmosphere is even aggravated by the fact that more woods are deforested than afforested, and that top soils are eroded, i.e. that the total amount of organically bound carbon on the earth is declining, thus releasing carbon in the form of CO_2 into the atmosphere. Every year a land area of the size of Bavaria is eroded (devastated) in the world. Forests decrease annually by approximately 0.5%, corresponding to an area of 200 000 km^2 [5]. The decline of the carbon organically bound in plants and top soils simultaneously reduces the photosynthetic capacity, i.e. the capacity of transporting carbon from the atmosphere into the soil. Thus a decreased plant growth presents a double negative effect.

[1] K = Kelvin; 0 K = −273.15°C, 0°C = +273.15 K.

[2] For binding CO_2 by, e.g., calcium hydroxide, calcium carbonate must first be burned, which requires more than the thermal energy for the combustion process. Moreover, the combustion releases that amount of CO_2, which can later be absorbed.

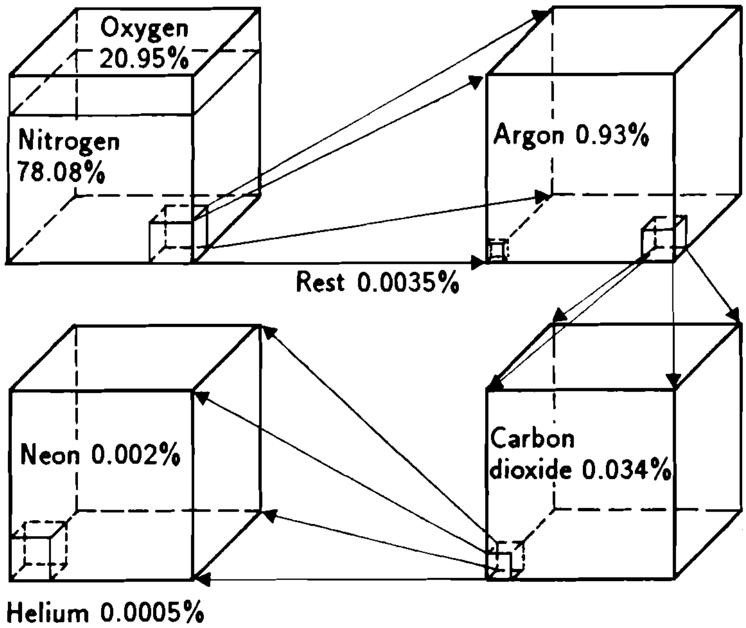


Figure 2: Composition of the air (volume share in %). Source: [6].

THE CARBON CYCLE

Figure 2 gives a schematic view of the most important components of the air we breathe [6]. The main components of the air, as illustrated in the Figure, are relatively evenly distributed in the troposphere. The other, lower quantities of trace gases and steam show wide regional differences in concentration.

Figure 3 gives the basic chemical reactions with regard to the CO_2 and O_2 content of

- respiration, combustion, weathering and rotting on the one hand, and
- photosynthesis on the other hand.

In the former reaction the carbon is released in the form of CO_2 from the ground (plants, top soils, coal, etc.) into the atmosphere. In the latter reaction the carbon from the atmosphere is restored into the soil. Photosynthesis is the only way for carbon, generating O_2, to be transported from the atmosphere back into the soil. Thus the carbon is circulating between soil (and water) and the atmosphere.

Figure 4 demonstrates an attempt of a quantitative representation of the carbon cycle [6].[3] In the upper part of the Figure we see a thick line indicating the route of 120×10^{12} kilogram carbon per year from the atmosphere via photosynthesis into the ground (biosphere, pedosphere). In the opposite direction there are two natural ways (indicated by the two narrower lines below) each transporting 60×10^{12} kilogram carbon per year back into the atmosphere: one route via respiration (mitochondrial respiration of singe-cell plants and animals) and one route from the ground via combustion and rotting. The exchange between atmosphere and ocean water of 100×10^{12} kilogram per year into each direction should, according to this simplified representation, be in balance. Many ecologists do, however, assume that even the carbon balance of the oceans is no longer stable. According to this theory, about half of the anthropogenic carbon input into

[3] A similar representation, containing more recent figures, can be found in Kohlmaier [7], an older figure is given in Revelle [2], p. 19.

RESPIRATION, COMBUSTION, WEATHERING, ROTTING

Release of thermal energy

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O$$

PHOTOSYNTHESIS

Supply of light energy

$$6\,H_2O + 6\,CO_2 \longrightarrow C_6H_{12}O_6 + 6\,O_2$$

Figure 3: Basic chemical reactions of respiration and photosynthesis.

the atmosphere is being absorbed by the ocean water, thus increasing its carbon content by approximately 3.5×10^{12} kilograms per year.

The CO_2 transportation through combustion as well as through the destruction of woods and soils is indicated by the thin lines (5 and 2). These mass flows, which seem to be relatively small, offset the total balance. Both mass flows show an increasing tendency. The flow labeled "wood and soil destruction", representing, in a way, the decreasing photosynthetic capacity of the earth, rises faster than the other.

It has been assumed for a long time that the CO_2 balance is not stable. The first "historical" proof for the validity of this assumption was furnished by a measuring station in Hawaii. There a clearly rising tendency of the CO_2 curve was observed over several years (see Figure 5). In the meantime such curves have been identified at many places. The individual values correspond surprisingly well. In his publication "Weltklima"[4] Revelle [2] compares, for example, values measured in Hawaii and at the South Pole. At present the annual rise in CO_2 concentration is found to be 2-3 ppm. Ten years ago the respective figure was only 1.6 ppm/year.

The increase in the world consumption of fossil fuels [6], as presented in Figure 6, may be considered as a confirmation of the fact that the rise in CO_2 concentration is not of a natural, but of an anthropogenic origin.

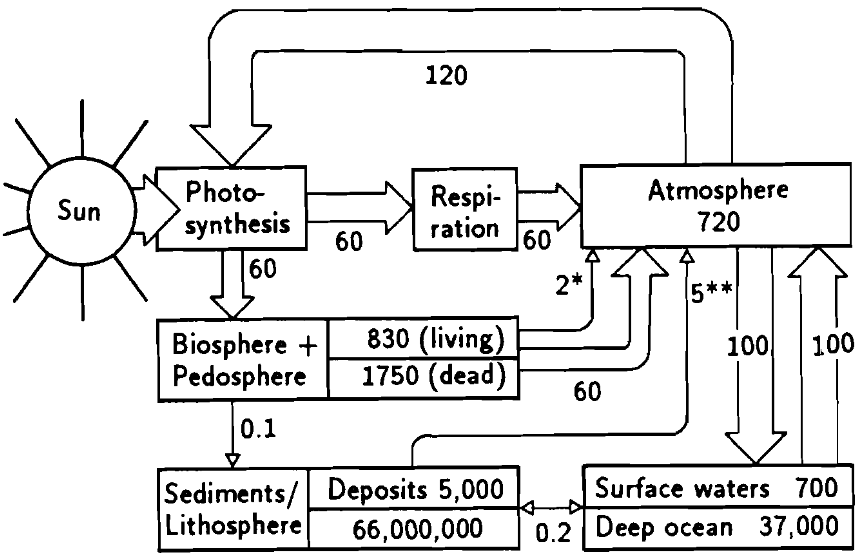
GEOLOGICAL DEVELOPMENT OF THE CO_2/O_2 RATIO IN THE TROPOSPHERE

We thought it would be interesting to design a fairly accurate model of the geological development of the tropospheric air over the last billion years. For this purpose we used data from a series of recent scientific publications [1-12] in the fields of physics, chemistry, biology, paleontology and astronomy, which helped us compose a plausible overall picture (see Figure 7).

Other authors [8, 3] have also suggested models on the tropospheric development, which do, however, differ widely from our picture. P. Cloud [8], for example, presents on page 133 of his publication a figure on the oxygen increase in the atmosphere, suddenly setting in two billion years ago and continually raising its O_2 concentration until—about 300 million years ago—the present level is reached. Another figure is presented by P. Fabian [3, page 24], in which he indicates a steep increase of free oxygen about 300 million years ago. A step-wise increase of the

[4] "The World Climate"

Units: 10^{12}kg of C/year in flows
10^{12}kg of C in reservoirs



*) from forest and soil destruction
**) from combustion

Figure 4: The carbon cycle. Source: [6].

atmospheric O_2 concentration is illustrated by Schidlowski [17]; Schidlowski assumes, however, (similarly to P Cloud) an early increase of the oxygen concentration to a high level.

Our model is exclusively based on assumptions which are, at the present state of knowledge, no longer subject to serious controversy:

- The primordial atmosphere of the earth did not, after cooling down to 50°C, contain any free oxygen; it consisted mainly of nitrogen, steam and CO_2 or CO [9].
- The photolytic decomposition of steam, caused by the irradiation of light, has produced and still produces free oxygen, though at a low quantity (which is negligible in the total balance) [9].
- The photosynthetic O_2 production by single-cell organisms in the ocean water (procaryotes) started early, more than four billion years ago, and resulted in a high O_2 output, which was, however, immediately consumed for saturating "oxygen-deficient" compounds in the "virgin" sea water, such as iron[II]-compounds, pyrite, uranitite (= UO_2 = uranium[IV]-oxide) and did thus not immediately increase the atmospheric O_2 concentration [3].
- Volcanic activities (a source of CO_2, CO) have shown a declining tendency in the course of the history of the earth.
- In the history of the earth there have always been tectonic movements of the earth crust, in which "virgin" rock formations were released from the interior; as these rocks are oxygen-deficient, they have a (slightly) decreasing effect on the atmospheric O_2 concentration.
- Insolation (solar radiation per square meter of the atmosphere, measured in KW) has, during the history of the earth, increased from 1 KW/m^2 to 1.4 kW/m^2, which is due

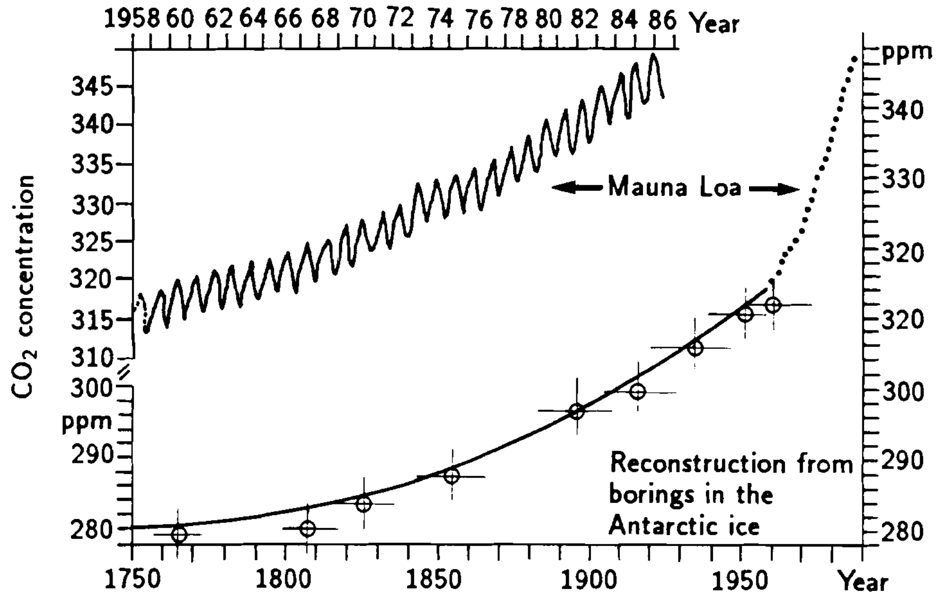


Figure 5: Carbon dioxide concentration of the atmopshere. Source: Adapted from Schönwieser, 1987.

Increase of atmospheric carbon dioxide (CO_2) concentration caused by fossil energy consumption and, indirectly, by deforestation and soil destruction. CO_2 is, in terms of its climatic impact, one of the most effective trace gases, which are assumed to cause anthropogenic climatic changes on a global scale. Direct measurements at Mauna Loa, Hawaii, according to Keeling (the monthly values, which also show the natural annual development, are given in the left upper corner; the dots in the right upper corner indicate the annual average). The circles marked by a cross are uncertainty ranges, taken from a reconstruction by Neftel, Oeschger and collaborators.

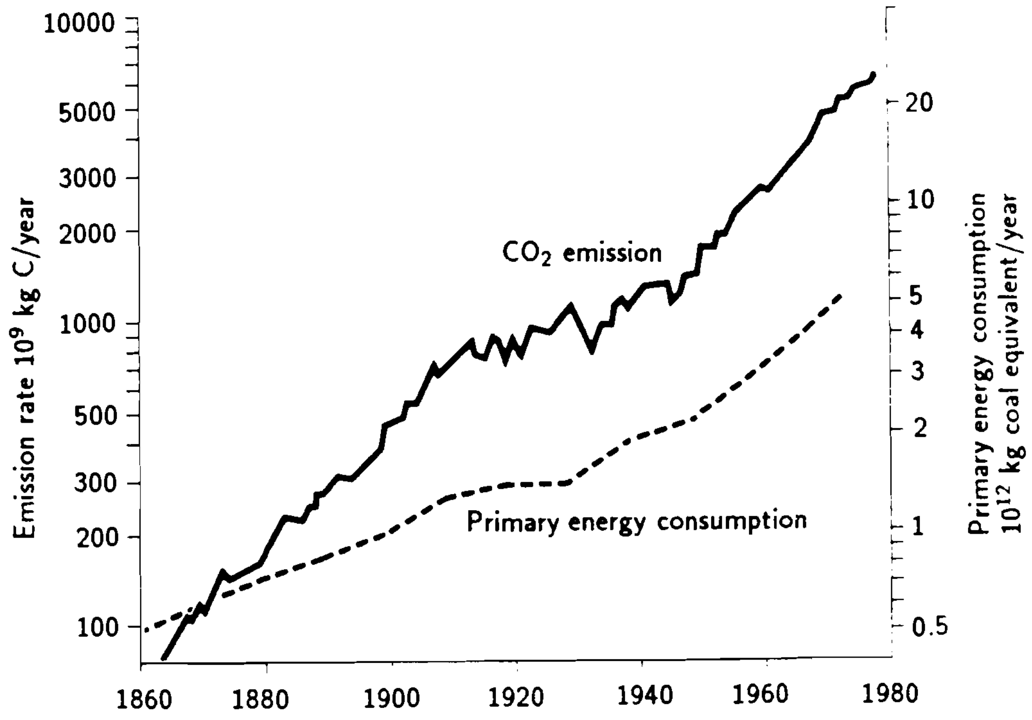


Figure 6: Anthropogenic carbon dioxide emissions. Source: [6].

to the growing intensity of the solar light [10]. This increase by far offset the minor fluctuations in insolation caused by the precession of the axis of the earth, the eclipse or the eccentricity of its orbit.

- In the beginning of the history of the earth the ocean water was, on the basis of the high atmospheric CO_2 concentration, considerably more acid than today [11, 12]. A decrease of the atmospheric CO_2 concentration led to a decrease of the CO_2 concentration in the ocean water and thus to a deposition of carbonates (decrease of the carbonate-lysoclines). An increase of the CO_2 concentration, on the other hands, leads to a dissolution of carbonate rock (increase of the carbonate-lysoclines).

- Carbonate-silicate minerals in land rock formations are partly dissolved by rain water, with the CO_2 contained in the rainwater acting as a solvent. Thus the rivers transport hydrogen carbonates and soluble silicates into the ocean. There these salts are deposited or integrated into the calcerous shells or skeletons of animals, again releasing the major part of the CO_2. This process presents, in itself, a slight, relatively continuous decrease in the CO_2 concentration.

- The photosynthesis of the water plants has the same effect on the CO_2/O_2 household as that of terrestrial plants.

The result of our modeling effort is represented in the above-mentioned Figure 7. The area expanding to the right-hand side (O_2) represents the oxygen concentration of the earth atmosphere in its development during the last 1000 million geological years. The increase of the oxygen concentration takes place in two major steps: in the Cambrian and in the Carboniferous/Permian, as well as in a further moderate increase in the Triassic and the Jurassic.

The area expanding to the left (CO_2) gives the CO_2 concentration of the atmosphere overlapping with the oxygen concentration. While the oxygen concentration increased in several

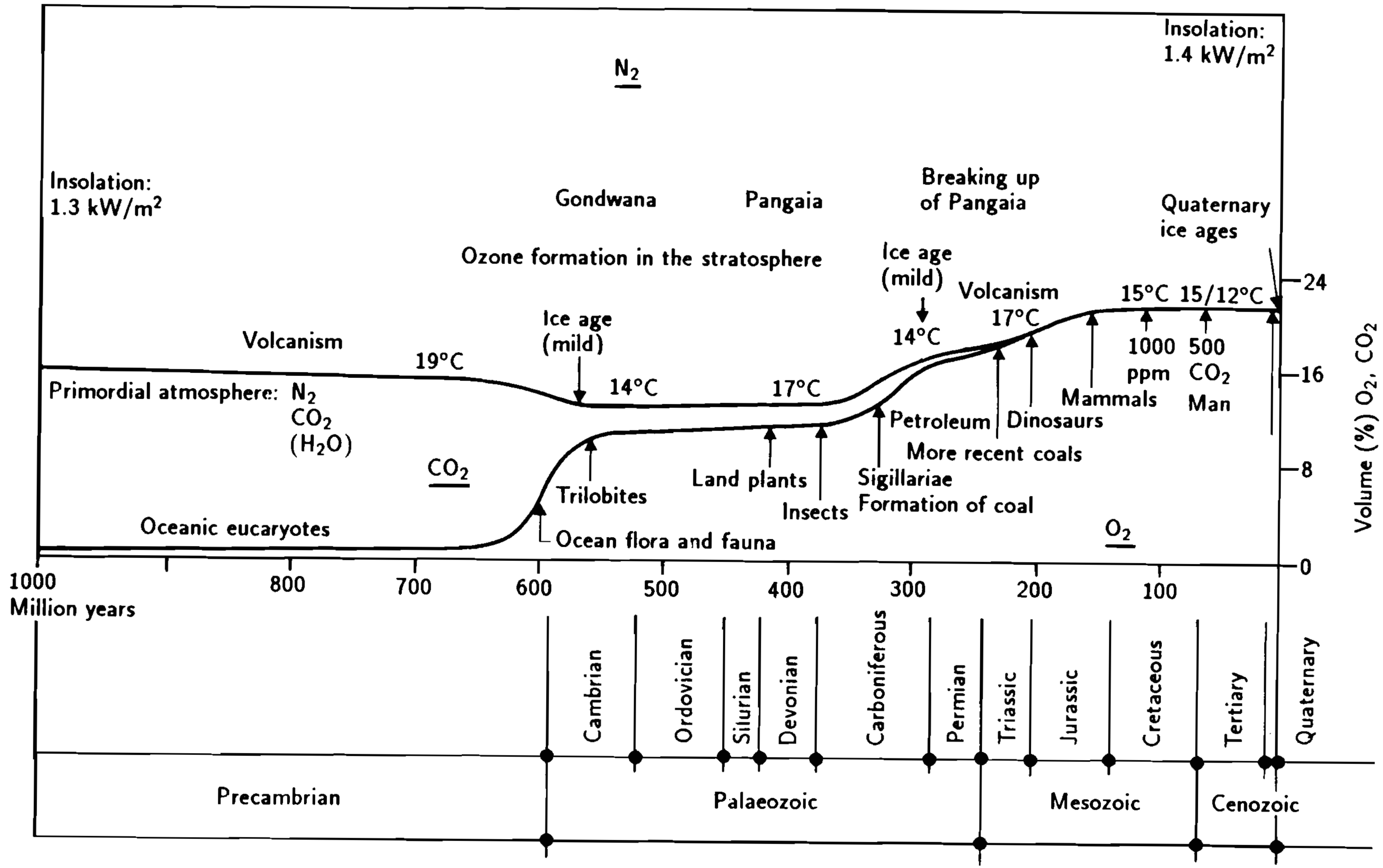


Figure 7: Oxygen and carbon dioxide concentration of the atmosphere during the last 1 000 million years.

steps, the CO_2 concentration of the atmosphere decreased, also in several steps. Both, the end of the Cambrian as well as of the Carboniferous/Permian decrease in CO_2 concentration mark the beginning of mild ice ages.

The developments in the last geological phase, the Quaternary, can not be identified from Figure 7. Therefore the further course of the curve has been enlarged and presented in Figures 8 and 9, which will be discussed later.

In the course of the Precambrian (left-hand side of Figure 7), when the atmospheric O_2 concentration remained at a low, relatively constant level of under 1 volume-percent (due to the saturation processes mentioned above), the oceanic population first consisted of procaryotes (single-cell organisms without a nucleus), and later of the more highly developed eucaryotes (single-cell organisms with nuclei). Other organisms did not exist at that time.

Only at the end of the Precambrian, approximately 600 million years ago, did the first multi-cellular oceanic organisms develop, starting with the so-called Ediacara fauna (Ediacara, Australia, is the place of first discovery), and consisting of jellyfish, worms, and mollusks of various species without a calcerous skeleton or shell. These animals were able to resorb oxygen through the total surface of their bodies. It can thus be concluded that they could live in an "acid" ocean with a relatively low oxygen concentration [8]. Then, in the Cambrian, the first animals with a calciferous or phosphorous external skeleton came into existence. Due to this external skeleton, they had a considerably smaller surface for oxygen resorption. These facts, verified by fossil findings, justify the conclusion that the oceanic animals in the Cambrian already lived in a less "acid" environment with a higher oxygen concentration.

At the beginning of and during the Cambrian there must have been fundamental changes in the composition of the ocean water as well as in the atmospheric composition, which were reflected by an increase of the O_2 concentration and a decrease of the CO_2 concentration. The evolution of oceanic life, which can be fairly exactly defined in time on the basis of fossil findings, followed the changes of the atmosphere with a considerable forward thrust in its development. It thus becomes evident that the end of the low oxygen level (left-hand side of Figure 7) indicates the end of the saturation phase of oxygen-deficient compounds in the "virgin" ocean water. This development can also be seen from another angle: In the Cambrian the production of free oxygen by photosynthesis of the ocean flora (as well as the corresponding CO_2 consumption) was more effective than any still existing source of oxygen reduction (or more effective than the sources of CO_2)—and this is why the oxygen concentration increased and the CO_2 concentration decreased.

The mild ice age towards the end of the Cambrian, which probably only affected the region of the continent Gondwana, situated at the South Pole [13], is considered to mark the (preliminary) end of the oxygen increase and the CO_2 decrease. A first minimum of the insulating effect of the CO_2 cover was reached, which could—considering the relatively high remaining CO_2 concentration as compared to today—only lead to an ice age, because the insolation (solar irradiation) was at that time even lower than today. Now the O_2 curve levels off again, at about 12 volume-percent. Thus the atmospheric O_2 concentration seems to have reached a level, which was necessary to saturate oxygen-deficient compounds on the land (e.g. by the formation of red sandstone), a process which probably took 200 to 250 million years and which prevented any further development of the atmosphere for the major part of this period. The fauna and flora on the land developed rather slowly during the Ordovician, the Silurian and the Devonian, and did not produce any major evolutionary events. Though the accuracy of our level of 12 volume-percent may be debatable, we are convinced that this estimate is not too low (or at least not far too low). Otherwise there would not have been enough room for the second step (Carboniferous, Permian), which brought even more drastic changes than the first step. The beginning of this second step is marked by enormous plant growth during the Carboniferous. Plant growth and the consequent formation of coal—which was, to such an extent, presumably only possible on the basis of the low O_2 concentration[5]—led to a rapidly decreasing CO_2 concentration and thus

[5]At the present level of O_2 concentration oxidation and rotting could not have resulted in such an extensive

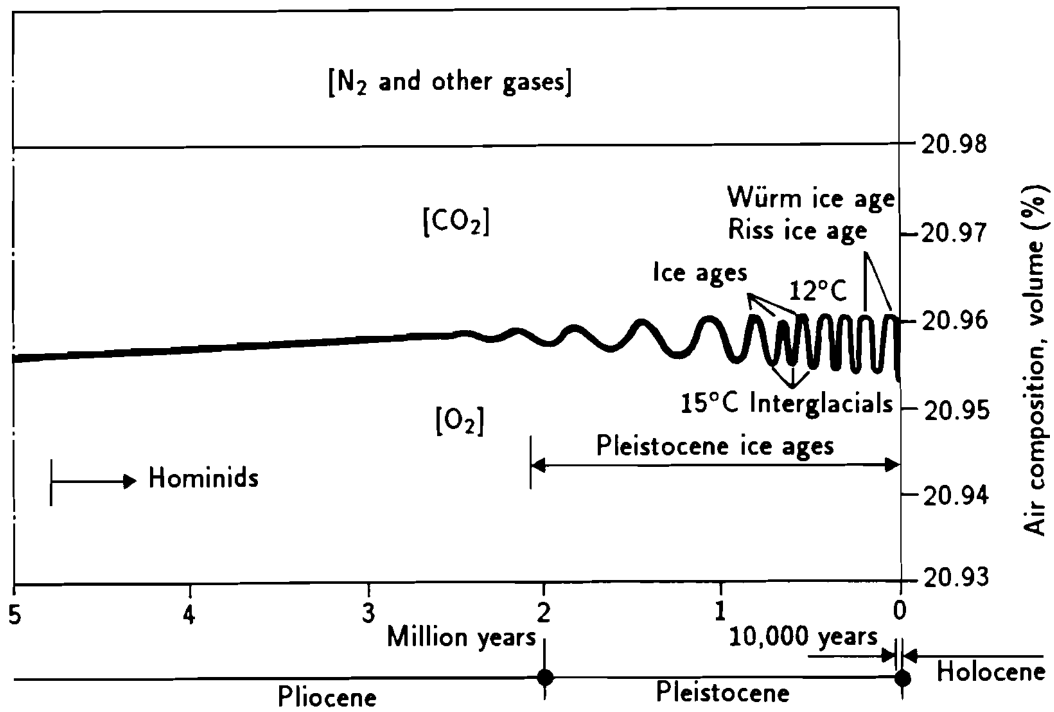


Figure 8: Oxygen and carbon dioxide concentration of the atmopshere during the last 5 million years

introduced the Carboniferous/Permian ice age. At the same time the ocean water changed as a consequence of the changing partial CO_2 pressure, which could, in our opinion, have been a reason for the "Permian extinction" in the oceans [14]. The development of animal life on the land progressed rapidly, resulting in the cold-blooded and later in the poikilothermic saurian species of the Jurassic and Cretaceous.

On the whole, the decisive evolutionary development thrust falls into the period extending from the Carboniferous to the end of the Mesozoic. The end of this development in the Jurassic/Cretaceous is marked by a reduction of CO_2 in the atmosphere and the ocean water, giving rise to a massive formation of lime (calcite) in the oceans.

In the Cenozoic the atmospheric O_2 concentration reached its present level, while the CO_2 concentration dropped into the "ppm-range". Figure 8 shows the final (right end) section of our curve at a larger scale. (Please note that due to the overlapping shares of the CO_2 and O_2 concentrations, a CO_2 increase results in a downward peak in the O_2 curve.)

With the increase of green vegetation (carbon being bound in plants and top soils) the CO_2 concentration of the earth' surface decreased to approximately 200 volume-ppm and thus introduced the first Pleistocene ice age. Then it began to fluctuate between 200 (at the beginning of each ice age) and 270 volume-ppm (at the end of each ice age). The last waves of this oscillation have been verified by CO_2 measurements obtained from ice core borings. When studying the course of the curve, it appeared to us that the fluctuations between CO_2 and O_2 may not have been the consequence, but the cause of the Pleistocene ice ages.

Today's most frequently cited theory on the origin of the ice ages was established by Milankovic [15]. In summary, this theory states that the ice ages are caused by insolation fluctuating in certain cycles (precession, ellipsis and eccentricity, see above).

In our opinion this theory has two weak points:

carbonization of woods.

1. The fluctuations of insolation are extremely low. It is doubtful whether they may have triggered off such big temperature changes.

2. Such ice ages would have originated much earlier, as the typical movements of the earth and its orbit have probably developed soon after the formation of the earth. There is, however, no proof for this assumption.

According to our hypothesis, whose arguments are based on the CO_2 concentration, it is not difficult to explain the beginning of the ice age fluctuations in the Pleistocene.

Temperature conditions suitable for introducing an ice age were only reached after the CO_2 concentration had dropped to 200 volume-ppm (due to the very low heat insulation of the CO_2 cover):

- The temperature in the polar zones dropped to a particularly low level.

- The large temperature differences between the Equator and the polar zones stimulated oceanic flows from the Equator to the poles as a consequence of the so-called thermosiphon effect. The most important example is the Gulf Stream. We assume that it became strong enough to penetrate into the Arctic Ocean.

- The warm Gulf Stream in the Arctic Ocean, and the very cold air above, led to an usually large-scale formation of freezing fog and snow.

- Large amounts of snow are the only explanation for the accumulation of the gigantic glacier masses in the North Pole region. Cold weather alone would not have been sufficient.

- The growing albedo of the glaciers (reflection of the solar light) reinforced this effect.

- The green vegetation of the earth (which had previously reached its maximum) gradually receded, which was due to the average heat reduction of the earth and the ice coverage of large areas. The quantity of bound carbon decreased and more CO_2 was again released into the air. The CO_2 concentration increased to 270 volume-ppm.

- As a consequence of the better insulating effect of the atmosphere the temperature on the earth increased again, and the ice age was followed by an interglacial period.

- Since there is no equivalent in the Antarctic to the Arctic ocean, the ice ages were less pronounced in that area.

According to this hypothesis the Pleistocene ice ages are directly related to plant growth. The ice age oscillations present a kind of regular fluctuation of the CO_2/O_2 control system in a dynamic equilibrium, in which photosynthesis assumes the control function.

Let us now look at the very last part of our curve at the right-hand margin of Figure 8, i.e. at the increase of the CO_2 concentration in the final phase of the Holocene. This is more clearly visible in Figure 9. There the right end of Figure 8 has been extended along the abscissa, depicting the last half of the oscillation of the Würm ice age and the following interglacial period of our present time. The slightly wavy course of the line is intended to represent the "noise level", i.e. the influence of natural climatic changes and the usual fluctuations between winter and summer (double line).

The sudden, steep decline of the O_2 curve at the end of the Holocene shows atmospheric changes caused by man (decline of the O_2 increase, increase of the CO_2 concentration). It becomes evident at first sight that this development is not natural. The CO_2 curve deviates from the range of regular ice age fluctuations. The system becomes instable. The natural forces of self-regulation, such as the CO_2-induced stimulation of plant growth or the increased CO_2 absorption of the ocean under partial pressure are obviously not sufficient to stop the increase. The further the deviation, the lower the chance of a natural stabilization. The currently prevailing CO_2

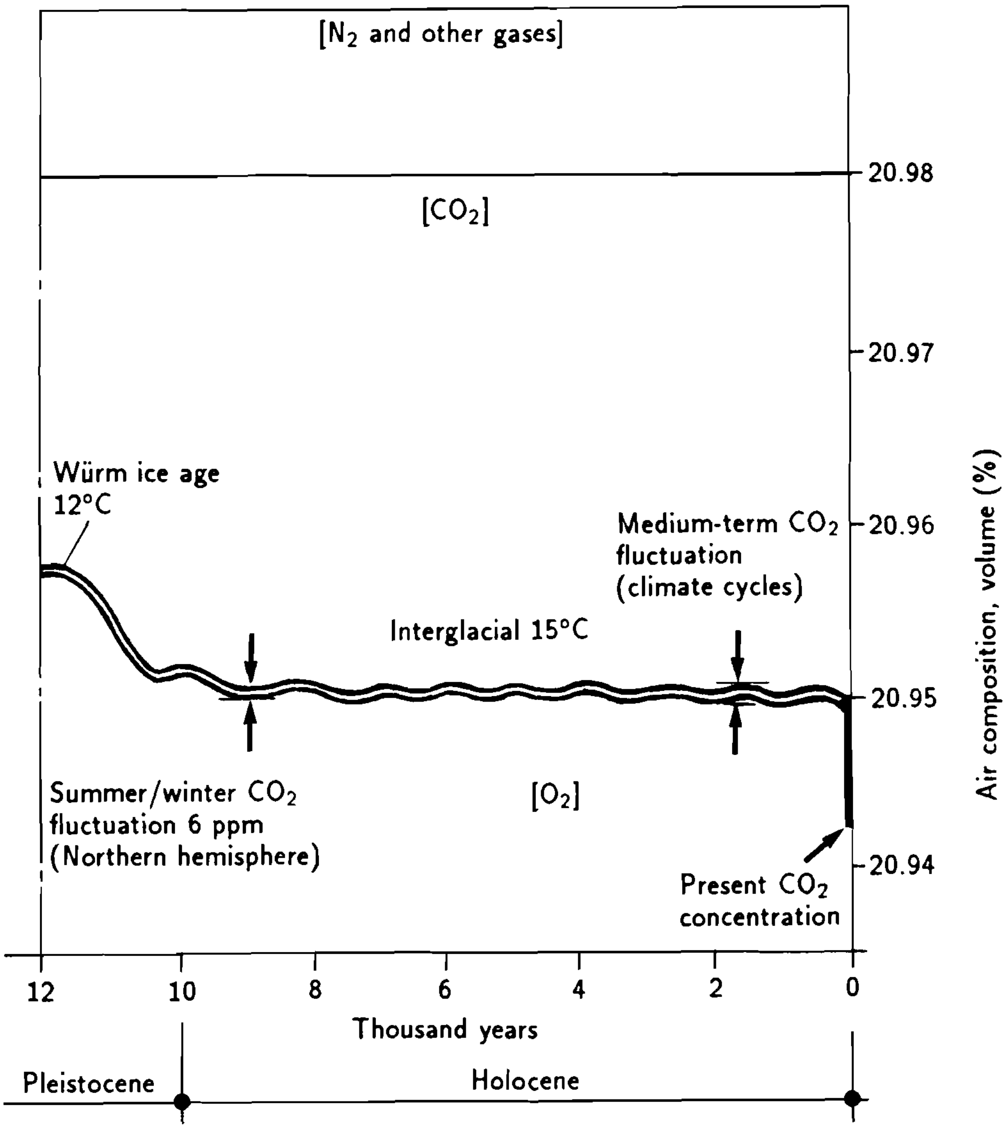


Figure 9: Oxygen and carbon dioxide concentration of the atmosphere during the last 12 000 years on an extended scale.

concentration of 350 volume-ppm already existed 35 million years ago. A CO_2 concentration of 500 volume-ppm would, according to our curve, produce an atmosphere equal to that 60 million years ago. A concentration of 1000 volume-ppm would mean a regression by 120 million years, i.e. into the atmosphere of the "saurian period".

EFFECTS ON THE BIOLOGICAL EVOLUTION

The reader will have noticed that we repeatedly mentioned plant and animal growth to be the cause of atmospheric changes. The atmosphere has, indeed, in the course of billion years, followed the development of biological life and vice versa; this process took place in a closely related and, in our opinion, irreversible interaction between life and the atmosphere.

All organisms, flora and fauna, as well as micro-organisms such as bacilli, fungi and viruses, had to adapt, step by step, by mutation and selection in a continuous evolution process [16], to a constantly changing atmosphere. As the O_2 concentration increased in more than 99% of the time in the history of the earth, species of a lower oxygen compatibility would usually be replaced by those compatible with a higher oxygen concentration. In animals, the increased partial pressure of oxygen in the blood has probably initiated a tendency towards a higher body temperature, individual temperature control, higher metabolic rates, more vivid cerebral functions, and, on the whole, towards more complicated forms of life. The changing CO_2/O_2 ratio in the troposphere in the course of the history of the earth was, in our opinion, the fundamental and most important factor in the evolution of plant and animal life. It is, however, clear that other driving forces of the evolution have also contributed their share [16]. But none of them has had this enormous, evenly directed potential for change. The existence of such a fundamental factor explains the goal-oriented direction of the evolution. On an earth, which has always had the same atmospheric composition, developments would probably have taken a different course. The CO_2/O_2 ratio has, as shown by the geological development of the atmosphere and the population of the earth, influenced its direction by exerting selective pressure. This fact is remarkable, since neither CO_2 or O_2 have a toxic or mutagenic effect on any population.

An impressive example is given in Figure 10 [13]. It shows the geological ranges of about 150 species of trilobites in the last phase of the Cambrian. As can be derived from Figure 7, the atmospheric composition changed at that time at a rate of approximately 0.25% in five million years. Most trilobite species have, as indicated by the length of the vertical lines, historically confirmed periods of existence amounting to less than two million years, i.e. they became extinct after a change of the CO_2 and O_2 concentrations by approximately 1000 ppm (O_2 increase/CO_2 decrease). In view of such a slight change, toxicity is not likely to be the cause. There must be another reason.

We maintain in our hypothesis that the reason lies in the following mechanism of biological evolution:

1. The composition of the atmosphere is changing.
2. Micro-organisms, such as viruses, adapt, due to their fast rate of generation change (in the order of hours), more rapidly to new situations than big organisms with a rate of generation change in the order of years.
3. This presents an advantage to micro-organisms.
4. The faster the change in atmospheric composition, the higher the pace of development of new micro-organisms.
5. This results in an increased risk of deceases.

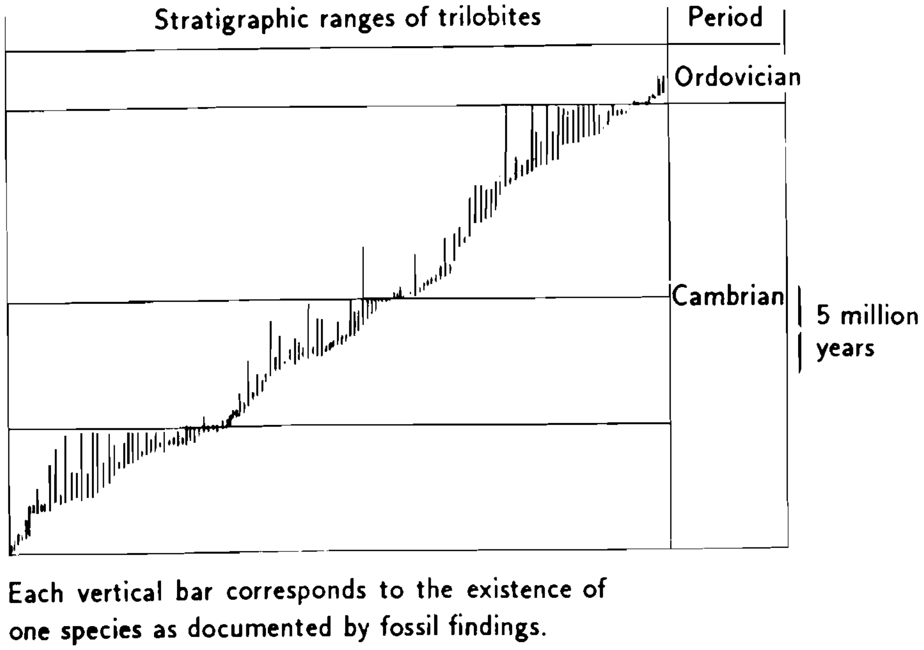


Figure 10: Geological ranges of various North American trilobite species in the last phase of the Cambrian. Source: [13].

The natural evolution of plants and animals has so far followed the composition of the atmosphere. This will not change in the future. The abrupt change in the composition of the atmosphere, as is taking place at our time, presents an extraordinary development in terms of its unnatural direction and, above all, in terms of its enormous gradient of change. While micro-organisms and viruses, with rates of generation change in the order of hours, do not have difficulties adapting to the new environment (atmosphere) by mutation and selection, e.g. within a time frame of ten years, big animal and plant species lack the necessary time. The better adaptability of micro-organisms presents a disadvantage to bigger organisms. The probability of the development of new deceases could thus increase.

It may be argued that the change in CO_2 concentration, as discussed above, is too small to influence organisms and their further development. Such arguments can be offset by two facts:

- The relative change of the CO_2 concentration of, e.g., 270 ppm to 350 ppm means an approximately 30% change of the CO_2/O_2 ratio. As a consequence, the chemical potential[6] of all chemical reactions relating to CO_2 changes significantly—by about 4%. The chemical potential is decisive for any physiological reaction.
- Even the absolute value of change of the CO_2 concentration in relation to the O_2 concentration is significant. It lies in the same range as the climatically effective changes in absolute temperature.

Experiences in greenhouses have furthermore shown that an increase of the CO_2 concentration, in connection with the greenhouse-gas effect, leads, on the one hand, to an increased growth rate [18], but, on the other hand, it also increases the probability of pests, which are usually controlled by pesticides.

What should really give rise to concern is not the increased CO_2 concentration as such, but its effects on the biological evolution, if the hypothesis of the close connection of evolution and the change in the composition of the atmosphere is correct.

[6]Chemical potential: Change of the free enthalpy in a system in relation to the change in the number of moles.

The problem can be exemplified by one question: How can we predict if man can live in a "saurian atmosphere" without incurring health problems?

If the presently observed increase in CO_2 concentration continues, we will one day—maybe at 2000 volume-ppm—pass a critical threshold, where the growth or even the existence of today's plants will be threatened by the above-described effects of the CO_2 increase. If such a situation develops and a major fraction of the vegetation is eliminated for reasons of the CO_2 increase, the CO_2 increase will develop its own self-enforcing dynamics without any further human contribution. The atmosphere will then be exposed to the danger of "tipping over".

These hypothetical considerations have so far only been supported by indications, but are not yet verified by adequate research results. In our opinion there is a necessity to launch a comprehensive research program on the effects of the CO_2 increase on the biological evolution.

COUNTERACTIVE MEASURES

It certainly is the aim of research to stop the increase of CO_2. Technological measures alone are not sufficient. A basic change in attitude as well as many changes in behavioral patterns, such as changes leading to a limitation of the population explosion, are required world-wide, and they can only be achieved through international cooperation. Purely national measures would be too limited in scope.

Efforts must be taken to limit the combustion of fossil fuels and to utilize energy sources with a lower environmental impact. Such sources are nuclear energy and hydropower. In the Federal Republic of Germany the utilization of nuclear power is hardly possible for political reasons. However, the relevant political decisions have, unfortunately, not been based on an objective comparison of the hazards of nuclear power versus the hazards arising from the greenhouse effect. The utilization of newly developed hydropower resources in Siberia, Africa, Asia, South America and Canada will produce thousands of GW of electricity, but Central Europe will only be a consumer of this energy source, provided that an economic transportation system for large quantities of energy over big distances can be found.

The public research programs of our country, aimed at a solution of the atmospheric problems, include research work demonstrating more rational energy policies, i.e. ways of a more economic transfer and storage, and of a more effective energy utilization. It is the aim of such research to find access to alternative energy sources provided by nature, such as solar energy, biomass, geothermal heat, wind energy, etc., and to solve the problems related to the lower energy density of these sources.

We have tried to group these ideas into a systematic scheme. The measures to be taken (compare Figure 4 on the carbon cycle) are divided into two categories:

1. How can the increase of carbon released into the atmosphere be controlled?

   By a reduction of respiration, combustion, weathering, rotting, i.e. by

   - Limitation of the population explosion;
   - More economic energy utilization (better insulation of apartment buildings and private houses);
   - More rational energy utilization (light material construction, higher conversion efficiency, more economic cars);
   - Utilization of combustion-free energy sources (hydropower, nuclear power, wind and solar energy);
   - Combustion of such energy sources as would otherwise be rotting (straw, refuse, sewage sludge).

2. How can a more effective reduction of the carbon concentration in the atmosphere be achieved?

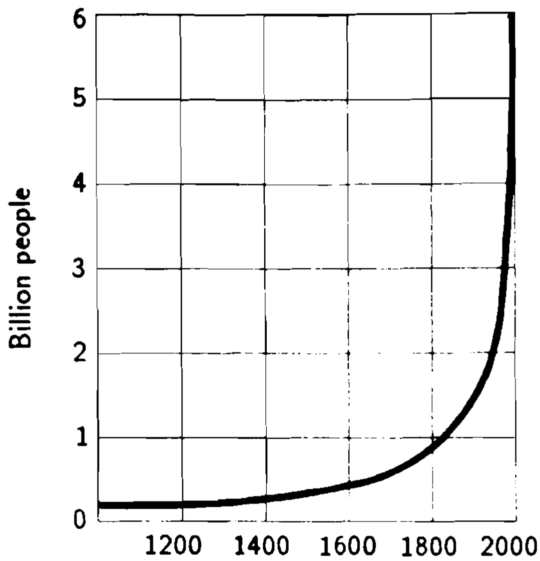


Figure 11: Increase of the world population.

By increasing photosynthesis, i.e.

- Cultivation of top soils; effective, rational fertilization;
- Plant growth; afforestation;
- Stopping wildfires;
- Health control of waters.

It is evident that the various measures that can be taken to overcome the CO_2 problem are not equally effective. It would be an interesting research task to work out clearly defined, quantitative values. For the time being, however, we have to resort to estimates.

We feel that the upward trend of the population figure plays a decisive role (see Figure 11). The world population—currently 5.1 billion people—rises at present by 2% per year, i.e. it will double in 35 years if this growth rate continues. Taking a mean increase in consumption of approximately 1% per year into account, this would add up to a 3% annual increase in the environmental "base load" of the CO_2 concentration (assuming that the additional population maintains the average life-style of today). All people, including those in the developing countries, contribute to the burden imposed by CO_2.

Even respiration, the necessity of cooking and heating and the unavoidable restrictions on plant growth significantly contribute to the hazards of CO_2. Assuming an increase at the above rate over a period of 44 years of the population maintaining its present life-style, the CO_2 concentration can be estimated to have risen to 540 volume-ppm (i.e. it would have doubled) by 2032.

We consider afforestation programs as well as programs for a rational energy utilization to be very important. Their effects can partly compensate for the consequences of population growth. The development of new energy sources will, in our opinion, only make a very limited contribution in the near future. Much time and capital is required for such new sources to be developed and to penetrate the world markets.

The latter two points fall into the field of energy policy, i.e. they should be dealt with by the industries of the developed countries. Many activities have already started in this respect.

We must, however, be aware of the fact that industry alone will probably not be able to solve the problem.

CONCLUSION

In the brochure "Klimaprobleme und ihre Erforschung"[7] of the Federal Ministry of Research and Technology, 1987, it is stated (on page 28) that: "Apart from an adaptation to slightly changed climatic conditions, global warming[8] is not expected to affect human health". There still seems to be a wide-spread belief that the CO_2 increase does not present any hazards to health.

In our cause-effect arguments we have come to the conclusion that the change in the atmosphere—if it really takes place at the threatening extent envisaged today—may have consequences on the biological evolution, endangering the health of man and nature.

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[7] "A Study of Climatic Problems"

[8] I.e. the warming caused by the greenhouse effect and the CO_2 increase.