Registration of Atmospheric Carbon Dioxide Concentration Changes in Tree-Rings

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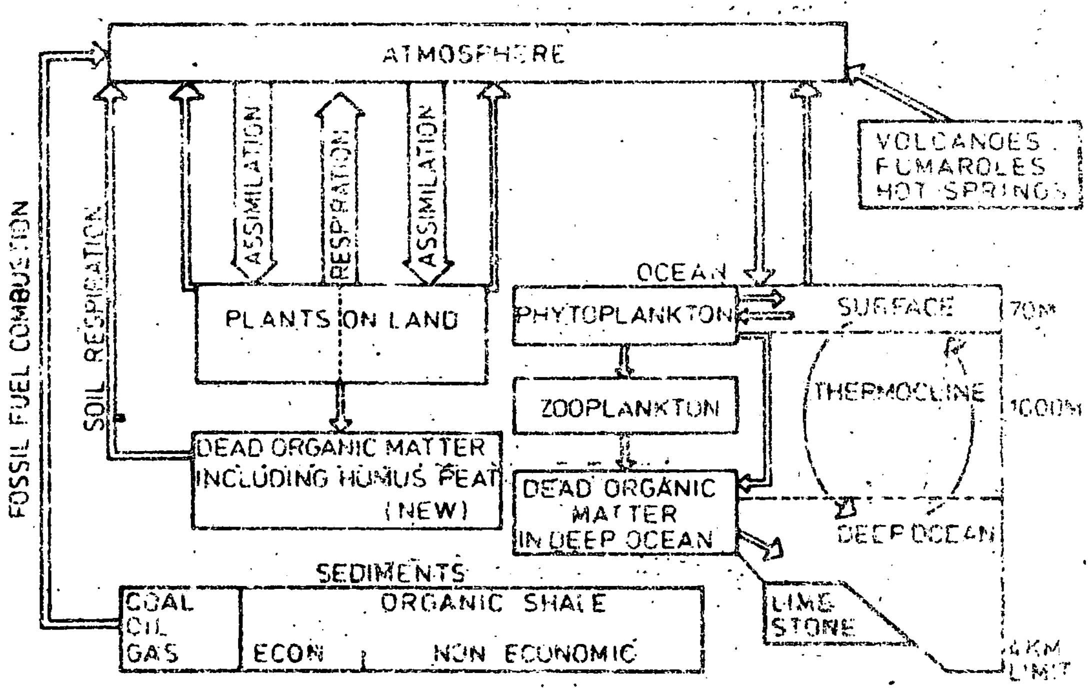
Introduction

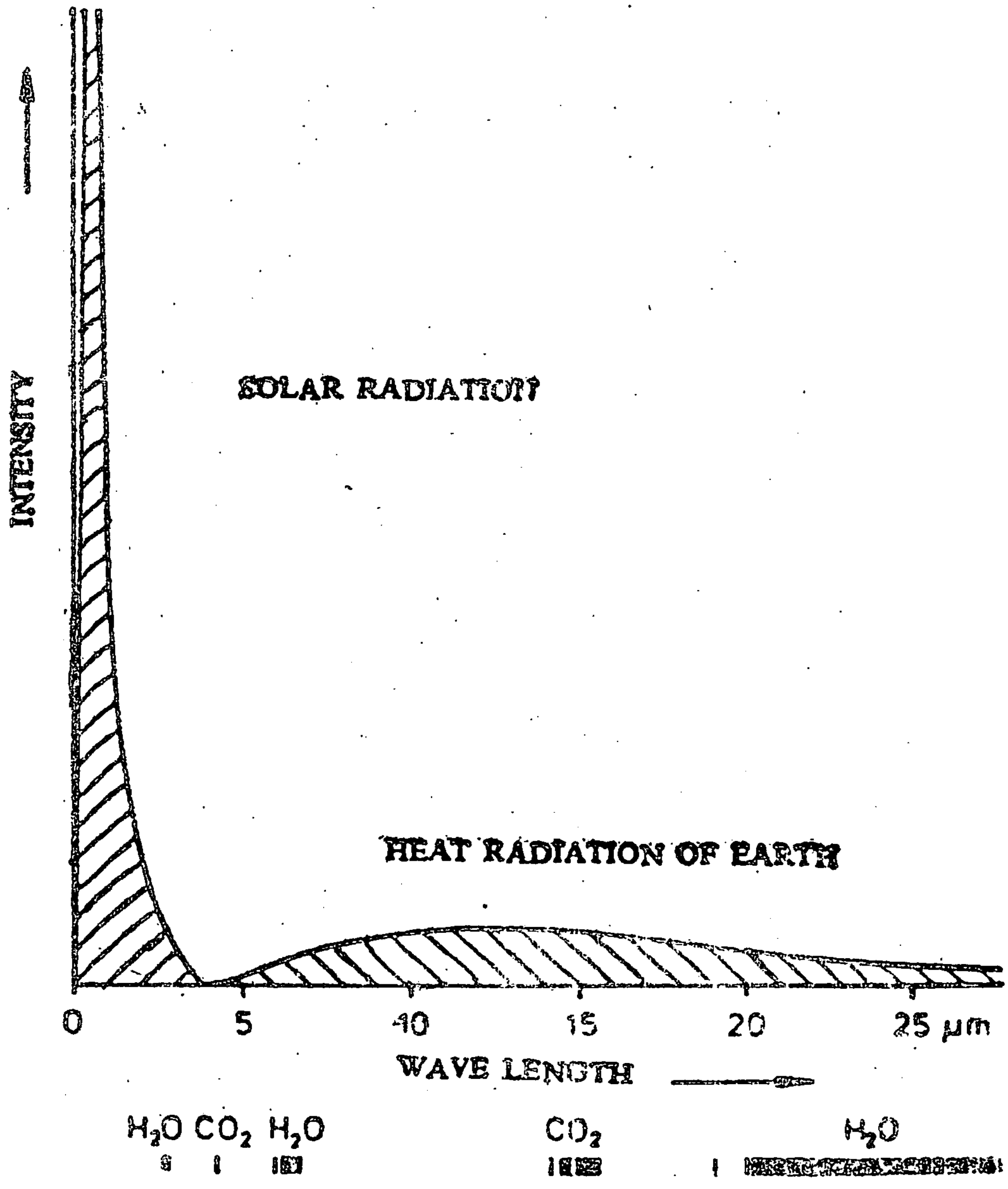
Man's impact on the geochemical cycles has been investigated, and among them the carbon cycle has drawn special attention owing to its vast geo-climatic importance. The fate of man-made carbon dioxide that is released to the atmosphere has been under discussion for the last three decades. The sediments deposited since the formation of the earth in the form of organic shales, coal, oil and gas are being recycled as fuel for combustion, and the CO_2 (fossil carbon-dioxide) released into the earth's atmosphere causes an imbalance in the carbon cycle (*Dg.* 1).



Dg. 1

Although a part of the released CO_2 re-enters the biosphere and is also dissolved in the ocean, a sizeable amount is known to remain in the atmosphere. The CO_2 which does not absorb the incoming solar radiation, however, absorbs the re-emitted IR-radiation from the earth's surface (*Dg.* 2). This results in the "TREIBHAUS effect" (Green-house effect), which may influence the average global temperature. The effects of such a temperature change are well known.

Although other energy forms (such as solar and nuclear) are being increasingly used for man's requirements, the fossil-fuels yet remain the prime and most important energy sources, and would continue to be so at least for the next two decades.

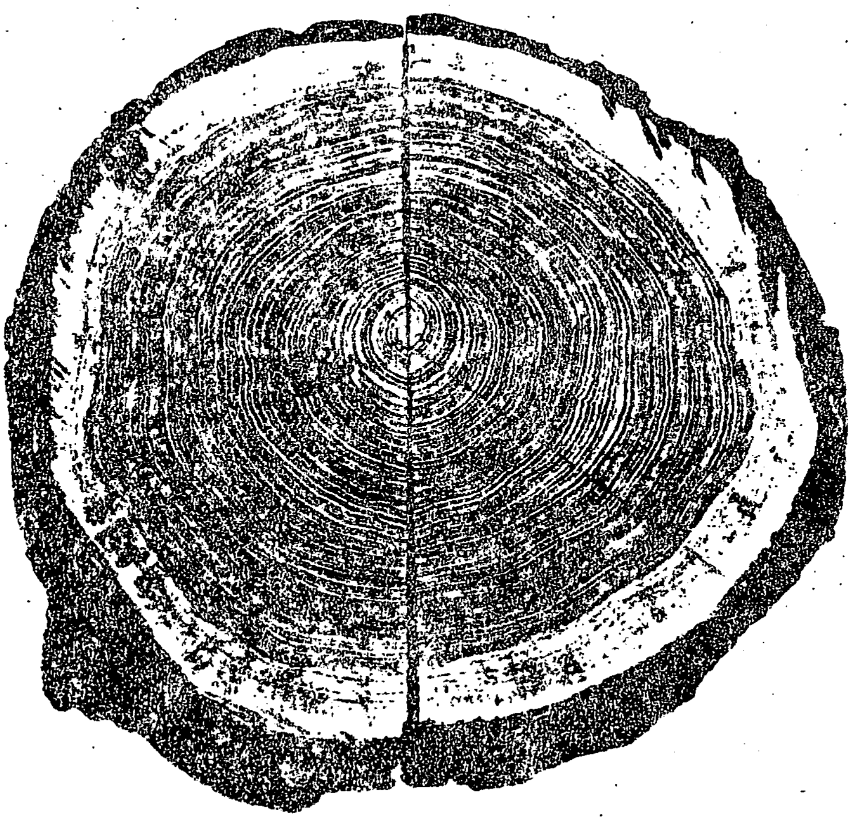


Dg. 2

The carbon dioxide production by man is increasing exponentially. Several methods of direct analysis, and that by the use of natural or artificial tracers, have been made use of to investigate the fate of this anthropogenic CO_2 released in the global system. The use of the stable isotope ^{13}C is described here.

Method

The long-term increase of CO_2 in the atmosphere as a result of the burning of fossil-fuel, and of man's changing of landbiota (biospheric CO_2) is registered in the wood of tree-rings (*Dg.* 3) because both fossil and biospheric CO_2 are marked with a ^{13}Cisotope deficit of about -18‰ on the PDB standard scale as against the background atmospheric CO_2 (*Dg.* 4). Since fossil-fuels are completely decayed in ^{14}C, a decrease of $^{14}C/^{12}C$ in the atmosphere indicates an increase through fossil fuel sources, whereas a $^{13}C/^{12}C$ decrease reflects both fossil fuel and biospheric CO_2 emissions into the atmosphere. Trees absorb carbon dioxide from the atmosphere during photosynthesis and build up sugars which are converted into the wood components like lignin, cellulose etc. Isotopic analysis of these components in the tree-rings, therefore, should give a representative record of the CO_2 isotopic composition in the atmosphere at the time of formation of the tree-ring.



Dg. 3

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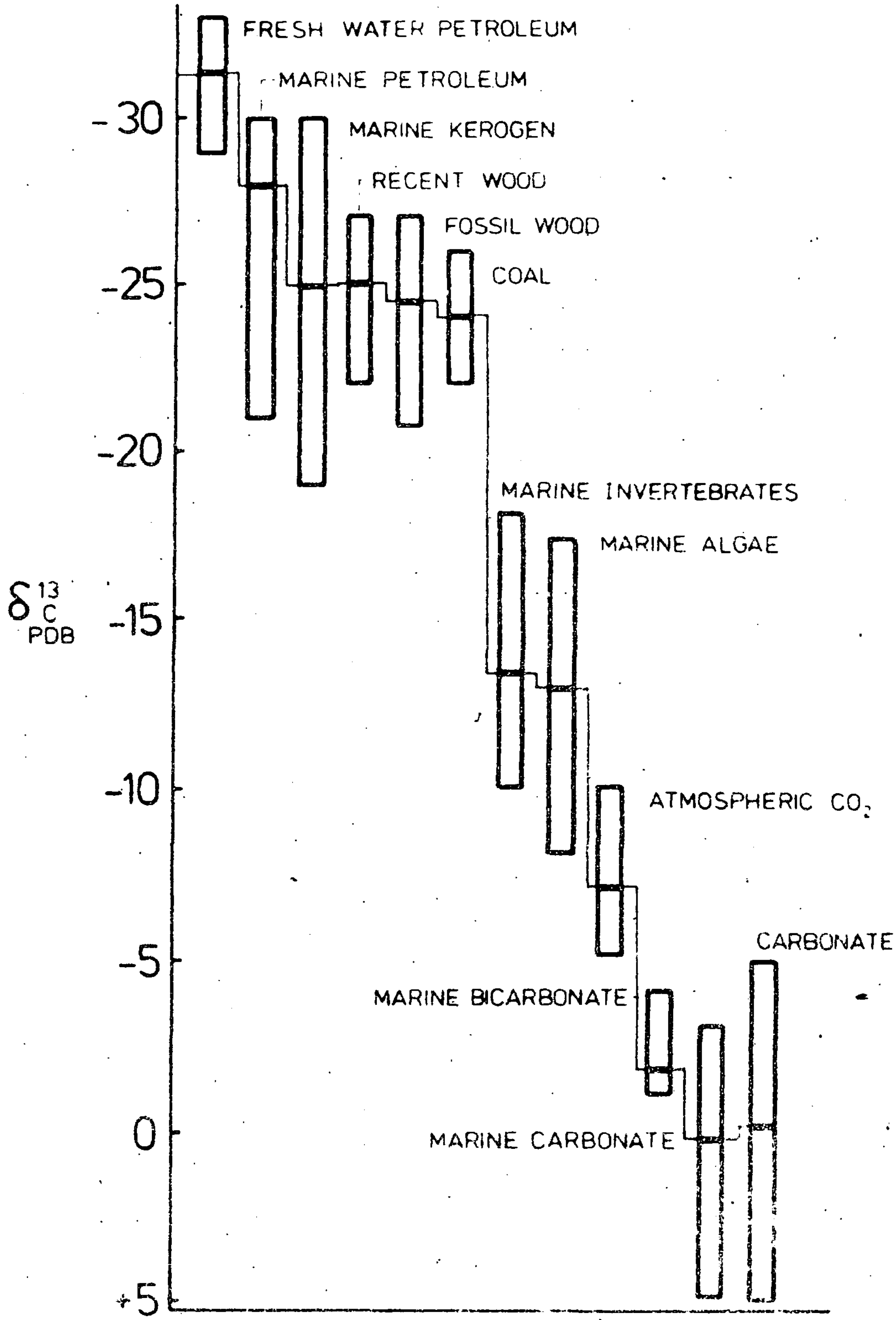

FRESH WATER PETROLEUM
MARINE PETROLEUM
MARINE KEROGEN
RECENT WOOD
FOSSIL WOOD
COAL
MARINE INVERTEBRATES
MARINE ALGAE
ATMOSPHERIC CO_2
CARBONATE
MARINE BICARBONATE
MARINE CARBONATE
$\delta^{13}C_{PDB}$
-30
-25
-20
-15
-10
-5
0
+5

Dg. 4

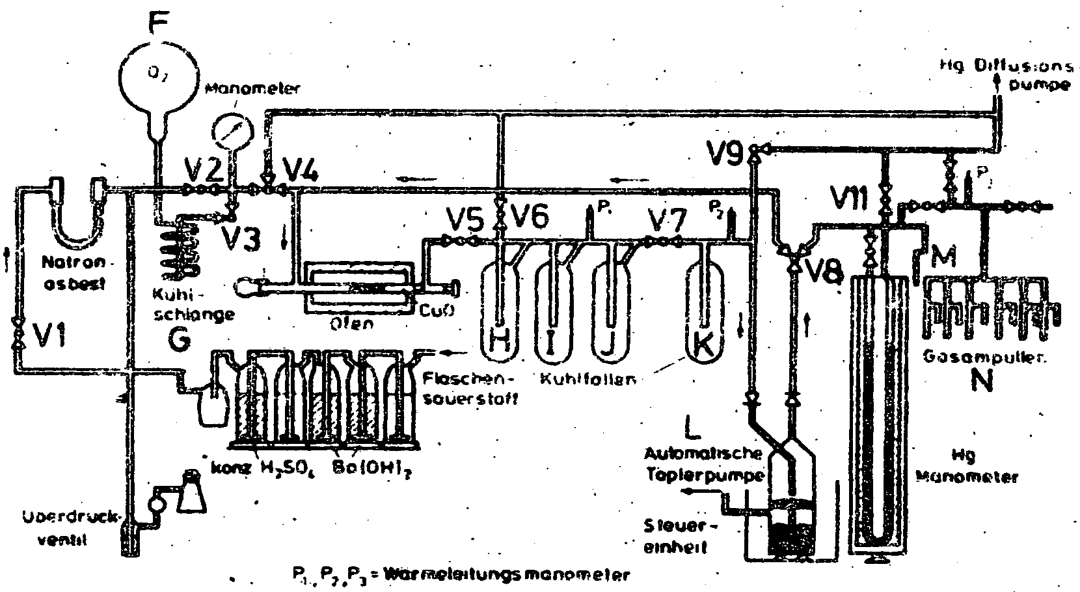
Cellulose, which is the wood component used here, makes 40-50% of the whole wood. This is extracted chemically and is burnt to CO_2 in a special combustion apparatus to collect the CO_2 in the cellulose (*Dg.* 5). The gas is then fed into a double-focussing mass-spectrometer to ascertain the isotopic ratio. The isotopic values are expressed in conventional $\delta^{13}C$ units according to the formula:

$$\delta^{13}C\ (\text{‰}) = \frac{(^{13}C/^{12}C)\ \text{wood}}{(^{13}C/^{12}C)\ \text{standard}} \times 100$$

The ratio is determined for each ring in the tree and expressed similarly.

Results and Discussion

For each analysed tree the $\delta^{13}C$ values over its entire time of record were calculated as deviations from its tree specific value which is the average value of $\delta^{13}C$ for the optimum growth period of the tree. The experimental procedure is described completely in de Silva (1978). Diagram 6 shows the trend of $\delta^{13}C$ decrease for this century as obtained by averaging the $\delta^{13}C$ data of 7 temperate trees. An overall δ^{13} C decrease is to be recognised with a well marked interruption during the period 1940-1955. The mean $\delta^{13}C$ during the periods 1900-1920, 1930-1940, 1955-1970 decreases with almost linear slopes.



Dg. 5

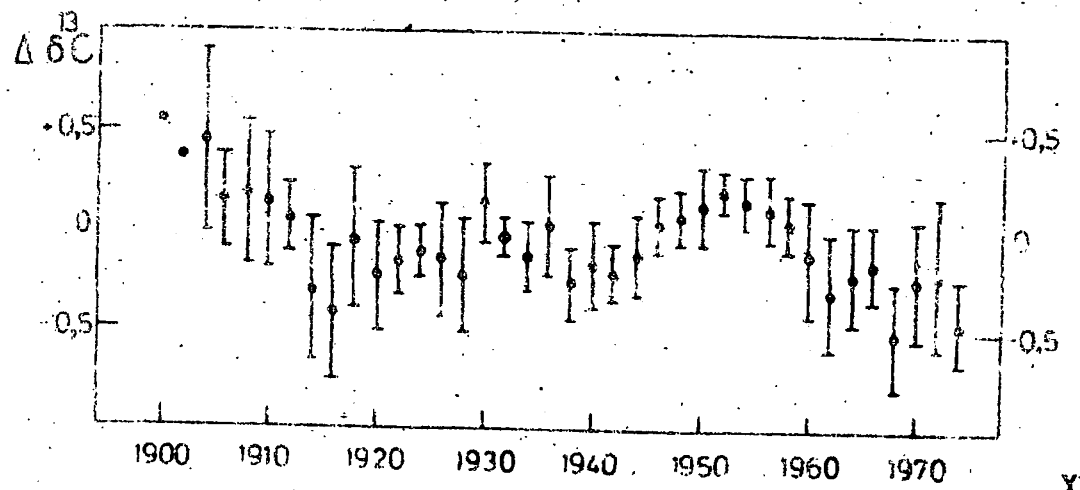
An increasing trend is to be seen between the 1940-1955 interval, as reported by Stuiver (1978). Though the cause of it is not fully established, it is possible that the increasing global temperatures during this period, which reached their maximum in 1940, could have caused a reflux of ocean CO_2 into the atmosphere causing a ^{13}C re-enrichment in the atmosphere.

The results indicate a 0.012‰ per year decrease of $\delta^{13}C$ in the atmosphere. Extrapolation of the linear regression curve upto 1850 gives a total of $\delta^{13}C$ decrease of -1.8‰ for the period of industrialisation. This, if attributed to fossil fuel burning alone, indicates that more than 50% of the released CO_2 remains in the atmosphere without being exchanged with other sinks like the biosphere and ocean. Wilson (1978) attributes this therefore to other CO_2 emission sources too, like the world-wide boom of pioneer agriculture during the latter half of the nineteenth century. The fraction of this biospheric CO_2 that remained in the atmosphere depleted the $\delta^{13}C$ content of the atmosphere by almost 0.9‰. This indicates that agricultural practices also influence the global CO_2 budget considerably as against those through fossil-fuel burning. However more data extending to the pre-industrial time and a review of the exchange processes between the ocean, biosphere and atmosphere are required.

The tree-ring method is a promising technique to develop modes for the investigation of the rise of CO_2 in the atmosphere.

References :

1. de Silva, M. P. (1978): 13C-Variationen in Baumjahresringen als Folge des Folge des anthropogenen CO_2-Anstiegs der Atmosphare. Untersuchung des Einflusses von Klimaparametern. Ph.D. Theses, Technical University of Aachen
2. Stuiver, M. (1978), Science, 199, 253-258
3. Wilson, A. T. (1978), Nature, 273, 40-41



Dg. 6