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VULCANISM AND RADIOCARBON DATES

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ABSTRACT

We consider whether the long term perturbation of radiocarbon dates, which is known to be approximately a sin function of period about 8000 years and amplitude of about 8% peak-to-peak, could have been caused in any major part by vulcanism. We conclude that this is not the case. On the contrary, present day volcanoes are a far less important source of inert CO_2 (about 100 fold less) than is man's burning of fossil fuels which has caused the Suess dilution of about 2%.

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I. Introduction

The emission of CO_2 by volcanoes could, in principle, reduce the concentration of radiocarbon in atmospheric carbon dioxide and thus produce errors in the radiocarbon dates for the past millenia. However the corrections are opposite in sign to the effects that are substantiated by the geologic evidence. Namely, the volcanic explanation would require that over the last eight millenia, volcanic activity would have had to increase substantially up to the present, contrary to the geologic evidence. Considerable evidence about the nature of such effects is at hand from the studies of the perturbations of the radiocarbon age caused by the burning of fossil fuel and consequent emission of carbon dioxide, which like volcanic gases, contains no radiocarbon.

II. Material Balance

As first suggested by Suess¹, the CO_2 generated by combustion of fossil fuels in the period 1850-1950 A.D. would have reduced the $\text{C}^{14}/\text{C}^{12}$ ratio in the atmosphere by a full 10% had all the fossil CO_2 remained in the atmosphere. The actual observed dilution is $2.0 \pm 0.3\%$. This smaller effect most likely is caused by the relatively short residence time of CO_2 in the atmosphere before absorption into the sea, a time variously estimated as being between 10 and 30 years^{1,2}. In the time of 100 years, which is much longer than the mixing time, most of the fossil CO_2 will have dissolved in the sea.

Over the last 100 years, the rate of injection of fossil CO_2 increased approximately exponentially with a mean life of about 34 years, for an aggregate³ total of 10% increase above the natural level. Today the rate of injection is 660.10^{-6} gms C per cm^2 year.

We may compare this to the average rate of outgassing of carbon dioxide over geologic time. Rubey⁵ estimates the total carbon in terrestrial sediments as 9.10^{22} gm or 2.10^4 gm/ cm^2 . This is in agreement with the quantity of atmospheric CO_2 observed on Venus⁶; (supposing that sediments cannot form on Venus because of the lack of oceans⁷, then the total CO_2 outgassed in the life of Venus is still all in the atmosphere). Some 100 atmospheres⁶ of CO_2 correspond to 3.10^4 gm C/ cm^2 , about the same as the total outgassed on the earth. Thus the average rate of evolution for either planet is then approximately 6.10^{-6} gm/ cm^2 yr for the lifetime of $4.5 \cdot 10^9$ yr. This is about one percent of the rate of evolution from fossil fuel. Thus volcanoes would have to increase their activity by some 100 times more than the average, and do so in a smooth way, sinusoidally dependent on time, to have caused the observed corrections for radiocarbon dates.

We may approach the problem in another way. Namely, B.E. Nordlie⁹ has analyzed the volcanic emissions from Kilauea in Hawaii and found them to be approximately 33% CO_2 by volume. We assume that this gas contains only inert carbon. An estimate of world-wide lava production of 1 km^3 per year has been made by G.C. Kennedy¹⁰. At production the lava has a density of about 3, and decompresses to pumice of density about 1, with emission of about 2 km^3 of gas. When corrected to NTP (the gas is emitted at about 1100°C) the CO_2 emitted totals about $4 \cdot 10^{-8}$ gm C/ cm^2 yr at this postulated level of vulcanism. This again is very small compared with the present rate of injection of inert CO_2 from fossil fuel injection and could have caused no serious effect on radiocarbon dates.

Finally strong evidence exists that vulcanism reached its greatest intensity early in earth's history and has been decreasing since⁵. Thus the present world-wide average should be much less than one percent of the present fossil fuel combustion rate.

III. Conclusions

Our conclusions are as follows: (1) there is evidence that vulcanism in the last eight millenia has been too inactive to have caused

a noticeable correction in radiocarbon dates. In fact the evidence is that vulcanism reached its greatest intensity early in the earth's history and has been decreasing since⁵. (2) At present, volcanoes appear to be evolving one percent or less of the CO₂ being evolved by burning fossil fuel.

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