RADIOCARBON DATING†

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A summary of the physical phenomena involved in radiocarbon dating is given. Laboratory procedure determines the amount of radioactiue carbon a sample contains now. Calculation of an age requires an ***assumption*** *concerning the relative amount of radioactive carbon in the environment at the time the organism from which sample was derived was living. The year A.D. 1850 is chosen as a standard since up to then man had not contaminated the air by either adding carbon dioxide from industrial fuel or neutrons from atomic explosions. Thus a decrease to one half of the amount found in A.D. 1850 samples indicates a radiocarbon age of 5730 years. Correlation with tree-ring dating shows a fair degree of accuracy to about 59 B.C. Attempts to correlate Bristlecone Pine growth-rings with radiocarbon age show a discrepancy of 500 to 1000 years, the pine ages being that much older than Carbon-14 ages. Reliable conversion between historical age and radiocarbon age goes back only 3-4000 years. Though only approximations, farming increased rapidly in 1200 "years" from 7,200 to 5,000 B.P. Evidently prior to the Flood the relative amount of Carbon-14 in the air was only about* $^{1}/_{1000}$ *of its present value. Several theories for increase in Carbon-14 are given.*

Introduction

It is common knowledge that radiocarbon laboratories have determined ages for organic material which in a vast number of cases appear to be in conflict with the specifications concerning Earth history given by the book of Genesis and endorsed by the Gospel writers and the apostle Paul in the New Testament. There is an evident need for intensive and careful study in the broad field of radiocarbon dating in order to find the agreement that we have been assured exists between the book of nature and the written Word.

In approaching any body of scientific literature it is well to keep in mind the unavoidable tendency of an investigator to harmonize the information available to him with his general world view. The human mind is designed to integrate and summarize its observations into generalized principles and viewpoints. This characteristic is necessary for the development of understanding and capability. As a consequence of their cultural and educational background, most of the radiocarbon specialists have a world view that is based on uniformitarianism and progressive evolutionary development of life.

In using some of the information provided by Carbon-14 analysis, the seeker for truth who begins with the commonly accepted uniformitarian viewpoint may experience a more difficult and devious path toward a fuller understanding than would have been the case if his initial viewpoints had conformed with the guidelines set forth in the Bible. Where scientific observation relates to the divinely inspired testimony, we have been assured that an honest search for truth will result in both increased understanding and in confirmation of the inspired testimony.

Individuals who are leaders in the development and application of Carbon-14 dating techniques are men and women of high ideals, who are intensely devoted to finding truth in their areas of investigation and are meticulous in maintaining a distinction between speculation and firmly substantiated evidence. However, with Carbon-14 dating, as in many other areas of human thought, the dogmatism with which speculative conclusions are advocated commonly increases with the distance one goes from prime sources of information.

Survey of Physical Phenomena

Before considering some recent developments on radiocarbon dating, many readers may appreciate a brief survey of the physical phenomena involved. Stars eject into space some of the matter of which they are composed. This ejected matter represents the chemical composition of its parent star and, consequently, is made up of hydrogen, small amounts of helium, and traces of more complex atoms.

Some of the atoms in this ejected matter are affected by forces which strip away the outer negative electric charge (electrons) and accelerate the positively charged nucleus to extremely high speeds. These high speed atomic nuclei which drift around through interstellar space are called primary cosmic rays.

Earth is constantly bombarded from all directions with primary cosmic ray particles. These particles have sufficient energy to break up atoms which they encounter on reaching the upper levels of the Earths atmosphere. The break-up of nitrogen and oxygen atoms by primary cosmic rays produces neutrons and atoms of carbon, boron, beryllium, helium, hydrogen and possibly lithium.

Neutrons are uniquely effective agents for producing atomic transmutation. The most frequent reaction produced by neutrons in air transmutes nitrogen into carbon which has 14 units of mass as compared with the 12 units characteristic of ordinary carbon (16½ percent heavier than an

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†Portions of this article appear in chapter form in the forthcoming book, *Creation–Accident or Design?* by Harold G. Coffin, Research Professor at the Geoscience Research Institute, Andrews University, Andrews, Michigan 49104.

ordinary carbon atom), and is radioactive (that is, unstable). In the order of 22 pounds of radioactive carbon are produced per year in the Earth's upper atmosphere as a result of reactions produced by primary cosmic rays. This radioactive carbon is oxidized to carbon dioxide, which in turn is mixed throughout the atmosphere by air currents and utilized by plants along with nonradioactive carbon dioxide to form carbohydrates. The high solubility of carbon dioxide in water transfers a large portion of the Earth's radioactive carbon to the oceans. Radioactive carbon is distributed through all living material as a result of the dependence of animal life upon plant food.

Death Stops Intake of Carbon-14

Death of a plant or an animal terminates the processes by which its tissue structure receives Carbon-14 from the environment. Since Carbon-14 is unstable and spontaneously converts to nitrogen, the remains of once living material will contain progressively smaller amounts of Carbon-14 with the passage of time. Laboratory measurements on known amounts of radioactive carbon have established, within an uncertainty of less than 100 years, that in 5,730 years, half of an initial amount of Carbon-14 will "disappear" as a result of radioactive decay into nitrogen. On the basis of this information, 5,730-year-old remains of plants and animals may be expected to contain half as much radioactive carbon as they did at death.

For convenience, data on the radioactive carbon content of a sample is reported by specifying a "radiocarbon age." The radiocarbon age describes the relative amount of radioactive carbon in the sample in terms of the relative amount of radioactive carbon in an oxalic acid standard supplied by the U. S. National Bureau of Standards. The NBS oxalic acid standard of Carbon-14 activity is adjusted to provide a reference based on the average Carbon-14 activity of wood which was growing in A.D. 1850.

The strength in which the NBS standardized oxalic acid is supplied is such that 95 per cent of its specific radiocarbon activity is equivalent to the specific radiocarbon activity to be expected from wood growing in A.D. 1950 under conditions that prevailed in A.D. 1850. The radiocarbon age of a sample is the number of years that would be required for the specific radiocarbon activity level defined by the NBS oxalic acid standard to decay to the specific activity level measured in the sample.

Radiocarbon "Time" Is Relative

Radiocarbon ages are based on a 5,568-year half-life for Carbon-14 decay (the average of early less precise measurements), rather than on the more accurate value of 5,730 years in order to avoid confusion in comparing recent determinations with the large number of radiocarbon ages that appeared in the literature during the time when 5,568 years was the best available value for Carbon-14 half-life. Since the radiocarbon time scale is arbitrary and does not directly measure real time, there is no need for basing it on an absolutely accurate determination of half-life.

Those who are unhappy with the 5,568-year half-life convention can convert radiocarbon ages to a 5,730-year-based scale with a simple multiplication by 1.03. A sample with a specific radiocarbon activity equal to one-half 95 per cent of the specific radiocarbon activity of the NBS oxalic acid standard is assigned a radiocarbon age of 5,568. The radiocarbon date for the time when this sample ceased to exchange carbon with its environment would be 5,568 B. P., or 3618 B.C. (5,568-A.D. 1950).

In summary it may he said that radiocarbon ages are based on a 5,568-year half-life and are standardized against preindustrial-revolution conditions (A.D. 1850), and that A.D. 1950 is used for the zero point on the radiocarbon time scale. (Stuiver and Suess, Editorial Statements, *Radiocarbon*, Vol. 8, 1966; Half-Life Statement, *Proceedings of the Sixth International Conference on Radiocarbon and Tritium Dating.)*

Reasons for basing radiocarbon ages on conditions in A.D. 1850 are of interest. Since A.D. 1850, man has introduced into the Earth's atmosphere large amounts of carbon dioxide produced by the use of fossil fuels-coal, oil, and natural gas. These fossil fuels contain a negligible amount of Carbon-14 and are described as "infinite age" on the radiocarbon time scale. During the 100-year period between A.D. 1850 and A.D. 1950, use of fossil fuels released infinite age carbon equivalent to approximately 11 per cent of the total carbon presently contained in the atmosphere. Had this contribution of nonradioactive carbon been confined to the atmosphere it would have reduced the radiocarbon activity of the atmosphere by approximately 10 per cent.

The actual decrease experienced (Suess effect) was only one to three per cent and probably averaged a strong one per cent, indicating that a large portion of the carbon released to the atmosphere by man's use of fossil fuels has been absorbed in the ocean (95 per cent of the carbon in the Earth's carbon dioxide exchange system is contained in the ocean.)

Another factor related to human activity that influences the radiocarbon concentration in the atmosphere is the release of neutrons by atomic reactors and nuclear weapons.

By using as a "contemporary" reference the most recent radiocarbon activity level that has not been significantly affected by human activity, radiocarbon ages can more readily be used in studies of the past. The most accurate value for the "contemporary" activity level is considered to be 13.6 disintegrations per minute per gram of plant or animal carbon.

Radiocarbon and Historical Ages

Measurements made in radiocarbon dating laboratories throughout the world do not determine dates or historical ages of samples. The laboratory procedures only determine the amount of radioactive carbon which a sample contains at present. The historical time lapse since a given specimen was a part of a living organism which exchanged carbon with its environment is an **interpretation** based in part on its radiocarbon age. The postulation of a date or age associated with the sample requires an *assumption* concerning the relative amount of radioactive carbon in the environment which supported the life of the organism from which the sample has been derived.

Major research effort is being directed toward developing reliable correlations between radiocarbon age and historical age. If the relative amount of radioactive carbon in the atmosphere had been at the A.D. 1850 level throughout the time life has existed on the Earth, radiocarbon ages, when adjusted to the 5,730-year half-life, would be identical with historical age. Tree-ring dating has established a precise and reliable chronology extending back to 59 B.C. By measuring the radiocarbon activity in precisely dated wood fiber, a chart can be prepared for converting radiocarbon age into historical age over the past 2,000 years. Such a chart shows fluctuations in the relative amount of Carbon-14 in the atmosphere during this period, but these fluctuations appear to have been limited within a range of less than five per cent of the A.D. 1850 level.

Because of the fluctuations in the atmosphere Carbon-14 activity and the difficulties in standardizing one radiocarbon laboratory against another, the minimum uncertainty in any radiocarbon age is commonly considered to be plus or minus 100 years (see *Radiocarbon*, Vol. 8, 1966, pp. 27, 213, 240, 340, and 453). Accordingly, if there are no contamination problems, the historical age of a sample which has a radiocarbon age no greater than about 2,000 years may confidently be considered to lie within a range of uncertainty equal to plus or minus twice the uncertainty specified for the radiocarbon age, providing this range is no less than plus or minus 200 years (see Radiocarbon, Vol. 8, p. 256).

Attempts to derive historical age from radiocarbon age yield increasingly uncertain conjectures for samples older than 2,000 years. Tree-ring chronology has been extended from 59 B.C. to approximately 2400 B.C. using the Bristlecone Pine. The growth characteristics of this tree make it unsatisfactory for the establishment of a precise long-term growth-ring sequence. Attempts to correlate Bristlecone Pine growth-rings with radiocarbon ages indicate that either ring counting has over-estimated the age of the oldest Bristlecone Pine material by 500 to 1,000 years, or the relative amount of Carbon-14 in the atmosphere around 2,000 B.C. was in the order of 10 percent greater than in A.D. 1850.

Radiocarbon Dating and Genesis

Aside from the information supplied in the book of Genesis, there is at present no firm basis for inferring historical age for any sample with a radiocarbon age greater than 3,500 to 4,000.

Those who accept the Genesis account as inspired and historically valid interpret the radioactive age for ancient material, such as Tertiary oyster shells, anthracite coal, mineral oil, natural gas, et cetera, to indicate that the atmosphere of the Earth before the Genesis flood had a relative Carbon-14 activity no greater than 1/100, and possibly less than 1/1000 of the level that became established by 1,500 B.C. (A relative Carbon-14 activity of 1/128 the contemporary level corresponds to decay over seven half-lives, or a radiocarbon age of 39,976. $2^7 = 128$; 7 X 5,568 = 39,976.)

Although up to the present no basis has been found for precise and reliable conversion between historical age and radiocarbon ages greater than 3,500, radiocarbon age determinations in the 4,000 to 30,000 range do, nevertheless, give important support to the book of Genesis. With a particularly appropriate figure of speech, radiocarbon dating has been described by a leading archaeologist as having an effect on previously-held archaeological viewpoints equivalent to the devastation produced by an atom bomb.

Radiocarbon dating of spruce trees buried by glacial advance in Wisconsin has forced geologists to **reduce** the presumed time which has elapsed since major glacial advance from 25,000 solar years to 11,400 radiocarbon years. Assuming a one-to-one correspondence between radiocarbon years and solar years results in a drastic compression of the time which previously had been considered available for the development of Western civilization.

Remarkable scarcity of objects which are clearly associated with human activity, and which have radiocarbon ages in excess of 12,000, suggests that the human population has grown from a small beginning in a short period of time. It is highly significant that the greatest radiocarbon ages firmly related to human activity are provided by material from the Middle East, the Ukraine, and the Mediterranean basin.

Radiocarbon ages for the oldest evidences of man indicate that the Earth was populated as a result of migration which spread out in all directions from the Middle East area, reaching the Western hemisphere by way of Alaska. Radiocarbon dating has established that the recent glacial periods in Northern Europe and Northern North America were coincident, that the earliest appearance of man in North America coincided closely with the latest advance of glacial ice across Wisconsin, and that both North America

and Northern Europe were settled rapidly after the first appearance of man in these regions.

Radiocarbon Age and Farming

By the time corresponding to a radiocarbon age of 7,200, farming had been established throughout a strip of approximately 10 degrees latitude in width extending from Greece across southern Asia Minor to Iran. During the succeeding period of time represented by a span of 1200 "years" on the radiocarbon time scale, farming extended over the Nile delta, Northern Egypt, Babylonia, and Central Europe.

By the time corresponding to a radiocarbon age of 5,000, farming had become established in Northwestern Europe, Northwestern Africa. and the Ukraine. Data are lacking concerning the spread of agriculture eastward from Babylonia, but there are remains in India from the highly developed Harappa culture which have radiocarbon ages as great as approximately 4,300. This culture developed elaborate irrigation facilities and had a written language which appears to be unrelated to the writing of subsequent Asian cultures and which modern man has been unable to decipher.

The limited time suggested by radiocarbon dating for the spread of human population over the Earth, and for the development of ancient civilization, has led many individuals whose world view is *not* based on the information given in the Bible to seek support for the postulate that in the ancient past the Earth's atmosphere contained a *greater* relative amount of Carbon-14 than it has over the 3,000 year period up to A.D. 1850. (Every doubling of the initial relative amount of Carbon-14 in a specimen over the relative amount which characterizes material living in A.D. 1850 would add 5,730 solar years to the difference between the historical age and the radiocarbon age of the specimen, if the historical age is greater than a radiocarbon age based on assumed initial conditions equivalent to those which existed in A.D. 1850.) Search for firm evidence to support a higher Carbon-14 level in the ancient atmosphere has not been fruitful.

Since primary cosmic ray particles are deflected away from the Earth by its magnetic field the role of this field in the Carbon-14 production rate has been investigated. Detailed calculation indicates that a complete disappearance of the Earth's magnetic field would no more than double the present Carbon-14 production rate, with consequent extension of the time indicated by the oldest radiocarbon dates by no more than 6,000 years.

A higher level of Carbon-14 activity would be brought about by an increase in the primary cosmic ray activity. Since studies of the cosmic ray effects in meteorites indicate that the cosmic ray flux in the solar system has remained close to its present level over a period of time many orders of magnitude greater than that with which radiocarbon dating is concerned, the only possibility for a large increase in the relative amount of Carbon-14 appears to be through a reduction in the amount of nonradioactive carbon in the atmosphere.

An addition of 17,190 solar years to the historical age of ancient material in this manner would require a reduction of the atmospheric carbon dioxide to one-eighth its present concentration (17,190 = 3 x 5,730; ½ x ½ x ½ = $^{1}/_{8}$). Since only 0.053 percent by weight of the Earth's atmosphere is carbon dioxide at present, and since the fossil record indicates much more extensive and more luxurious vegetation than now covers the earth, a significant reduction of atmospheric carbon dioxide below the present level does not appear to be a reasonable postulate.

It seems much more suitable to think of the Earth's ancient atmosphere as characterized by a higher, rather than a below-modern, carbon dioxide composition. Coal, oil, and gas reserves, limestone beds, shales, and vast amounts of organic materials scattered in gravel beds throughout the planet indicate that before the Flood the biosphere was many times richer in carbon than it is today. A plant or animal that might have lived at a time when the biosphere contained the same amount of Carbon-14 but eight times the amount of nonradioactive carbon as are characteristic of contemporary conditions would at its death have a radiocarbon age of 17,190 "years" in comparison with contemporary materials.

We have already noted that the testimony of radiocarbon dating and the testimony of the book of Genesis taken together support the view that prior to the Flood the relative amount of radioactive carbon in the atmosphere and in living things was at most 1/100 or possibly less 1/1000 of its present value. The reader must be cautioned that harmony between the historical requirements of the book of Genesis and radiocarbon ages cannot be obtained by postulating a hundred-fold greater concentration of carbon dioxide in the pre-Flood atmosphere, since carbon dioxide becomes highly toxic when it reaches unit per cent levels. It is the amount of carbon in the entire carbon dioxide exchange system, not the relatively small amount contained in the atmosphere, that determines the Carbon-14/ Carbon-12 ratio with which we are concerned.

While there are at present no scientific data to indicate that any of the following changes have taken place, it is worth noting that each one is within the range of possibility and would increase the relative amount of radioactive carbon in the atmosphere over its pre-Flood level:

(1) reduction of the Earth's magnetic field from a pre-Flood intensity which kept most of the primary cosmic ray particles from interacting with the atmosphere;

(2) loss of an outer region of water vapor which absorbed primary cosmic rays and cosmic-

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Initial Incredible Interpretation

The swing in the early eighteen-hundreds by geologists to concepts of uniformity and geological ages influenced the paleoecological interpretation of *Spirorbis.* Obviously the "bog theory" of coal formation cannot accommodate the abundant presence of a marine organism. Through the years this small annelid has been declared a salt-water worm throughout the geologic column except in the coal measures, where the supposed evidences for the *in situ* origin of coal made difficult the interpretation of *Spirorbis* at its face value.[9,10,11,12]

Consequently, seemingly without much question on the part of geologists and paleontologists through the decades, this worm when found in coal and coal-bearing rocks, has been designated a *fresh-water* dweller. This position has been taken despite the facts:

(a) that *Spirorbis* today is completely limited to the marine environment,

(b) that it reproduces by means of a trochophore larva, which, though characteristic of several marine phyla, is unknown for any fresh water invertebrates, and

(c) that it is associated with obviously marine organisms throughout the geologic column, including the Carboniferous period.

This highly questionable interpretation is a good example of the influence of a prevailing (ruling) theory.

Conclusion

Taken at face value, *Spirorbis* in coal and on plant fragments gives strong evidence for the allochthonous origin of much of the coal. Even as today the drifting Sargassum seaweed provides an attachment surface for *Spirorbis, so* flotsum of *Sigillaria, Lepidodendron, Calamites, Cordaites* and other coal-forming plants became spotted with the coiled tubes of this small worm. When depositing conditions buried the masses of vegetable material under sand and silt, the worms were buried also.

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ray-produced neutrons before they had opportunity to react with nitrogen in the atmosphere;

(3) removal by rains during and after the Flood of a large portion of the carbon dioxide characteristic of the pre-Flood atmosphere and conversion of this carbon dioxide to precipitated carbonates and carbonates carried in solution by the post-Flood oceans. (It has been reliably estimated that the carbon in the Earth that is not presently contained in minerals or fossils is distributed: 86.2 percent in solution in the oceans in a chemical form not directly associated with organic material, 8.7 percent in organic material contained in the oceans, 3.5 percent associated with organic life on land, and 1.6 percent in the atmosphere).

Thus it seems that continuing developments in the investigation of radioactive dating are certain to bring yet broader and more firm support for the information God has given to us through the written word.

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