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COSMIC RADIATION AND RADIO-CARBON AGE DETERMINATION

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All living things are radioactive because they undergo constant chemical exchange with the atmosphere which contains a minute proportion of a radioactive carbon isotope. After death, this exchange ceases and the radioactive carbon in the body decreases at a regular rate. Thus, measurement of the concentration of this radioactivity in a specimen tells how long it has been since the specimen was living—the older the specimen, the less will be the radioactivity. This is the basis of the so-called "radio-carbon age determination."

The technique of radio-carbon dating was developed by Willard F. Libby and others at Chicago's Institute for Nuclear Studies shortly after the end of the last war. During the war, it was found that by bombarding nitrogen with neutrons, it was possible to cause a transmutation of the nitrogen into carbon. Though the yield was small, it was found that the carbon produced differed from ordinary carbon by having an atomic weight of 14 instead of 12. Moreover, this artificially produced carbon was radioactive, and would emit an electron from its nucleus to turn itself back into nitrogen. A given amount of this carbon-14 decays at the rate of one-half every 5000 years.

Libby, in 1946, predicted that this radioactive carbon might be found in nature. He reasoned as follows: It is known that the cosmic rays from outer space that strike the earth's atmosphere cause nuclear reactions which result in producing energetic neutrons high in the atmosphere. Some of these neutrons will strike the nitrogen in the air and produce carbon-14. Taking the data on atmospheric neutrons from past cosmic-ray experiments, Libby was able to calculate the rate at which radio-carbon was being formed. If one assumes that this process has been going on for a long time, then one can estimate how much radio-carbon is present on the earth at any one time. This is done by noting that the amount of radio-carbon will increase only until the rate of decay (which is proportional to the amount present) is as great as the rate of formation. Using the 5000-year "half-life" as determined from the cyclotron experiments, one could say then that the current inventory of carbon-14 on the earth at any instant is 90 tons, a veritable drop in the bucket of non-radioactive carbon-12.

For the purposes of age determinations, the significant factor is the concentration of carbon-14 in the carbon of living things. It was thus necessary to etimate the reservoir of carbon-12 into which the radioactive carbon would be diluted. Clearly, the vast amounts of carbon in coal and petroleum are not to be counted, since these materials are inaccessible to newly formed carbon-14 and since any radio-carbon originally present has long since decayed away. The carbon-14 formed in the atmosphere is converted to carbon dioxide and finds its way into plants and animals. It also is to be found in dissolved compounds in sea water. Thus one can say that the diluting reservoir consists of the carbon in the atmosphere, the biosphere, and the hydrosphere. The total amount of carbon-12 (which is mostly in the ocean) that is mixed with the radioactive carbon thus turned out to be an estimated 40 trillion tons.

From these estimates Libby could say that a gram of carbon from a living specimen should be radioactive to the extent of about 19 atomic disintegrations per minute. Far from being "hot," this was a radioactivity that would just barely be detectable with the most sensitive geiger counters.

To check his guesses about the radioactivity of living matter, Libby and others developed new techniques of low-level radiation detection. After this was done, a world-wide assay of contemporary living matter was undertaken. It was found that the radioactivity on the average amounted to 16 atomic disintegrations per minute per gram of carbon. This remarkable agreement with the theoretical prediction suggested then that it might really be feasible to determine the age of once-living matter by measurements of its radioactivity. For example, if all recently living material has the same radioactivity per gram of carbon, then material that has been dead for 5000 years should be only half as radioactive; that is, once a specimen is dead it no longer can replenish its supply of carbon-14, and the amount it has will decay away at a regular rate.

To test this assertion that the radioactivity of a specimen could be used to determine its age, an archeological committee was appointed

to collect and have tested specimens of known historic age. From Egyptian history they knew the age of such specimens as a 2280-year-old wood mummy coffin and a 4900-year-old roof beam from a tomb. Samples of the centennial redwood stump which tree ring data determined as being 2900 years old were tested. In every case tested, the age derived fromthe radioactivity measurement agreed with the historic age to within the expected experimental error.

Thus tested, the "carbon-14 method" has been used to provide some valuable dates. Examples are:

1) By dating a buried tree from Two Creeks, Wisconsin, as being 11,000 years old, an important point on the geologists' relative time scale from which other dates could be inferred was determined.
2) An important date in history of the Oregon region is the formation of Crater Lake. A burned tree buried in the pumice from this event was found to have a radioactivity that indicates it was killed in 4400 B.C.
3) In a cave on the shore of the Dead Sea an apparently ancient scroll was found in 1947. Some Biblical scholars suspected this so-called "Isaiah Scroll" might be only a medieval forgery, but when samples were tested by the carbon-14 method it was found that the scroll was 2000 years old—the oldest known Bible manuscript.
4) The antiquity of some lotus seeds from Asia was established. This was of interest because some of the same seeds had recently been successfully brought to flower.
5) Some burned bison bones from Texas were found to be 10,000 years old. These bones were found in conjunction with some odd arrowheads which have come to characterize the so-called Folsom Man. This places man on the North American continent as early as 8000 B.C.
6) Some charcoal found in the Lascaux Cave in France was found to be more than 15,000 years old. This is the cave that contains the remarkable primitive paintings.

These examples illustrate the value of the "carbon-14 tool." The method has the advantage that it gives independent and "absolute" ages which can then be used to correlate other "relative" methods of age determination. The method is equally applicable to material from anywhere in the world and can be used to tie together other more geographically restricted geological and archeological methods.

The carbon-14 method has limitations, of course. One of the problems is that of contamination of ancient specimens with recent (and hence more radioactive) material, and even from dust from the explosion of nuclear weapons. With very old specimens, the problem is to measure accurately the very low radioactivity. Recent improvements in this connection have been made by the use of scintillation counters in place of the geiger counters for the radioactivity measurement. Still, dates cannot be established by this method beyond a maximum age of about 100,000 years.